



# PHYSIOLOGY TEAM 432

## LECTURE : 3

### Cardiac cycle I ( Mechanical Events )

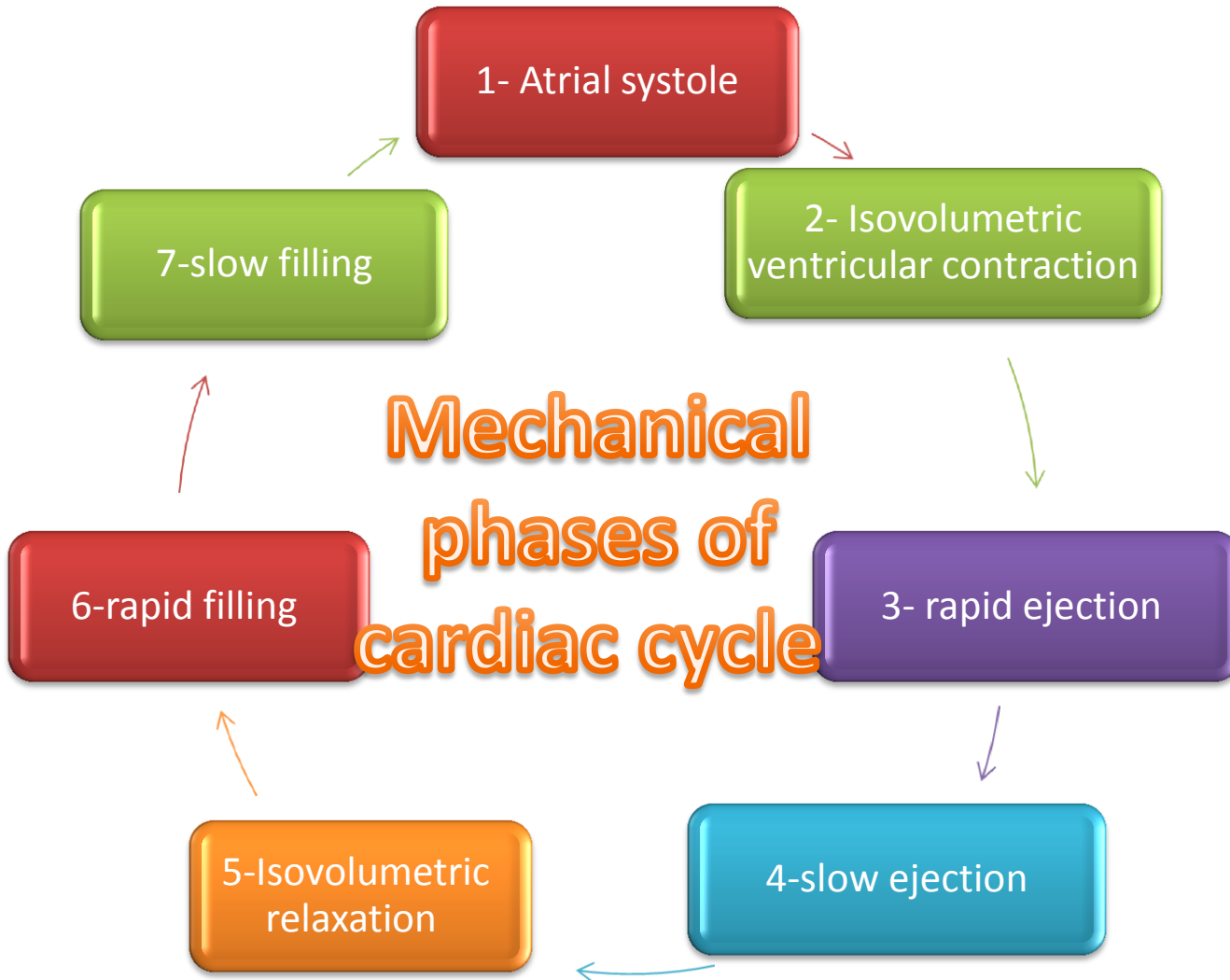
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Reviewed By: **Shroog Al-harbi**

