



## **Cardiovascular Physiology**

# **Cardiac Cycle - 1**

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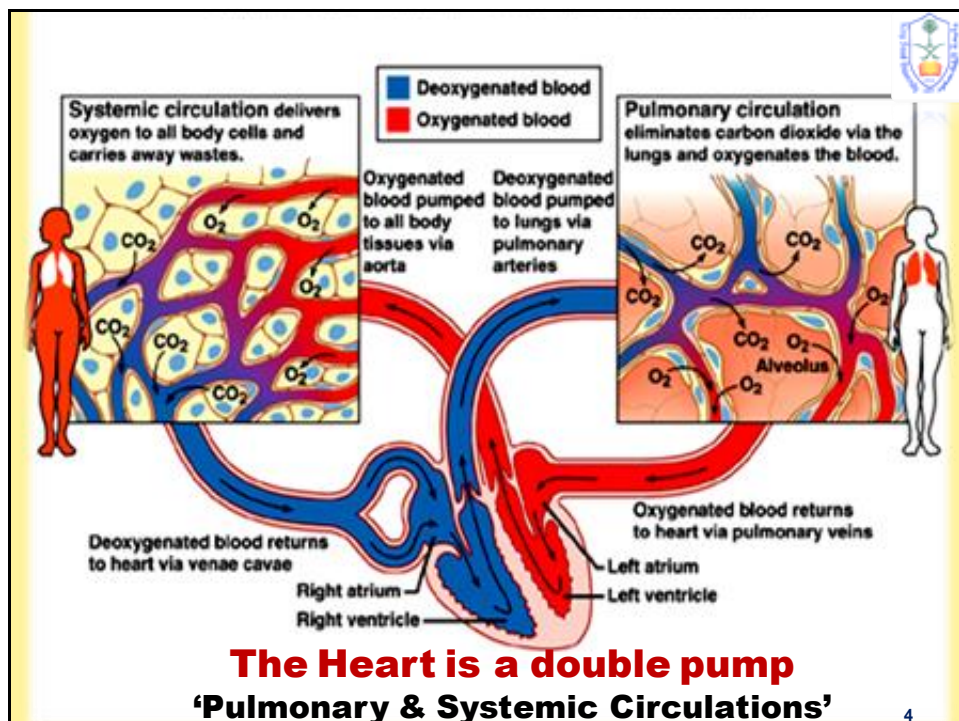


### **At end of this lecture you should be able to:**

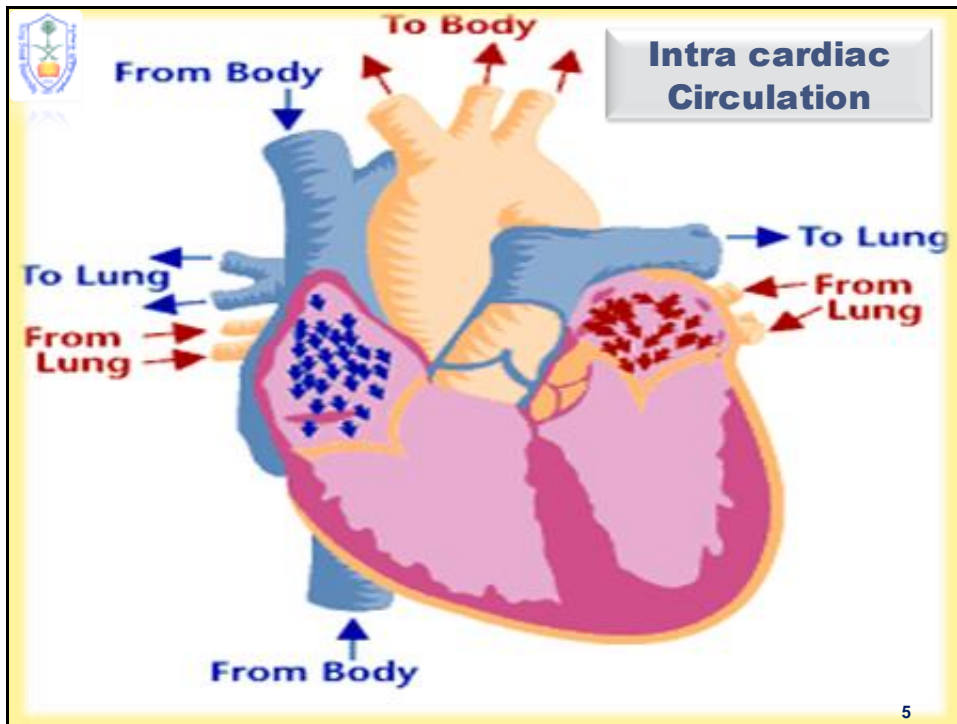
- ✓ **know general principles of cardiac cycle**
- ✓ **identify events occurring during cardiac cycle: mechanical, electrical, volume & pressure changes, & heart sounds**
- ✓ **understand the various phases of the cardiac cycle**

## Introduction

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## General Principles

- Blood flows from an area of high pressure to an area of low pressure
- Events on Rt & Lt sides of the heart are the same, but pressures are lower on Rt side



## Definitions

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

- Volume of blood in ventricle at end of diastole
- $\approx 110\text{-}130\text{ ml}$

- **Stroke volume (SV):**

- Amt of blood ejected from each ventricle during systole
- $\approx 70\text{ ml/beat}$

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## Definitions ... (Cont.)


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

- Amt of blood left in each ventricle at end of systole
- $\approx 40\text{-}50\text{ ml}$

- **Ejection fraction (EF):**

- Fraction of end-diastolic volume that is ejected
- $\approx 60\text{-}65\%$


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## Intra-cardiac Pressures

Right Side	Left Side
<ul style="list-style-type: none"><li>● <b>Right ventricle:</b> 25-30/2-8 mmHg</li><li>● <b>Pulmonary artery:</b> 25-30/4-12 mmHg (mean press 9-18 mmHg)</li><li>● <b>Right atrium:</b> 2-8 mmHg</li></ul>	<ul style="list-style-type: none"><li>● <b>Left ventricular:</b> 100-120/3-12 mmHg</li><li>● <b>Aorta:</b> 120/80 mmHg</li><li>● <b>Left atrium:</b> 2-10 mmHg (pulmonary wedge press)</li></ul>

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## Cardiac Cycle



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

- **Cardiac cycle duration = 0.8 sec ...**
  - When HR 72/min
  - Shortened when HR ↑

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## Definitions

- **Systole = Phase of contraction**
- **Diastole = Phase of relaxation**
- **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

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## To Revise:

- Blood flows from an area of  pressure to an area of  pressure
- Cardiac cycle duration is  when HR = 72bpm
- Normally  period is longer than  period
- EDV  $\approx$   ml
- SV  $\approx$   ml/beat
- ESV  $\approx$   ml
- EF  $\approx$   %

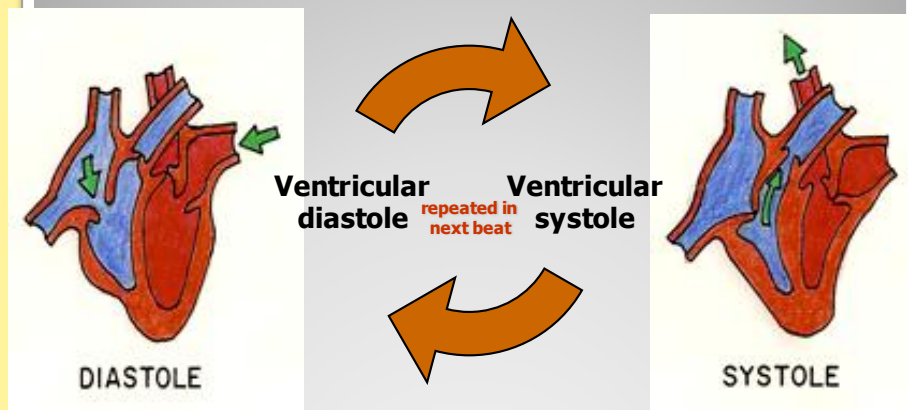
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## To study cardiac cycle:

