

# Physiology Team 431



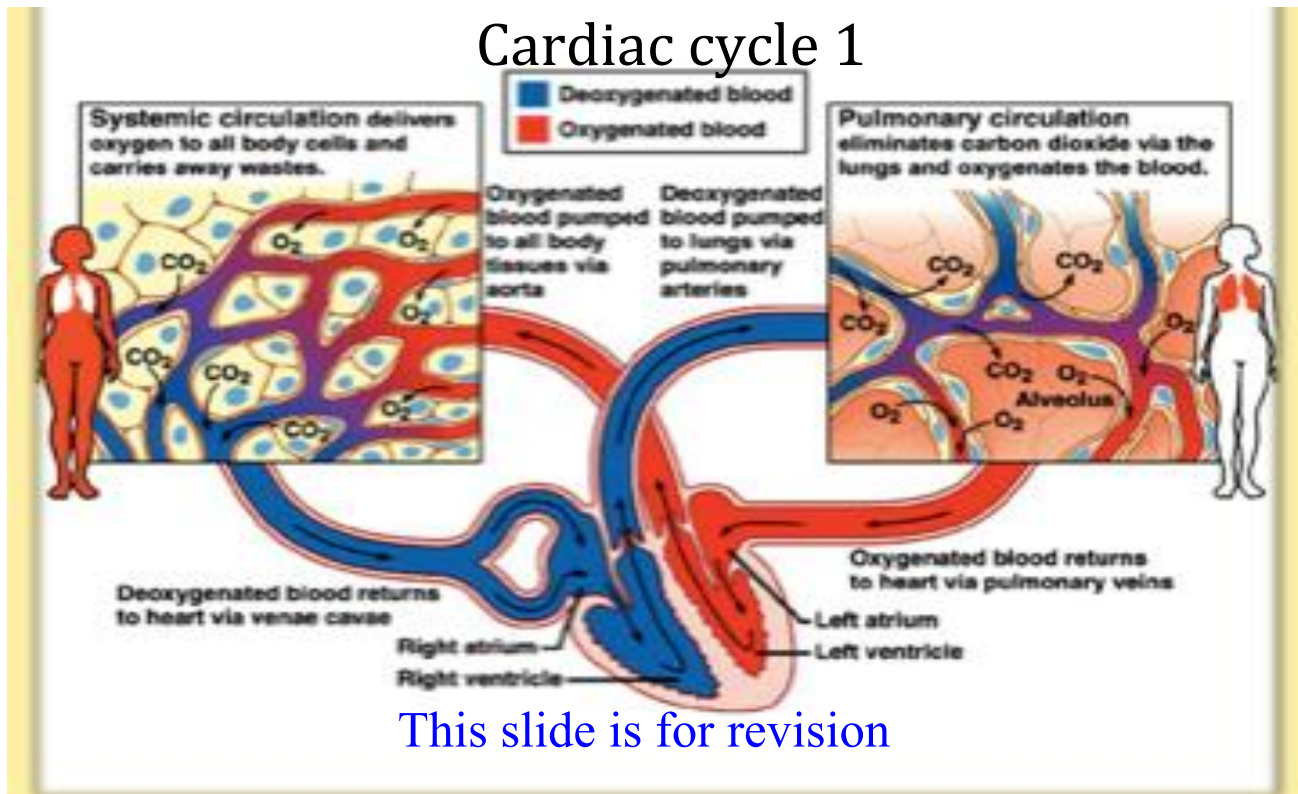
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# Cardiac cycle 1



**The Heart is a double pump**

## ‘Pulmonary & Systemic Circulations’

What is cardiac cycle?

Describing sequence of events that take place in the heart in each beat (heart beat)

Events in the cardiac cycle?