# **OBJECTIVES**

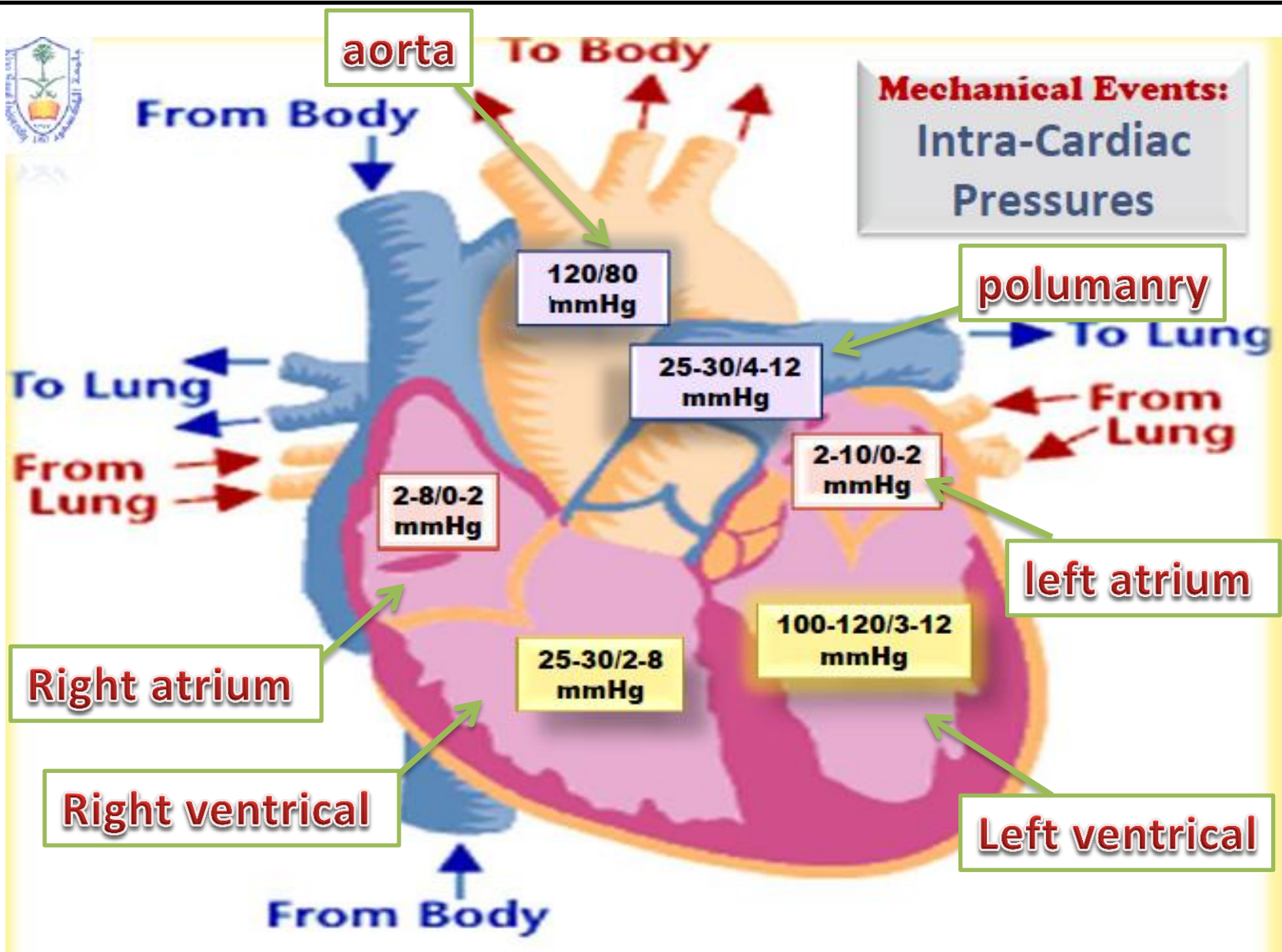
- 1- General principles of cardiac cycle .**
- 2- Different events that occur during cardiac cycle: mechanical, electrical, volume/pressure changes & heart sounds .**
- 3- Correlation of the different events that occur during cardiac cycle.**
- 4- Various phases of mechanical events of cardiac cycle.**