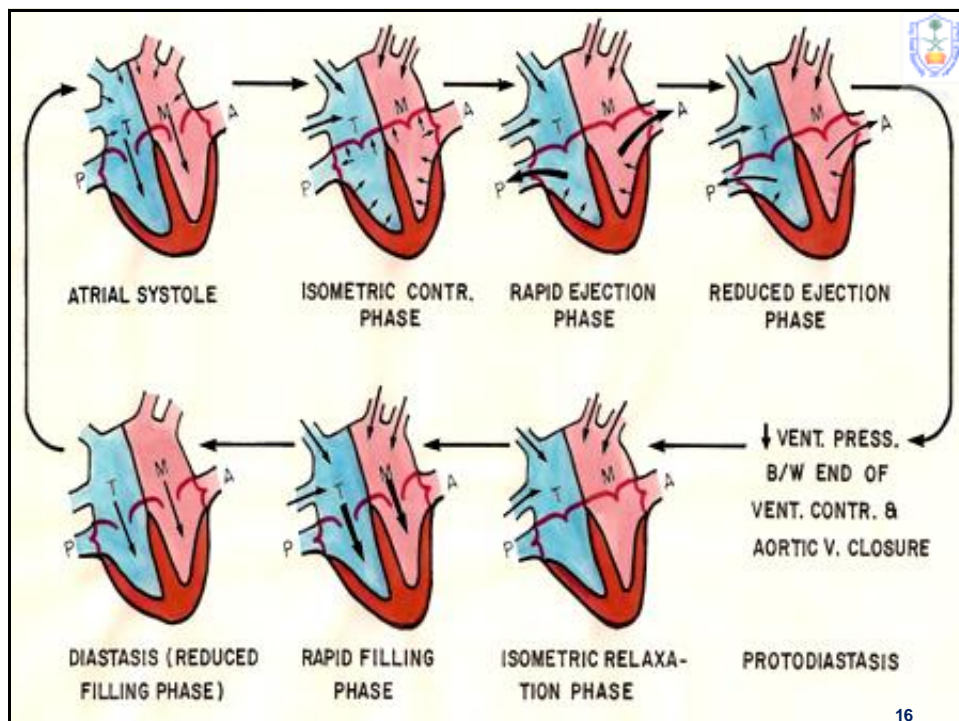
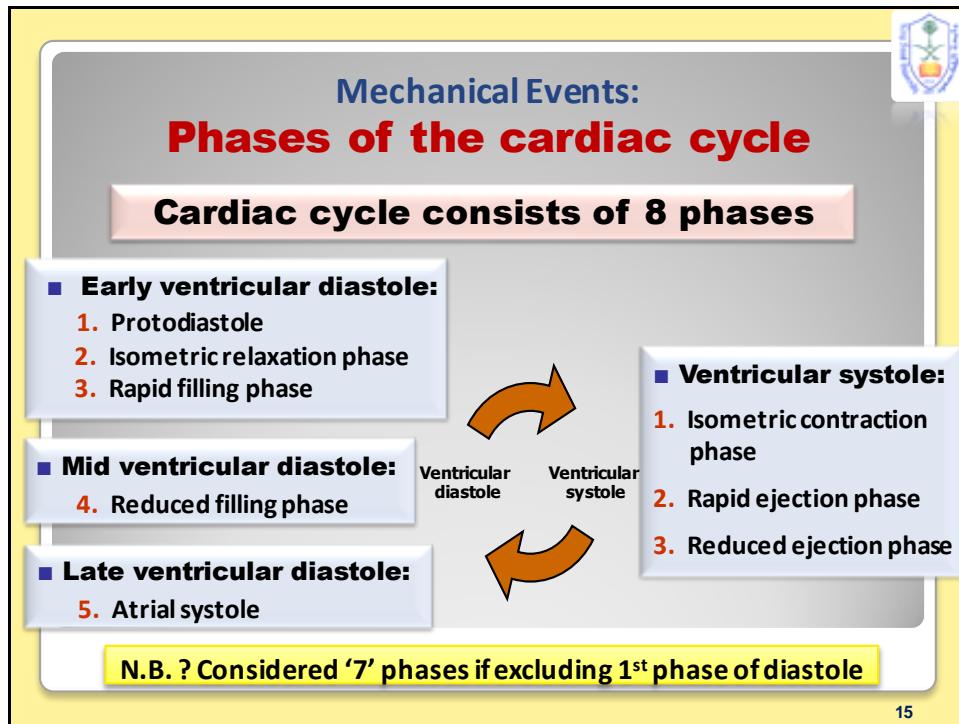
- I: Mechanical events**
- II: Volume changes**
- III: Pressure changes**
- IV: Heart sounds**
- V: Electrical events (ECG)**

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## Mechanical Events:



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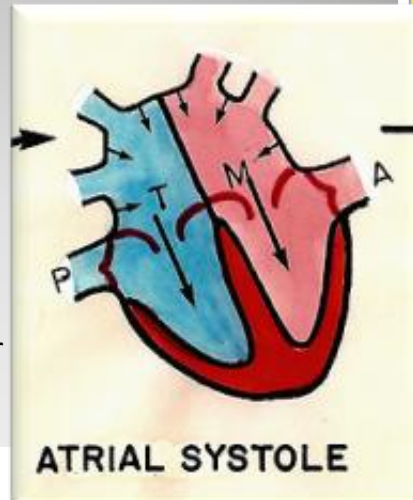




## Phases of cardiac cycle:

### 1. Atrial Systole:

- At end of ventricular diastole ... lasts 0.1 sec
- AV-vs open & semilunar-vs closed
- Tops off last 27-30% of ventricular filling
- Blood arriving heart can't enter atrium, it flows back up jugular vein