- ❖ Mechanical events
- ❖ Volume changes
- ❖ Pressure changes
- ❖ Heart sounds
- ❖ Electrical events (ECG)

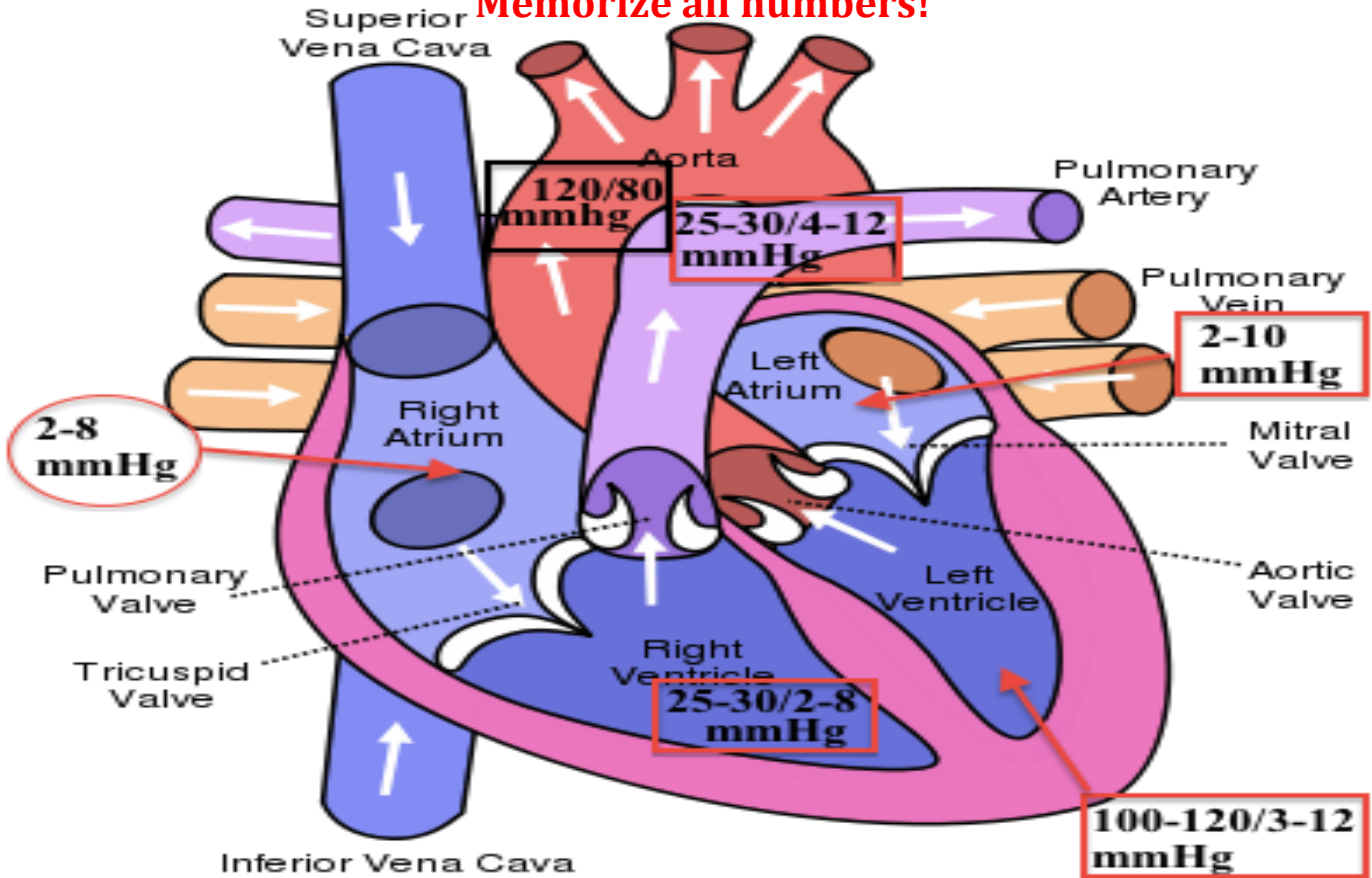
What is one heartbeat?