# MIND MAP



## General Principles

- 1- Contraction of the heart generates pressure changes, resulting in orderly blood movement .
- 2- Blood flows from an area of **high pressure** to an area of **low pressure**.
- 3- Heart is a **double pump**: right & left sides that work together.
- 4- Events in the right & left sides of the heart are **the same**, but with **lower pressures in the right side**.
- 5- **Valves open** when there are **differences in pressures** between atrium & ventricle or difference between ventricle & artery



# Definitions :

## Cardiac cycle :

Sequence of events that takes place in the heart in each beat .

### 1- End-diastolic volume (EDV):

Volume of blood in ventricle at the end of diastole  
110-130 mL

### 2-Stroke volume (SV):

2- Amount of blood ejected from ventricle during systole  
70 mL/beat

### 3- End-systolic volume (ESV):

Amount of blood left in ventricle at the end of systole  
40-60 mL

### 4- Ejection fraction (EF):

Fraction of end-diastolic volume that is ejected  
% 60 - 65 ( No way to be more than 65% )

Beat per minute

Cardiac cycle duration =  
0.8 sec ...  
- When HR 72 bpm  
- Shortened when ↑HR

## Events in the cardiac cycle :

I: Mechanical events

II: Volume changes

III: Pressure changes

IV: Heart sounds

V: Electrical events (ECG)

Each heartbeat consists of 2 major periods:

1- Systole (Contraction)

2- Diastole (Relaxation)

Atrial: systole & diastole

Ventricular: systole & diastole

## Mechanical Events' Periods:

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 long ventricular diastole?

1. Coronary blood flow.
2. Ventricular filling.



## Mechanical Events: Mechanical Phases

Consists of 7 phases

### ■ Early ventricular diastole:

Protodiastole ????