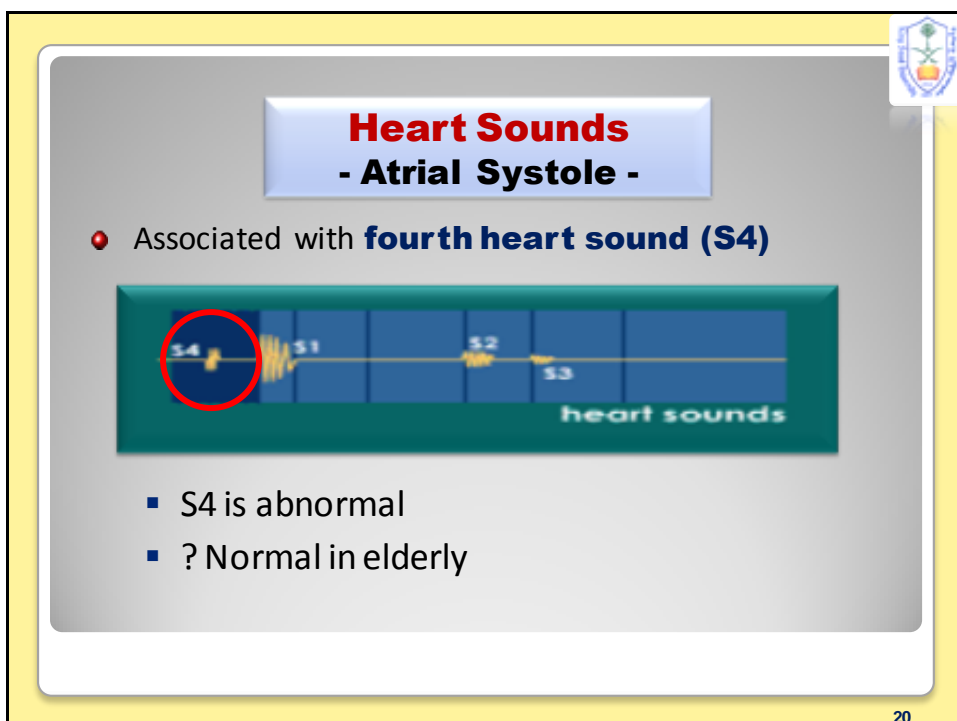
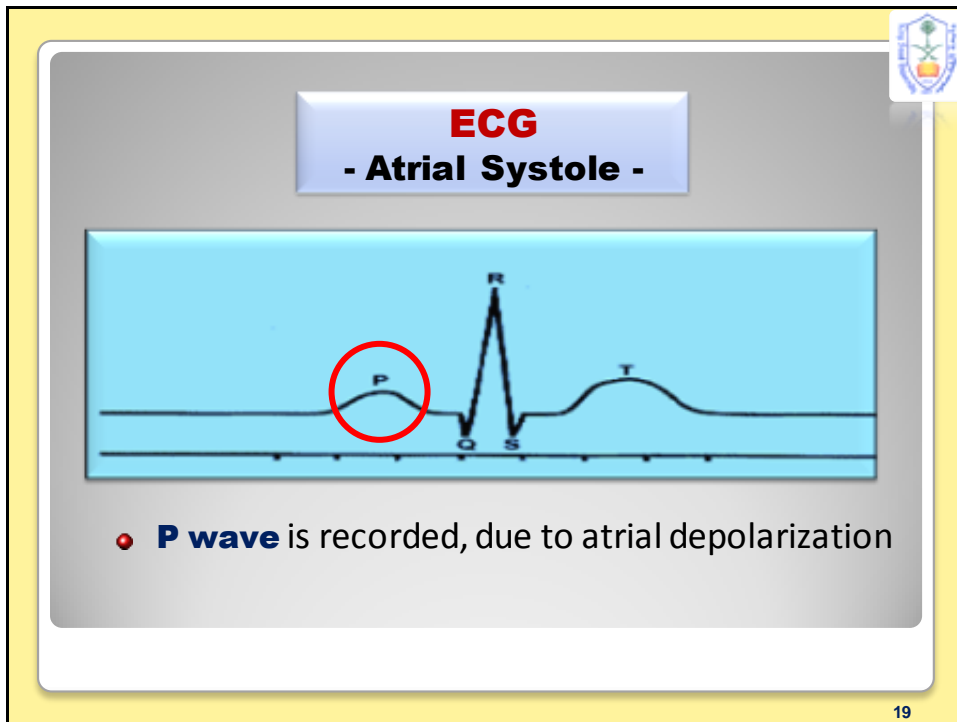
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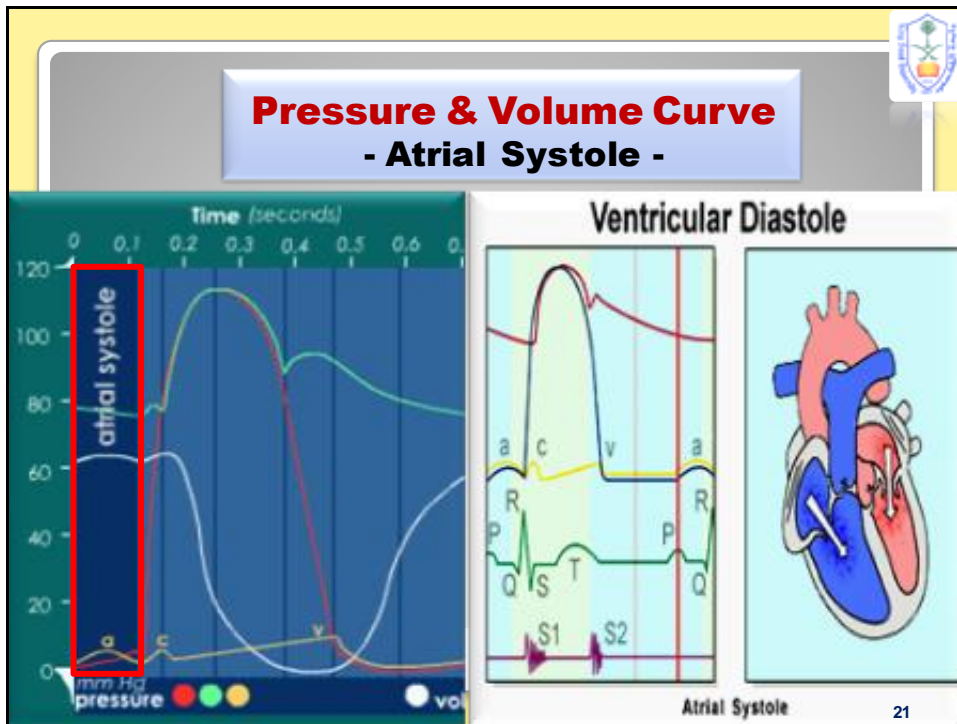
### Atrial Pressure Curve - Atrial Systole -



- "a" wave is recorded, due to  $\uparrow$  atrial press during atrial contraction
- In jugular venous pressure curve, a delay record of "a" wave occurs due to back regurgitation of blood to jugular vein

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## To Revise:

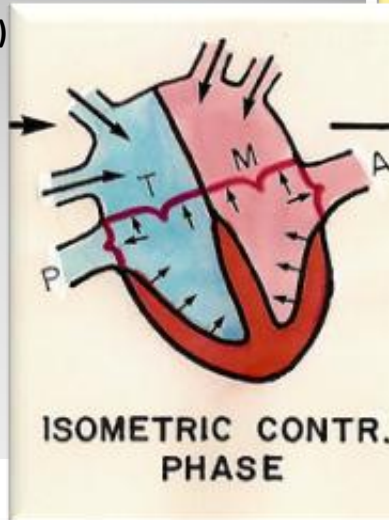
Regarding 'Atrial Systole':

- Atrial systole occurs at the end of ventricular
- Tops off last % of ventricular filling
- On Atrial Pressure Curve,  wave is recorded
- In ECG,  wave is recorded
- Associated with  heart sound

**Phases of cardiac cycle:**

## 2. Isovolumetric Contraction Phase:

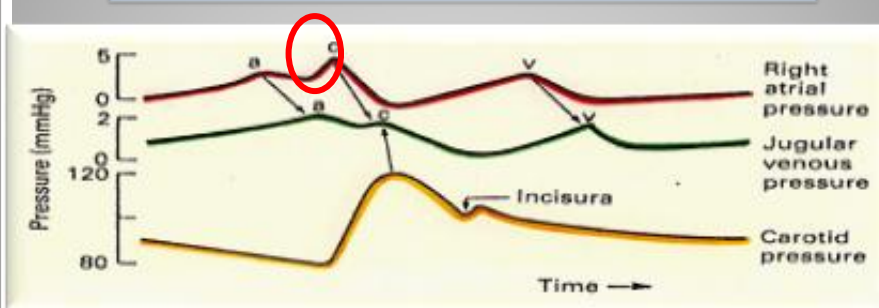
- At beginning of systole ... (0.04 sec)
- Period b/w closure of AV-vs & opening of semilunar- vs
- All valves are closed
- Ventricle is a closed chamber, contract w/out change in volume
- Volume in ventricle is **EDV**
- Ventricular press < aortic press
- Aortic v opens at end of this phase (when LV = 80mmHg)



ISOMETRIC CONTR. PHASE

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## Atrial Pressure Curve - Isovolumetric Contraction Phase -



Pressure (mmHg)