Systole and diastole phases

### General Principles

- Contraction of the heart generates pressure changes which result in the orderly movement of blood
- Blood flows from an area of high pressure to an area of low pressure
- Events on right & left sides of the heart are the same, but pressures are lower on right side
- Regurgitation, or backflow, occurs if a valve doesn't close tightly. Blood leaks back into the chambers rather than flowing forward through the heart or into an artery.
- Valves open when there are differences in the pressures.

**Memorize all numbers!**



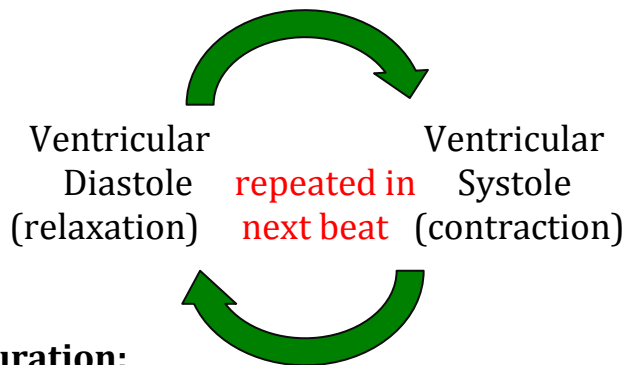
- The top value is the systolic blood pressure and the other value is the diastolic pressure
- Systole = maximum contraction, diastole = maximum relaxation

**Pressures during the cardiac cycle in different chambers**

(left ventricular pressure)	(Systole) (125 max) ( 100 minimum)	Diastole (12 max) (3 minimum)
Right ventricular pressure	(systole) (30 max) (25 minimum)	Diastole (8 max) (2 minimum)
Right atrial pressure	(10 max) (2 min )	
Left atrial pressure	(9 max) (2 min)	
Aortic pressure	Systole 120	Diastole 80
Pulmonary pressure	Systole 25	Diastole 8

## Mechanical events:

**In each beat:** one complete contraction & relaxation of the heart



## Cardiac Cycle Duration:

❖ **Cardiac cycle duration = 0.8 sec ...**

- When HR 72 bpm
- Shortened when HR ↑

❖ **Normally diastole is longer > systole**

- Ventricular systole = 0.3 sec
- Ventricular diastole = 0.5 sec
- Atrial systole = 0.1 sec
- Atrial diastole = 0.7 sec

❖ **Importance of ventricular diastole:**

- 1-Coronary blood flow
- 2-Ventricular filling

## Definitions

▪ **End-diastolic volume (EDV):**

- Volume of blood in ventricle at end of diastole
- ≈ 110-130 ml

▪ **Stroke volume (SV):**

- Amount of blood ejected from each ventricle during systole
- ≈ 70 ml/beat

▪ **End-systolic volume (ESV):**

- Amount of blood left in each ventricle at end of systole
- ≈ 40-60 ml

**Why there is a big difference between the systole and diastole in atrium?** Because the main function of it is to receive blood

### Why is diastole is longer than systole?

1. The heart needs more time to be filled with blood
2. The coronary circulation is embedded inside the cardiac muscles and for the blood to flow the muscle need to be relaxed

**Factors that effect SV:** Preload, Afterload, and the autonomic nervous system

**The ventricle is never empty of blood that's why the pressure is always above 0 in diastole**



▪ **Ejection fraction (EF):**

- Fraction of end-diastolic volume that is ejected
- ≈ 60-65 %

**Parasympathetic (Vagus nerve):**

Decrease the heart rate with no significant effect on the contraction; works mainly on the SA node (it doesn't supply all the ventricles) if it's stimulated it doesn't stop the heart