1. Isometric relaxation phase
2. Rapid filling phase

### ■ Mid ventricular diastole:

3. Reduced filling phase

### ■ Late ventricular diastole:

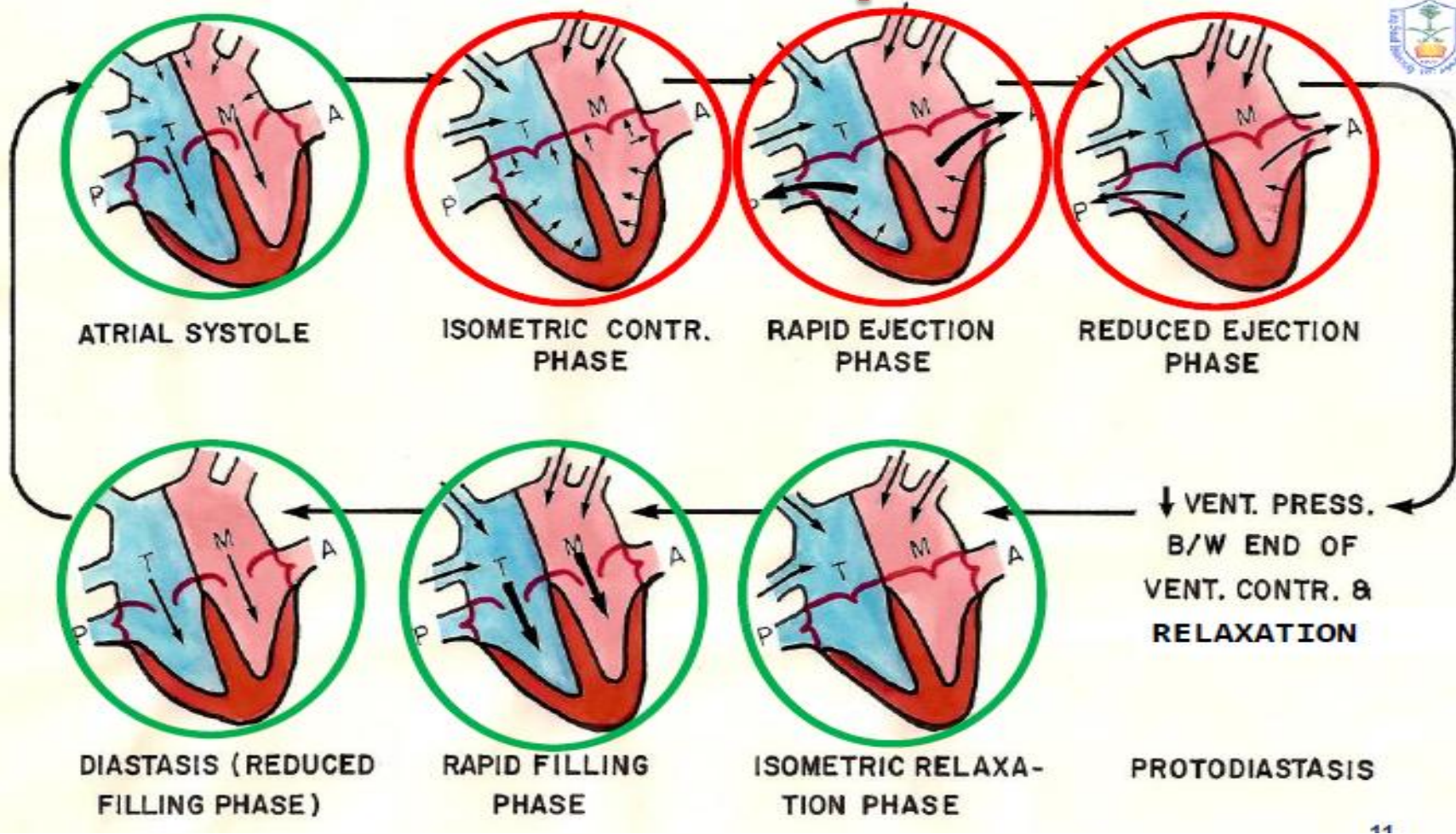
4. Atrial systole

Ventricular diastole      Ventricular systole

### ■ Ventricular systole:

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

# Mechanical phases



I will explain each phase in a simple way in gray color .. And to get the explanation clearly I advice you to see the videos which I will put there links in each phase ..

# 1- Atrial systole :

At the end of ventricular diastole ... (lasts 0.1 sec)

Preceded by atrial depolarization

## Valves:

AV- vs open (semilunar- vs closed)

## Volume changes:

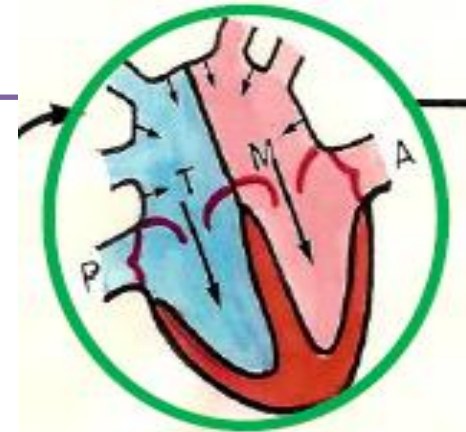
Tops off last 27-30% of ventricular filling ≈ 40 mL

## Pressure changes:

Atrial pressure ↑

## 4<sup>th</sup> Heart sound heard

Blood arriving the heart can't enter atria, it flows back up jugular vein



ATRIAL SYSTOLE

-In each phase we have to focus in **3 main things** : what are the changes in ( aorta , left atrium , left ventricle ).

-During this phase the **atrial pressure increases** and the input valve ( **mitral** ) **open** ( ( opening of any valve doesn't produce any sound only they produce sounds when they are closing ) ) while the output valve ( aorta) close because the aortic pressure in this phase is higher than the ventricle its about 80 mmHg..

-Already **80% of the atrial blood will transport passively** to the ventricle ..