Time →

Right atrial pressure

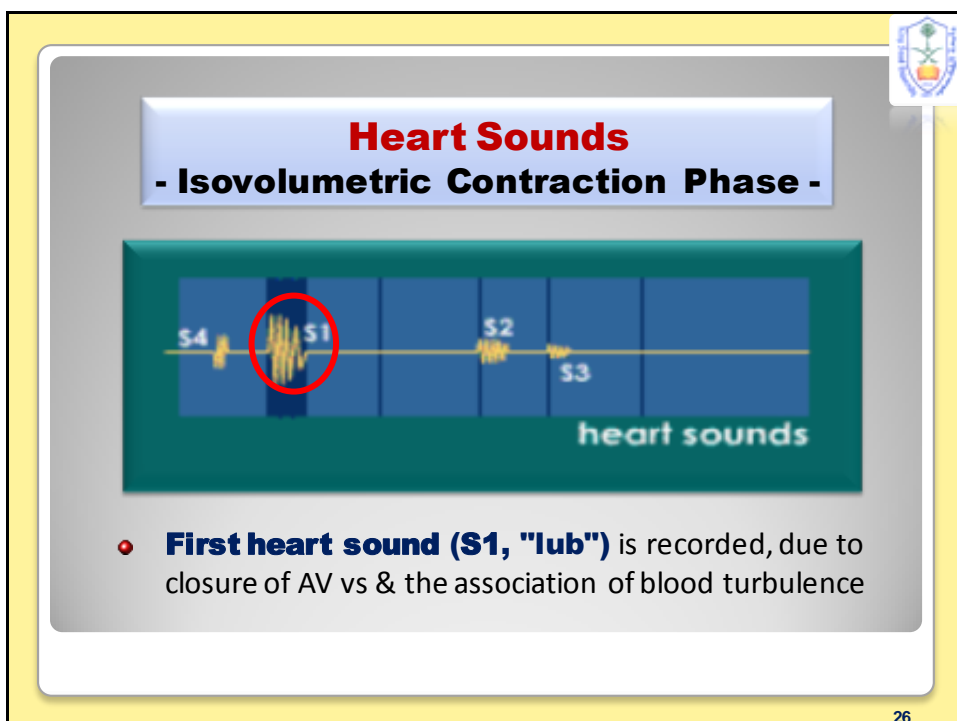
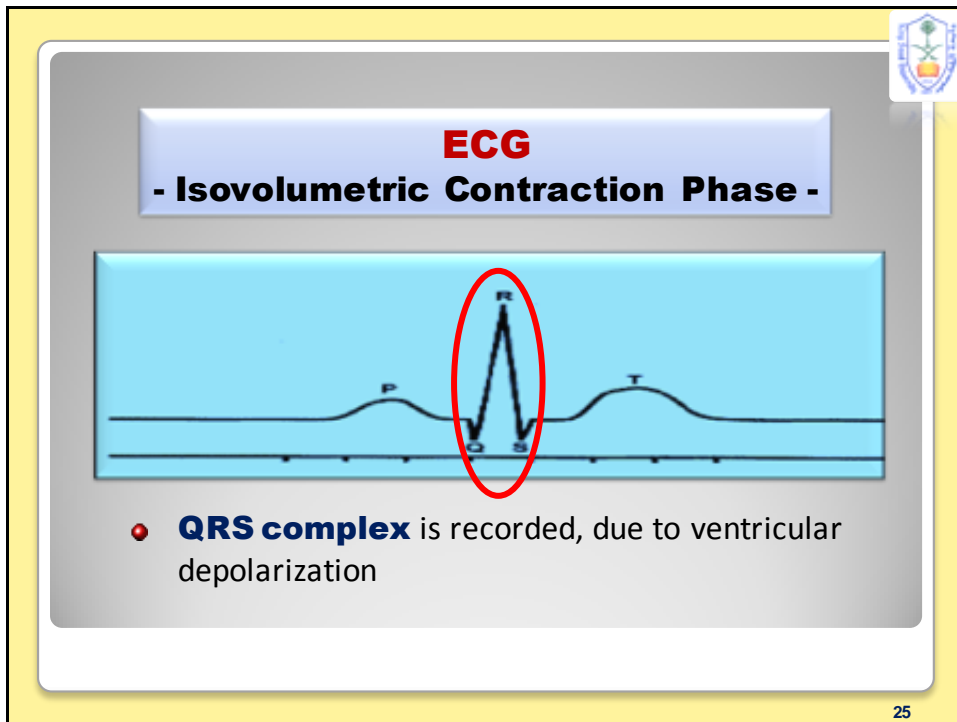
Jugular venous pressure

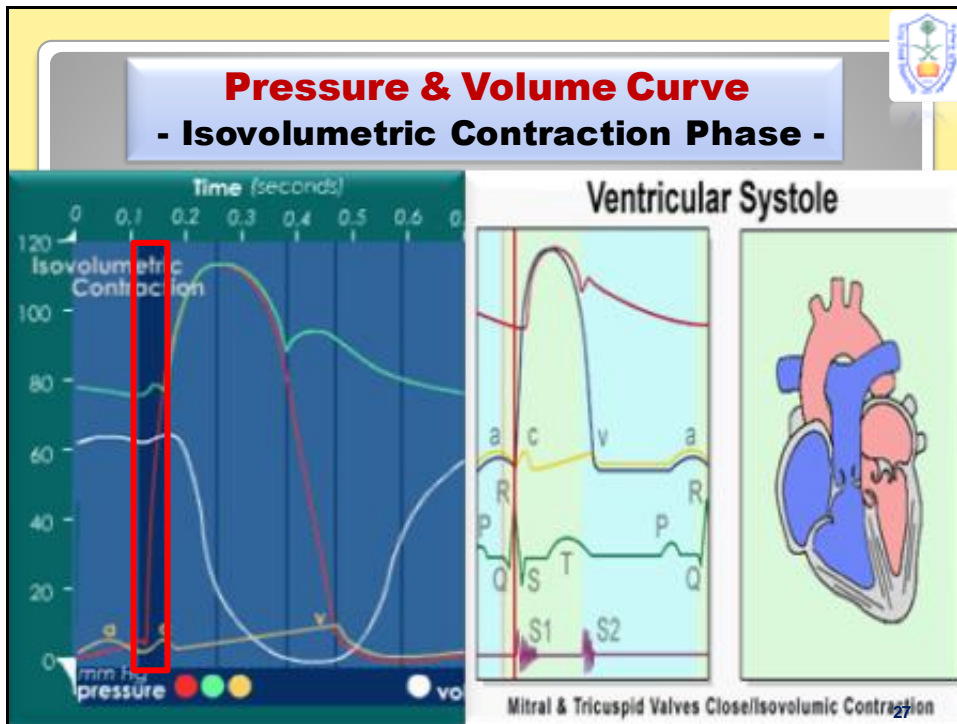
Carotid pressure

Incisura

- Ascending limb (+ve) of "c" wave is recorded:
  - ↑ atrial press as a result of RV contraction
  - Pushes TV into atrium (bulging of cusps)

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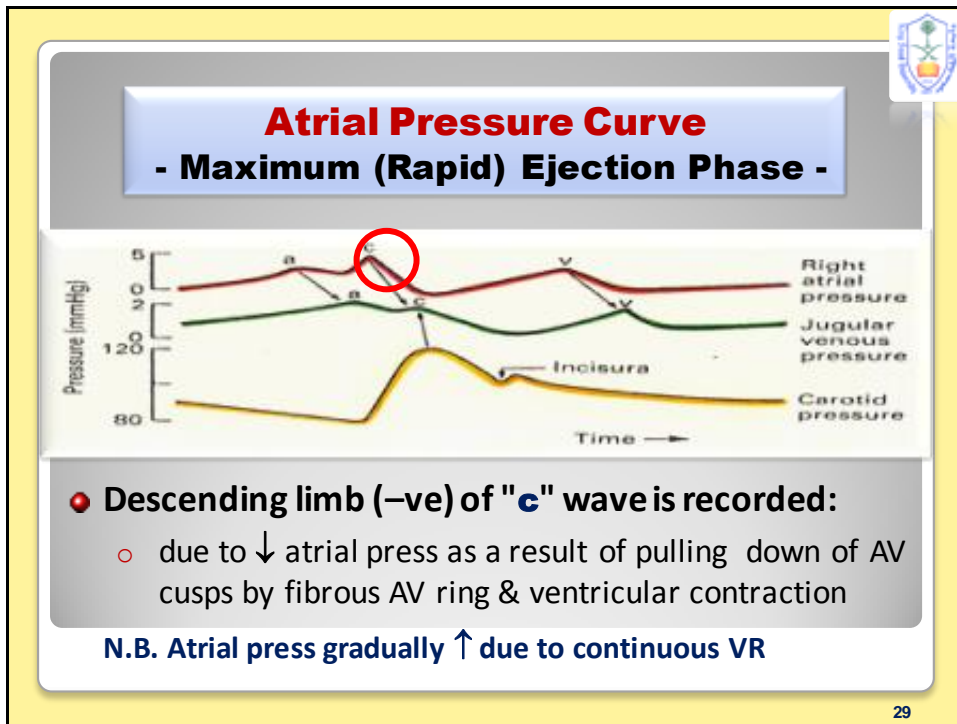