**Phases Of The Cardiac Cycle(8 phases):**

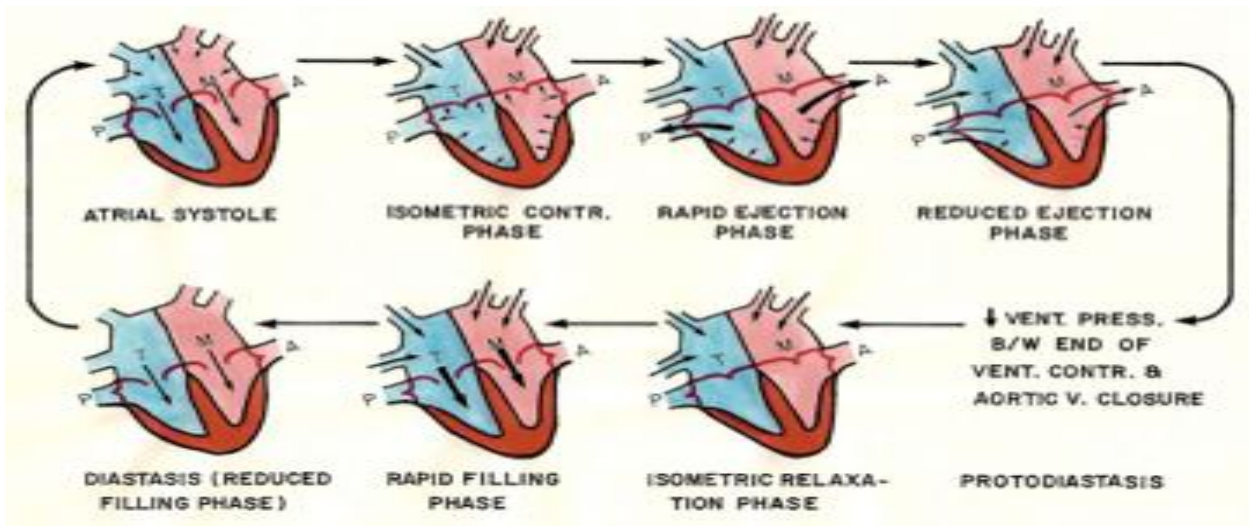
**Ventricular systole:**

1. Isometric contraction
2. Rapid ejection phase
3. Reduced ejection phase

**Ventricular Diastole:**

- **Early ventricular diastole:**
- **Mid ventricular diastole:**
- **Late ventricular diastole:**

1. Protodiastole
2. Isometric relaxation phase
4. Reduced Filling phase
5. Atrial systole



3. Rapid filling phase

❖ Sometimes it's considered 7 phases if 1<sup>st</sup> phase of diastole is excluded.

**Isotonic**= shorten of length (contract and produce work)  
**Isometric**= same length (contract but doesn't produce work)

## 1. Atrial Systole:

- ❖ At end of ventricular diastole ... lasts 0.1 sec
- ❖ Pressure changes:
  - - Atrial pressure slightly ↑ - Aortic > ventricular pressure
- ❖ Volume changes:
  - - Tops off last 27-30% of ventricular filling □ 40 ml
- ❖ Valves:
  - - AV-vs open & semilunar-vs closed
- ❖ Blood arriving heart can't enter atrium, it flows back up jugular vein
- ❖ Heart Sounds:
  - **S4** is recorded it's usually abnormal, however it's normal in elderly people
- ❖ ECG:
  - **P wave** is recorded, due to atrial depolarization happens before the contraction itself
- ❖ Atrial Pressure curve:
  - **"a" wave is recorded**
  - Due to ↑ atrial pressure during atrial contraction
  - Note: In jugular venous pressure curve, a delay record of "a" wave occurs due to back regurgitation of blood to jugular vein

Because the atria is contracting the veins narrow or shut therefore the blood do not enter it and flows back to the Jugular vein

The AV valves and the semilunar valves never ever open together in a normal condition but they can be closed at the same time