- The atrium will contract to pump the rest 20% of the blood to the ventricle..

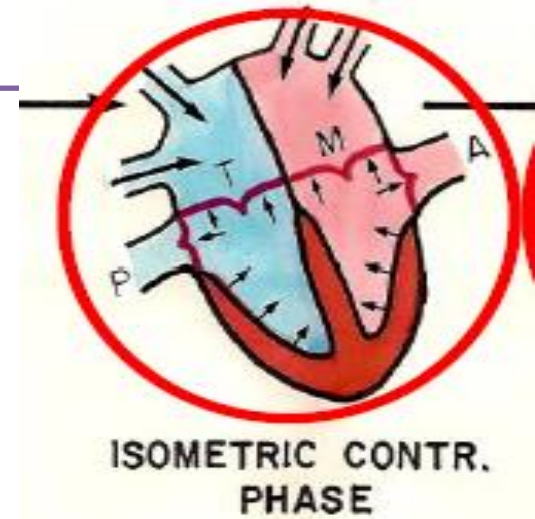
-The **arising in the atrial pressure** will form a pressure wave ( " a " wave )..

-We may hear the ( **S4** ) Sound which is a **pathological** sound usually due to ventricle hypertrophy ..

<http://www.youtube.com/watch?v=XbivlaFPoQI>

## 2- Isovolumetric contraction:

- At the beginning of systole ... (0.04 sec)
- Period b/w closure of AV- vs & opening of Semilunar- vs
- Preceded by ventricular depolarization
- Starts with closure of AV- vs:
- Ventricular pressure > atrial pressure
- Atrial diastole
- 1st Heart sound heard
- Ventricle is a closed chamber:
- Ventricle contracts w/out change in volume:
  - o Volume in ventricle is the 'EDV'
  - Ventricular pressure < aortic pressure
  - o Aortic v opens at the end of this phase: (when LV = 80 mmHg)



-During this phase the **ventricle pressure increases** and the **mitral valve will close** ( because the ventricle pressure is higher than the atrial pressure )but the **ventricle here will act as a close chamber** (cause the mitral not open anymore and the aortic still close due to its higher pressure in comparing with the ventricle ) so the **volume and size of the blood will not change** ..

-At the same time , the ventricle continue increasing its pressure to exceeds the aortic (**the aortic open when the ventricle pressure become 80-81 mmHg** )..

-While the ventricle increases its pressure , it will produce a pressure wave ( "**c** " **wave caused by the ventricle contraction** )..

-**Role : during all the phases of the ventricle systole , the atrium will act as a (tank) and resaves the blood which come from lungs and this accumulation of blood in the atrium will produce other pressure wave ( "**v** " wave )..**

-in this phase we will be able to hear the ( **S1** ) Sound which produce du to the **closing of the ( Mitral and Tricuspid valves )..**

<http://www.youtube.com/watch?v=sLLLOaZ85Lk>

### 3- rapid ventricular ejection:

Semilunar- vs open at beginning of this phase:

- when LV = 80 mmHg

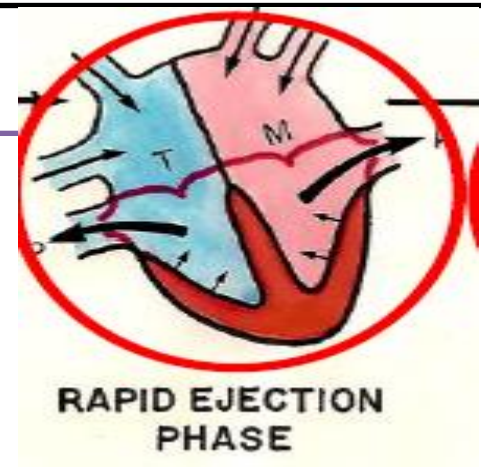
Contraction of the ventricle causes ventricular pressure > aortic pressure

Almost 75% of ventricular blood is ejected:

- Volume of ejected blood = SV

- Ventricular volume ↓ rapidly

Atrial diastole



- Aorta will stretch out and resaves the blood from the ventricle ..