**Phases of cardiac cycle:**

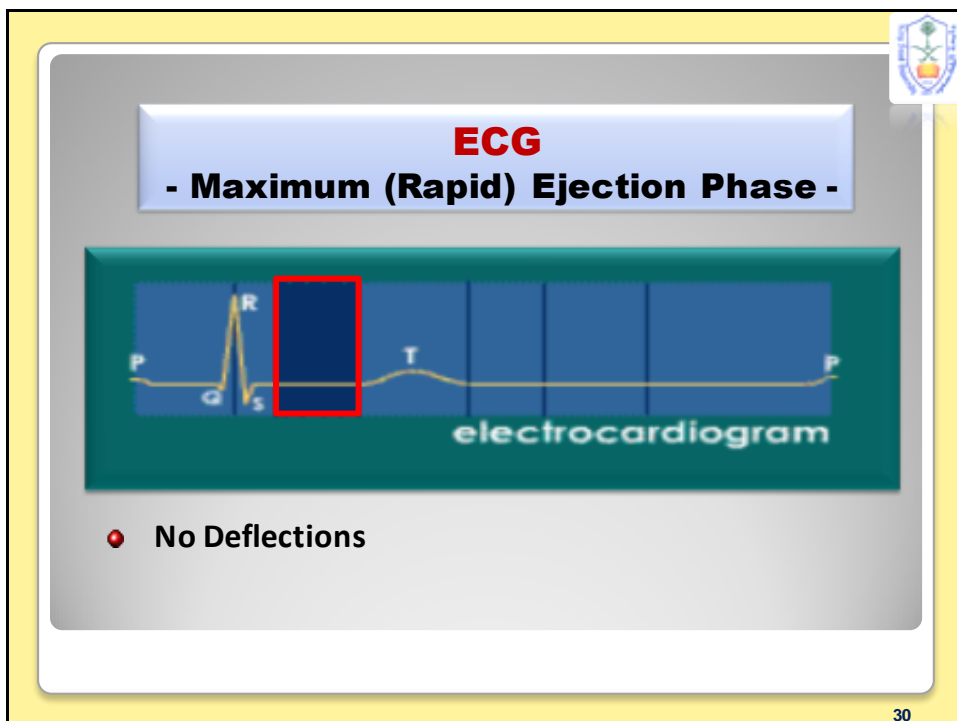
**3. Maximum (Rapid) Ejection Phase:**

- Contraction of ventricle causes ventricular pressure to  $\uparrow >$  aortic pressure
- Semilunar valves open at beginning of this phase
- Volume of blood ejected = **SV**
- Ventricular volume  $\downarrow$  rapidly

**RAPID EJECTION PHASE**

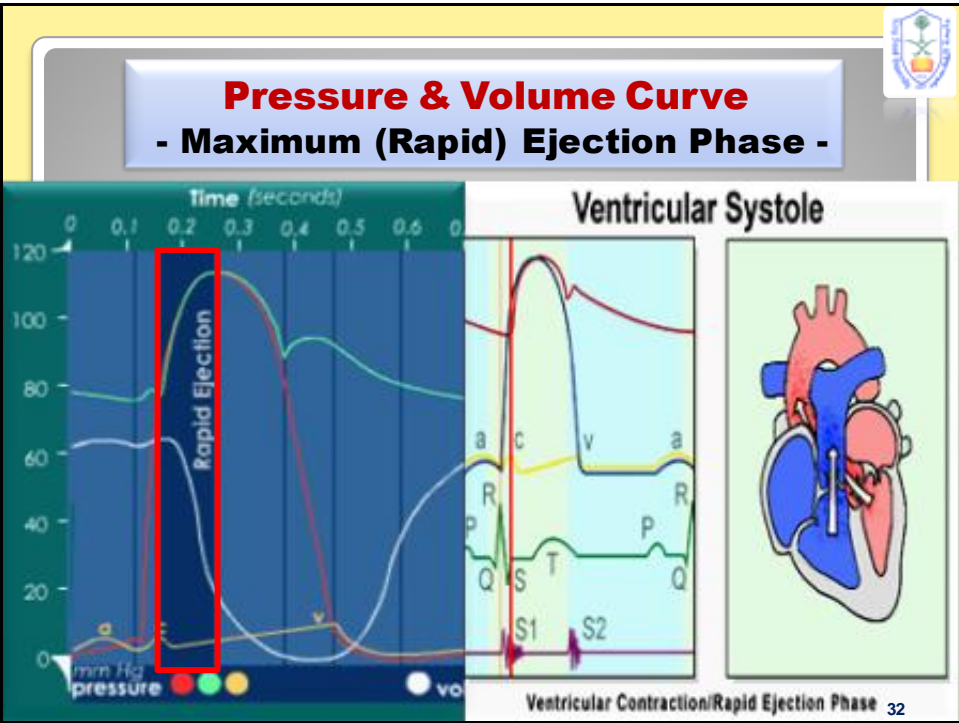
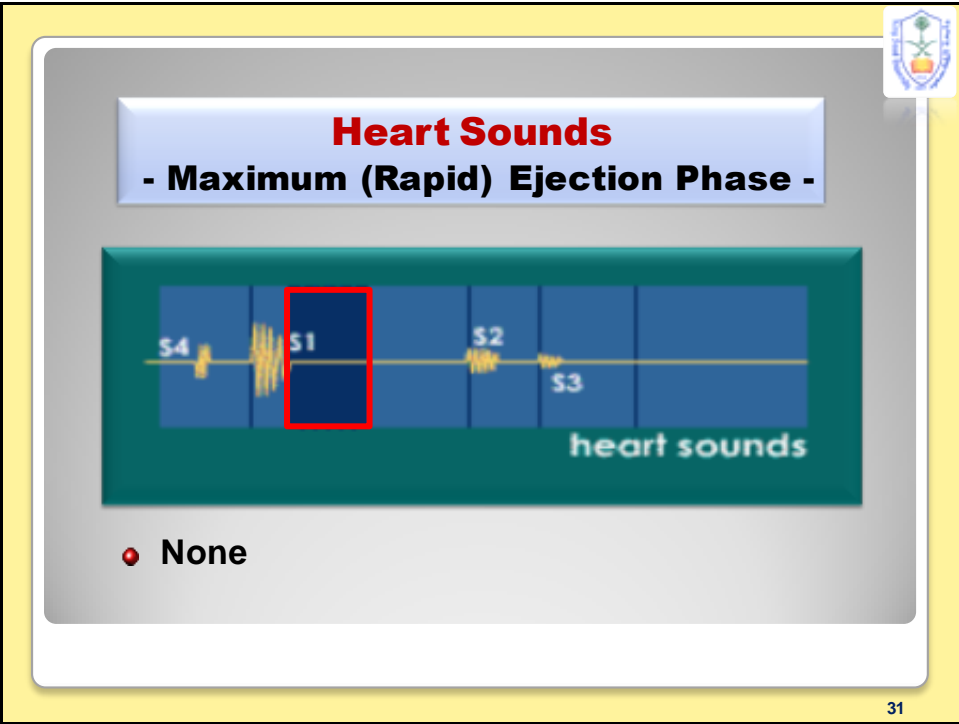