➤ **Dr.Sultan said this phase isn't important!**

## 2. Isovolumetric Contraction Phase:

- ❖ At beginning of systole ... (0.04 sec)
- ❖ Starts with closure of AV-vs:
  - Due to ↑ ventricular pressure
  - Atria repolarize & relax
- ❖ Ventricle is a closed chamber
  - **All valves are closed**
- ❖ Ventricle contracts w/out change in volume
- ❖ Volume in ventricle is **EDV**
- ❖ Ventricular pressure < aortic pressure
- ❖ Aortic v opens at end of this phase: (when LV = 80 mmHg)
- ❖ Heart Sounds:
  - **First heart sound (S1, "lub")** is recorded (marks the beginning of systole)
  - Due to closure of AV-vs & the association of blood turbulence
- ❖ ECG:
  - **QRS Complex** is recorded
  - Due to ventricular depolarization
- ❖ Atrial Pressure Curve:
  - **Ascending limb (+ve) of "c" wave is recorded:**
    - ↑ atrial pressure as a result of Right Ventricle contraction
    - Pushes Tricuspid Valve into atrium (bulging of cusps)

The pressure in the ventricular cavities continues to rise but remains less than aortic and pulmonary arteries so the valves will not open.

### 3. Maximum (Rapid) Ejection Phase:

- ❖ Contraction of ventricle causes ventricular pressure to  $\uparrow >$  aortic pressure
  - ❖ Semilunar-v vs open at beginning of this phase
  - ❖ 75% of ventricular blood is ejected
  - ❖ **Volume of ejected blood = SV**
  - ❖ Ventricular volume  $\downarrow$  rapidly (blood leaves the ventricles rapidly)
  - ❖ Heart Sounds:
    - None
  - ❖ ECG:
    - No Deflections
  - ❖ Atrial Pressure Curve:
    - **Descending limb (-ve) of "c" wave is recorded:**
      - Due to  $\downarrow$  atrial pressure as a result of pulling down of AVcusps by fibrous AV ring & ventricular contraction
      - N.B. Atrial pressure gradually  $\uparrow$  due to continuous Ventricular Repolarization
- **At the end of this phase, intraventricular pressure reaches its peak level**

### 4. Reduced Ejection Phase:

- ❖ At end of systole
- ❖ 25% of ventricular blood is ejected
- ❖ Contraction is weaker than the last phase.
- ❖ Ventricular volume  $\downarrow$  more slowly
- ❖ **Ventricular pressure decrease but is still more than aortic & pulmonary pressure.**
- ❖ Semilunar v close at **end of this phase**
- ❖ Heart Sounds:
  - None
- ❖ ECG:
  - T wave is recorded
  - Due to ventricular repolarization
- ❖ Atrial Pressure Curve:
  - **"x" Descend is recorded**
    - Due to more  $\downarrow$  atrial pressure as a result of pulling down of AV cusps by fibrous AV ring & ventricular contraction
    - N.B. Later, atrial pressure gradually  $\uparrow$  due to continuous Ventricular Repolarization

### 5. Protodiastolic Phase: (this phase is excluded sometimes)

- ❖ Period begins with end of ventricular systole & aortic-v closure
- ❖ Very short ... (lasts 0.04 sec)
- ❖ Aortic v closes at this phase, as a result of
  - $\downarrow$  ventricular pressure  $<$  aortic pressure
  - aortic back pressure (when left ventricle pressure 110 mmHg)

- ❖ Atrial pressure still  $\uparrow$ , due to continuous Ventricular Repolarization

## 6. Isovolumetric Relaxation Phase:

- ❖ Quiescent period
- ❖ At beginning of diastole ... (0.04 sec)
- ❖ Period begins with closure of semilunar-vs & opening of AV-vs
- ❖ Left ventricle is a closed chamber, i.e. relax without change in volume
- ❖ Volume of blood in ventricle = **ESV**
- ❖ Left ventricle relaxes with  $\downarrow\downarrow$  pressure (to 3 mmHg)
- ❖ AV-vs open at end of this phase
- ❖ Heart Sounds:
  - Second heart sound (S2, "dup") is recorded, when semilunar (aortic & pulmonary) vs close
  - S2 physiologically splits, as aortic v closes slightly earlier than pulmonary vein
- ❖ ECG:
  - No Deflections
- ❖ Atrial Pressure Curve:
  - **"v" wave is recorded**
  - Due to back flow of blood (venous blood) hitting closed AV v
  - Ventricular pressure continues  $\downarrow$
- The Aortic pressure rise slightly due to 'elastic recoil' the blood would come back hit the semilunar valve then it will continue the circulation.