- Ventricle pressure still increasing until it reaches the maximum pressure - ( 120 mmHg )..

- At this stage , the ventricle and aorta act as a one chamber so the pressure of aorta also will be ( 120 mmHg )..

## 4- slow ventricular ejection :

At the end of systole

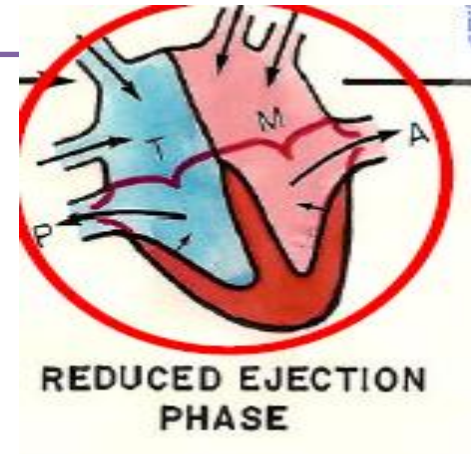
Almost 25% of ventricular blood is ejected:

- Ventricular volume ↓ more slowly

Aortic- v closes at the end of this phase, as a result of:

- ↓LV pressure 110 mmHg (Aortic back pressure)

Atrial diastole



Pressure in the ventricle start to fall down , the same thing for aorta ..

<http://www.youtube.com/watch?v=HNkwXZSSsU>

**Protodiastolic Phase :** They don't consider it as important phase any more

Period b/w end of ventricular systole & ventricular diastole Very short ... (lasts 0.04 sec) Atrial diastole:

- Atrial pressure still ↑ due to continuous VR(venous return )

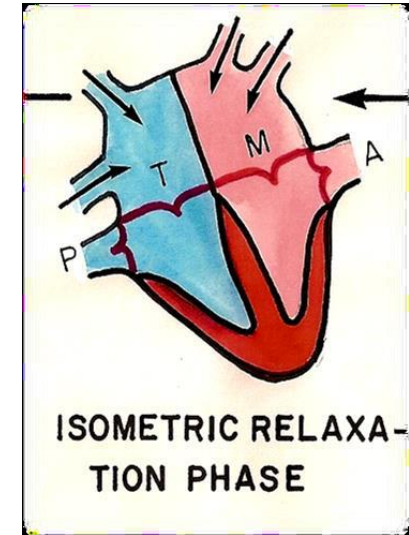
## 5- Isovolumetric Relaxation Phase:

- Quiescent period
- At beginning of diastole ... (0.04 sec)
- Period b/w closure of semilunar- vs & opening of AV- vs
- Preceded by ventricular repolarization

### 2nd Heart sound heard

**LV is a closed chamber**, i.e. relax w/out change in volume:

- Volume of blood in ventricle = **ESV**
- LV relaxes with  $\square$   $\square$  pressure
- AV- vs open at the end of this phase



The ventricle pressure become less than the atrium , ventricle systole stop and the blood in the ventricle at the end of systole is ESV ..

We will hear the ( S2) sound which produced due to closing of Aorta and pulmonary valves ..

<http://www.youtube.com/watch?v=dmPtaJxgRQU&noredirect=1>

## 6- rapid filling :

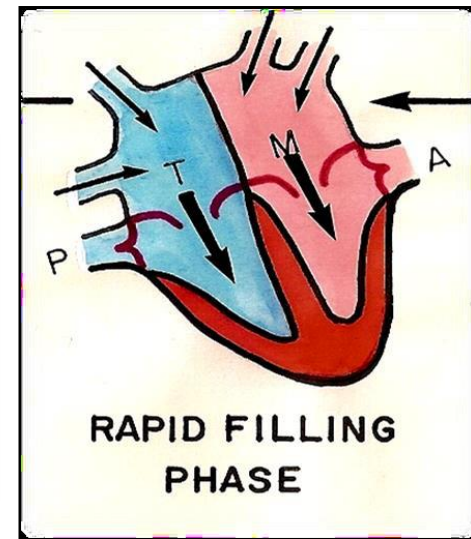
Atrial pressure > ventricular pressure

AV- vs open

- 60-70% of blood passes passively to the ventricles along pressure gradient:

- Ventricular volume ↑ rapidly

**3rd Heart sound heard**



The **mitral** valve will **open** , and we will have R.P.V.F ( rapid passive ventricle filling )  
And “ **v** “ **wave start to decrease** because the blood start to move passively to the ventricle >> note that there is **NO ATRIAL SYSTOL YET** .. Also its not act any more as a tank ..