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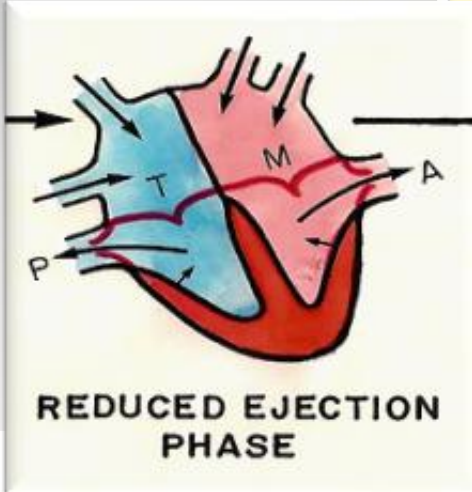




**Phases of cardiac cycle:**

**4. Reduced Ejection Phase:**

- At end of systole
- Ventricular volume ↓ more slowly
- semilunar v close & AV- vs open at end of this phase
- Ventricular press ↓ < aortic press




REDUCED EJECTION PHASE

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**ECG**

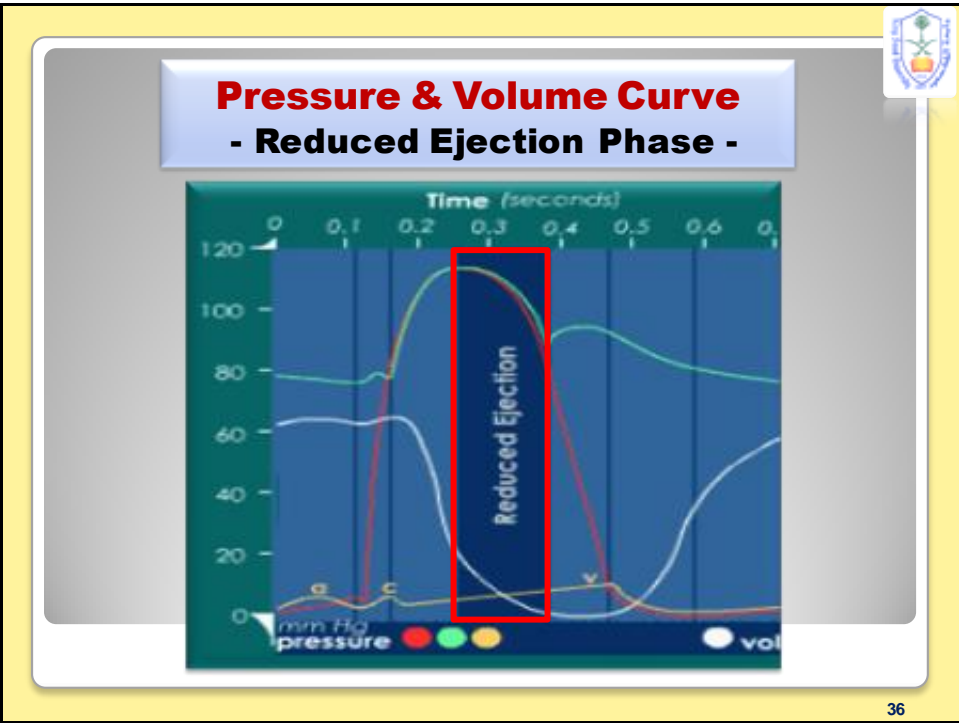
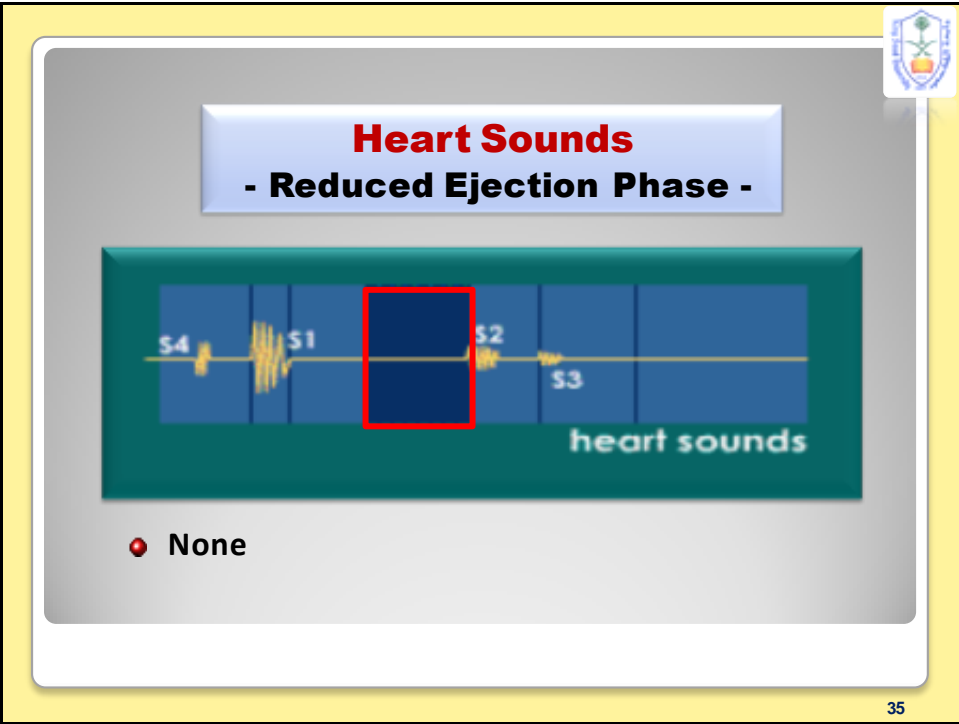
**- Reduced Ejection Phase -**



electrocardiogram

- T wave** is recorded, due to ventricular repolarization

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## To Revise:

Regarding phases of ventricular contraction:

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

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Phases of cardiac cycle:

### 5. Protodiastolic Phase:

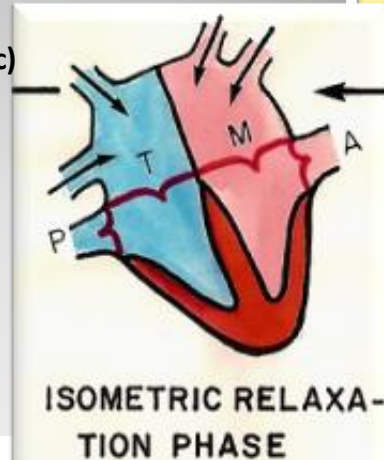
- Period b/w end of ventricular contraction & aortic valve closure
- Lasts 0.04 sec
- ↓ ventricular pressure < aortic pressure
- Aortic valve closes by end of this phase as a result of back pressure (when LV pressure 110 mmHg)
- Atrial pressure still ↑, due to continuous venous return (VR)

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## Phases of cardiac cycle:

### 6. Isovolumetric Relaxation Phase:

- At beginning of diastole ... (0.04 sec)
- Period b/w closure of semilunar- vs & opening of AV-vs
- LV is a closed chamber, i.e. relax w/out change in volume
- Volume of bl in ventricle = **ESV**
- LV relaxes w ↓↓ press
- AV-vs open at end of this phase