**V is for venous Blood**

## ❖ Ventricular filling has two parts:

- Maximum filling; due to weight of blood (70%)
- Reduced filling; due to atrial contraction (30%)

## 7. Rapid Filling Phase:

- ❖ Atrial  $>$  ventricular pressure AV-vs open
- ❖  60-70% of blood passes passively to ventricles along pressure gradient (no contraction of atrium)
- ❖ Ventricular volume  $\uparrow$  rapidly
- ❖ Heart Sounds:
  - **Third heart sound (S3)** is recorded Due to rapid passive ventricular filling
  - S3 is usually abnormal, it could be normal in children
- ❖ ECG:

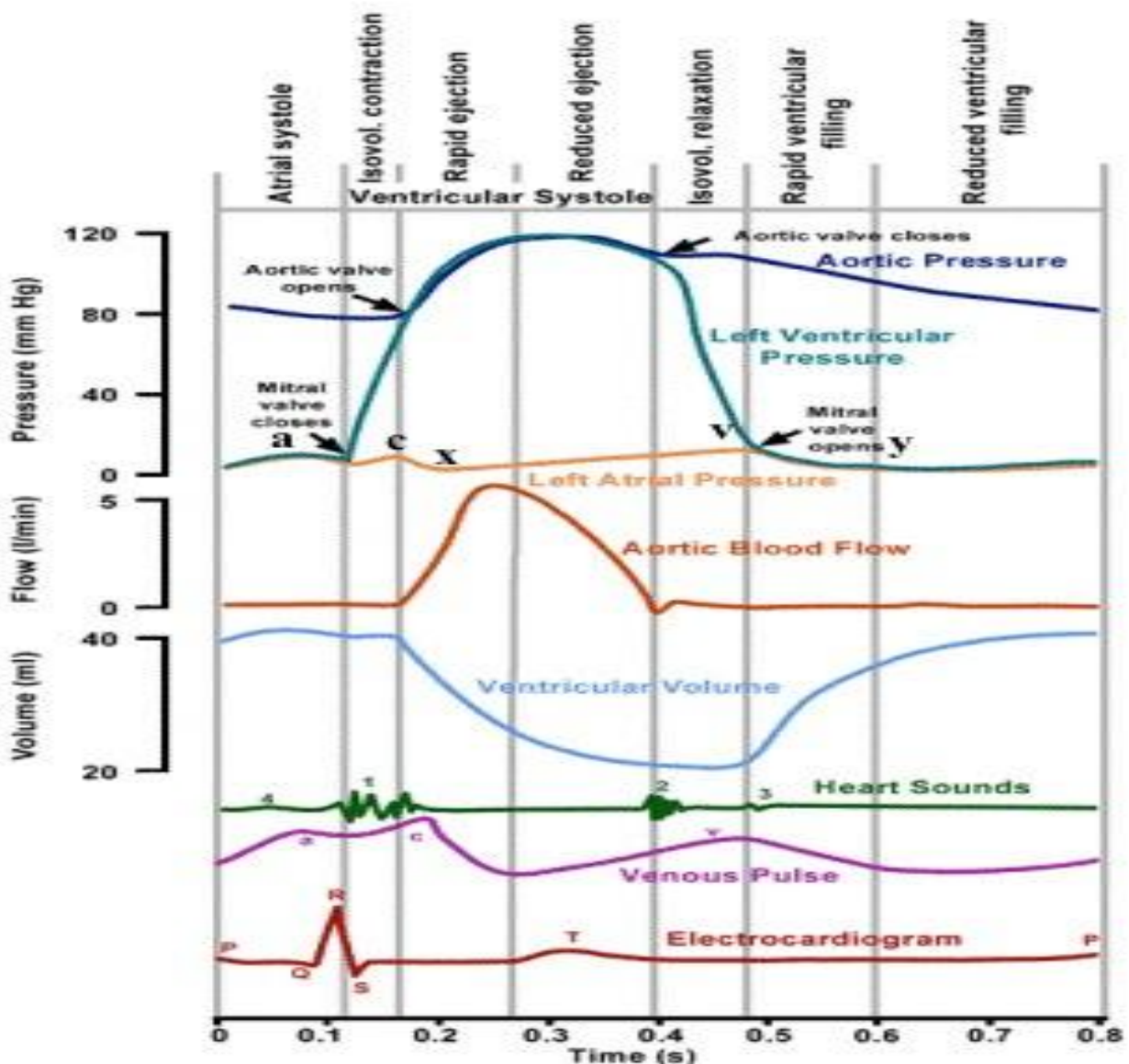
**S3 is caused by vibration of papillary muscles**