We **may** hear the (**S3**) Sound , caused by hyperactivity such as exercise ( rapid ventricular filling )

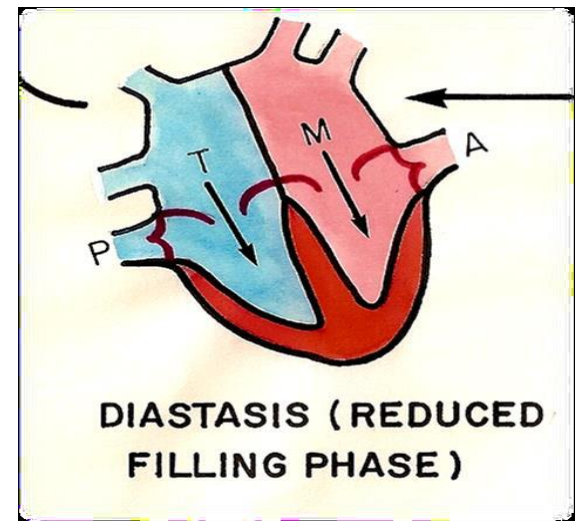


## 7- slow filling ( Diastasis ) :

Remaining atrial blood flows slowly into ventricles..

AV- vs still open

LV volume  $\uparrow$  > slowly



- Here the atrium will act as a passage to connect the blood which come from the lungs directly with the ventricle ..

Also here the blood movement still ( **passive** ) = no atrial contraction ..

[http://www.youtube.com/watch?v=VI9zo\\_CzQ9g](http://www.youtube.com/watch?v=VI9zo_CzQ9g)

| Phase                 | Mechanical changes                             | Volume & Pressure change  | Valves                       | Blood Movement  |
|-----------------------|--|---|------------------------------|---|
| Isometric contraction | Ventricles start to contract<br>Atrium relaxed | Volume constant<br>Pressure increases                                   | None                         | None  |
| Rapid ejection        | Ventricles contract<br>Atrium Relaxed          | Volume decreases<br>Pressure increases<br>P=120 in left, P=25 in right  | Semilunar valves are open    | Blood flows into aorta & pulmonary artery                         |
| Reduced ejection      | Ventricles contract (weaker)<br>Atrium relaxed | Volume decreases<br>Pressure decreases<br>P<120 in left, P<25 in right  | Semilunar valves are open    | Less blood flows into aorta & pulmonary artery                    |
| Protodiastole         | Ventricles relax<br>Atrium relaxed             | Volume increases<br>Pressure decreases                                  | Semilunar valves close       | None  |
| Isometric relaxation  | Ventricles relax<br>Atrium relaxed             | Volume constant<br>Pressure decreases                                   | None                         | None  |
| Rapid inflow          | Ventricles relax<br>Atrium Relaxed             | Volume increases<br>Pressure decreases<br>P=2-4 in left, P=0-2 in right | Atrioventricular valves open | Blood flows passively into the ventricles from the atria (60-70%) |
| Reduced inflow        | Ventricles relax<br>Atrium relaxed             | Volume increases<br>Pressure decreases                                  | Atrioventricular valves open | Blood continues to flow   |
| Atrial systole        | Ventricles are relaxed<br>Atria contract       | Atrial volume decreases<br>Atrial pressure increases                    | Atrioventricular valves open | Rest of the atrial blood is pumped into the ventricles            |

***THE END***

**If there are any problems or suggestions  
Feel free to contact:**

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***THANK YOU***

**Actions speak louder than Words**