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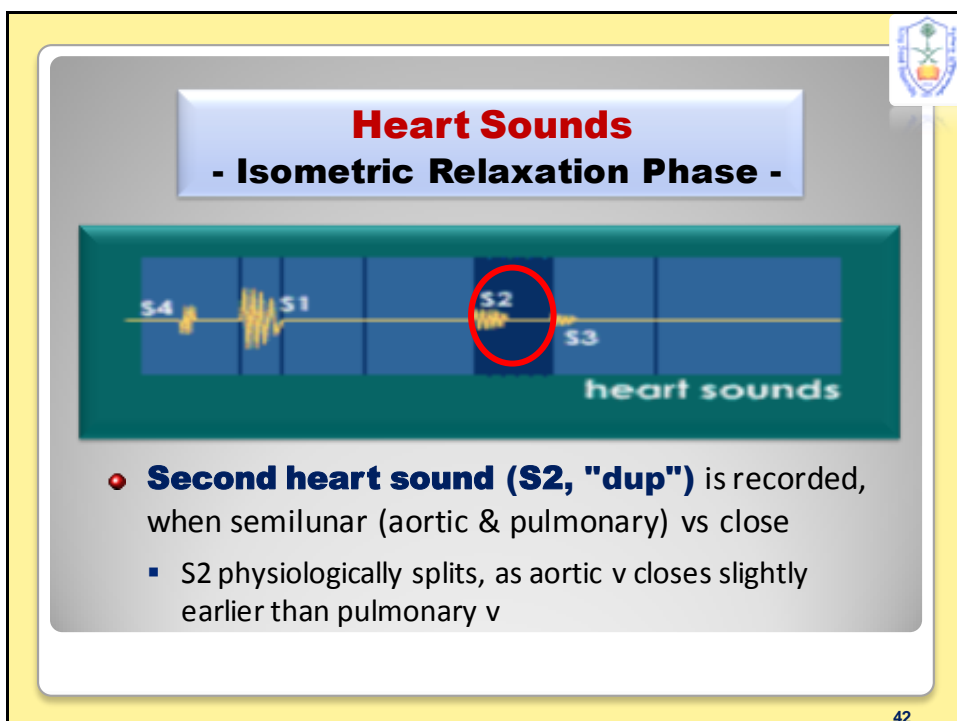
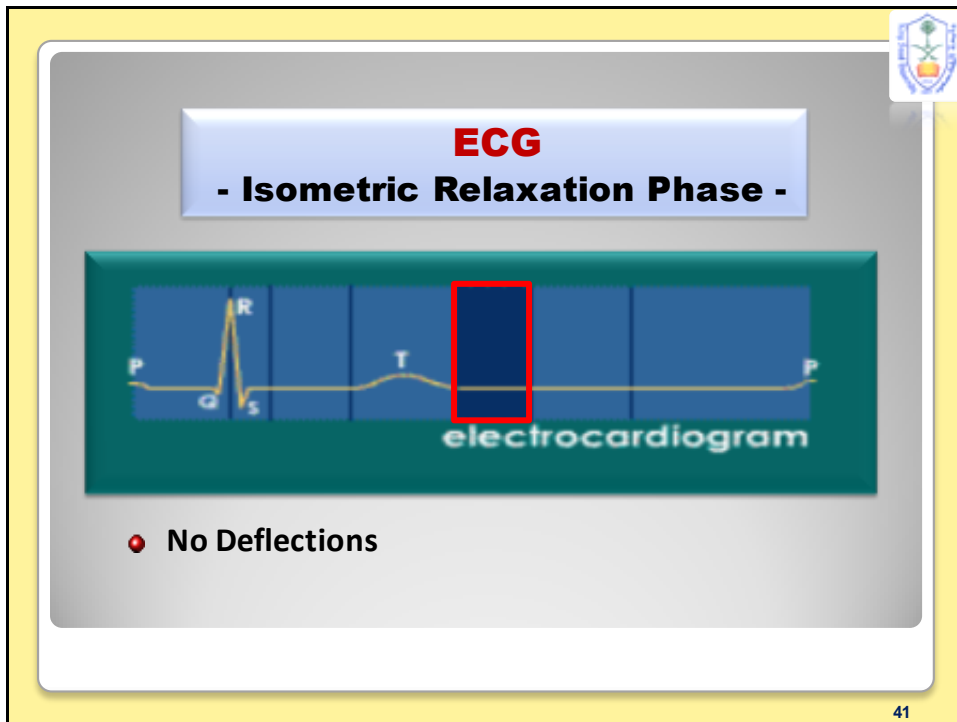
## Atrial Pressure Curve

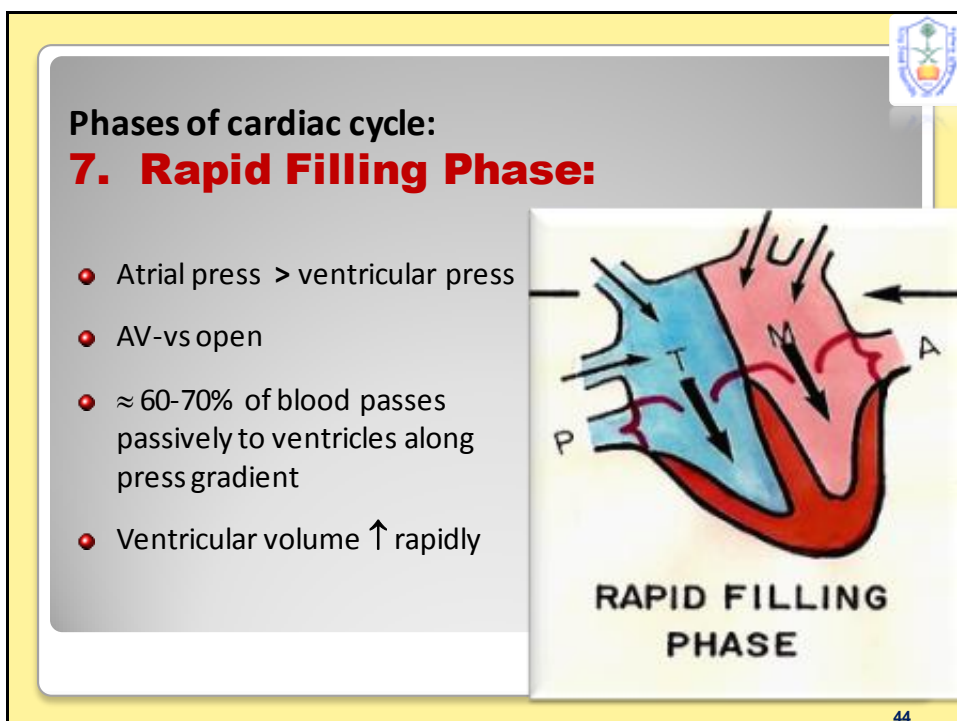
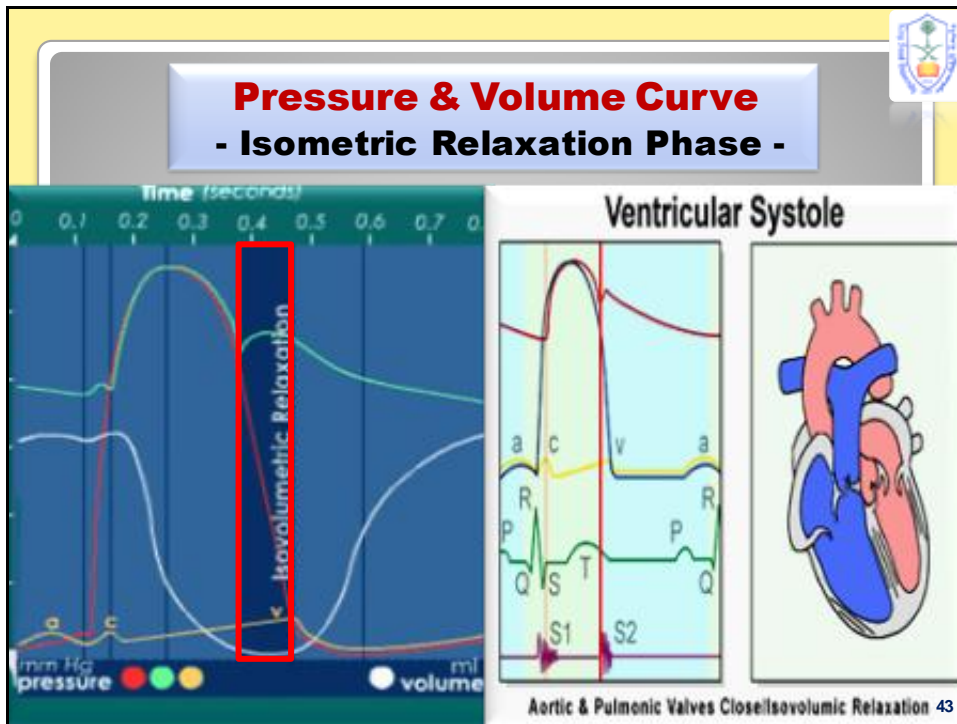
### - Isovolumetric Relaxation Phase -