- No Deflections
- ❖ Atrial Pressure Curve:
  - “y” Descend is recorded:
  - Due to more ↓ atrial pressure as a result of emptying blood

## 8. Reduced Filling Phase (Diastasis):

- ❖ Remaining atrial blood flows slowly into ventricles
- ❖ AV-vs still open
- ❖ LV volume ↑ > slowly
- ❖ Heart Sounds:
  - None
- ❖ ECG:
  - No Deflections



## Summary

Phases		Semilunar Valves	AV Valves	Heart Sounds	Status Of Ventricles And Atria
<b>Systole</b>	Iso-Volumetric Contraction	Closed	Closed	S1	Ventricles begin to contract. Ventricle volume unchanged
	Max Ejection	Open	Closed	-	ventricles fully contract, 75% of ventricular blood is ejected
	Reduced Ejection	Open	Closed	-	Weak contraction 25% of ventricular blood is ejected
<b>Diastole</b>	Protodiastole	Closed	Closed	-	Ventricles relax, Ventricular pressure less than aortic and pulmonary pressure
	Iso Volumetric Relaxation	Closed	Closed	S2	ventricles relax, ventricle volume unchanged, <b>atria</b> expand and are filling
	Rapid Inflow (Filling)	Closed	Open	S3	Atrial > ventricular pressure 70% of blood passes <b>passively</b> to ventricles
	Reduced Inflow (Filling)	Closed	Open	-	blood flows slowly into ventricles
	Atrial Systole	Closed	Open	S4	Atrial contraction tops off last 27-30% of ventricular filling

# Revision Questions

**1:**

- Blood flows from an area of **high** pressure to an area of **low** pressure
- Cardiac cycle duration is **0.8 sec**, when HR = 72bpm
- Normally **diastolic** period is longer than **systolic** period
- EDV  $\approx$  **110-130** ml
- SV  $\approx$  **70** ml/beat
- ESV  $\approx$  **40-60** ml
- EF  $\approx$  **60-65** %

## Regarding 'Atrial Systole':

- Atrial systole occurs at the end of ventricular

## Diastole

- Tops off last **27-30%** of ventricular filling
- On Atrial Pressure Curve, **'a'** wave is recorded
- In ECG, **'P'** wave is recorded
- Associated with **'S4'** heart sound

## Regarding phases of ventricular contraction:

- During 'isovolumetric contraction' phase, all valves are **closed**
- 'c' wave in atrial pressure curve occurs during: **'isovolumetric contraction'** & **'rapid ejection'** phases
- QRS is reported during **'isovolumetric contraction'** phase
- **'S1'** heart sound marks the beginning of systole
- Maximum Lt ventricular systolic pressure = **120** mmHg
- In ECG, 'T- wave' occurs during **'reduced ejection'** phase

## Regarding phases of ventricular relaxation:

- 'v' wave in atrial pressure curve occurs during: **'isovolumetric relaxation'** phase
- **'S2'** heart sound marks the beginning of diastole
- **'60-70** % of blood passes passively during 'rapid filling' phase
- **'S3'** heart sound is recorded during 'rapid filling' phase