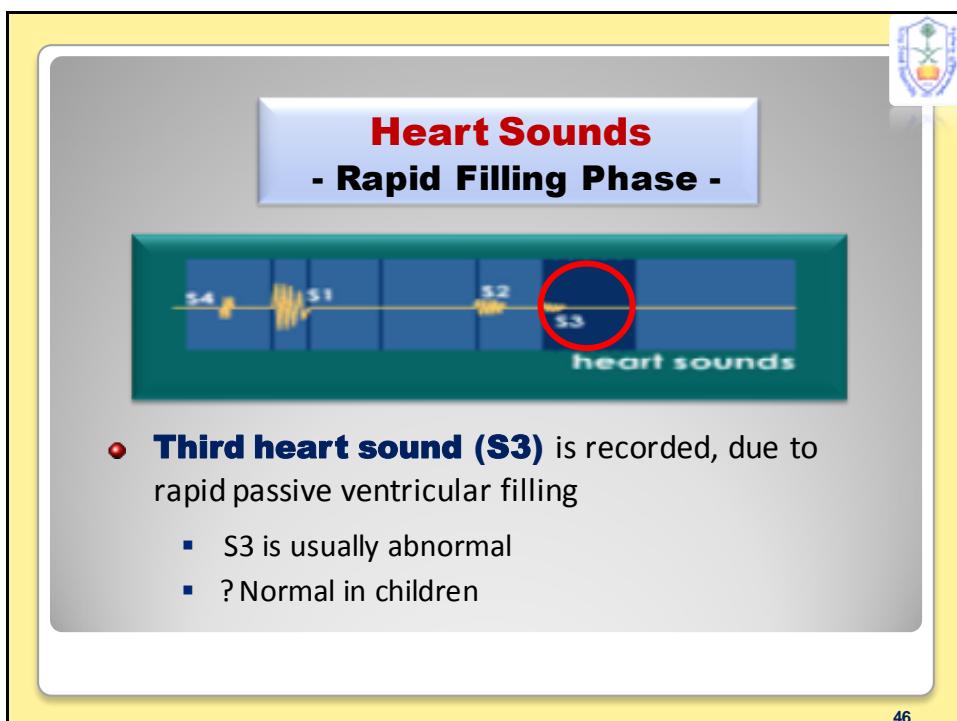
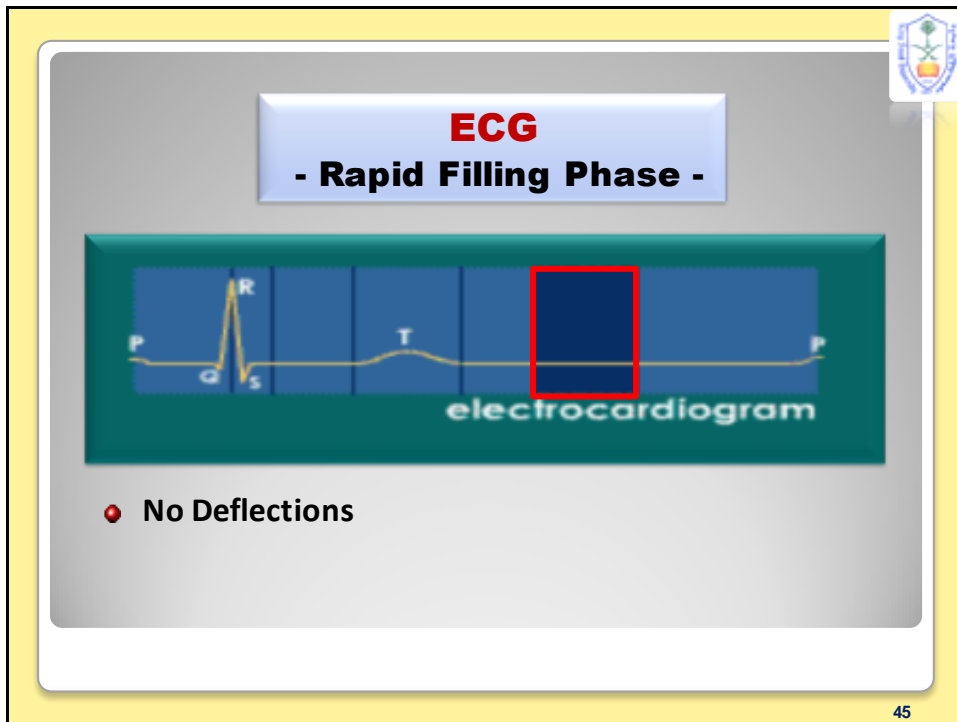


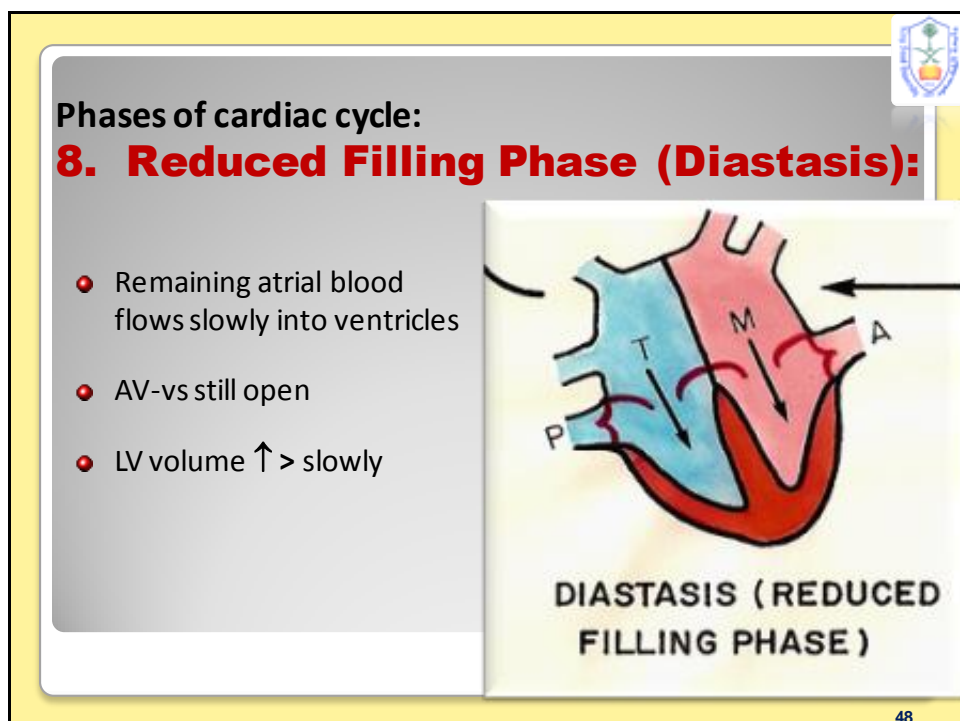
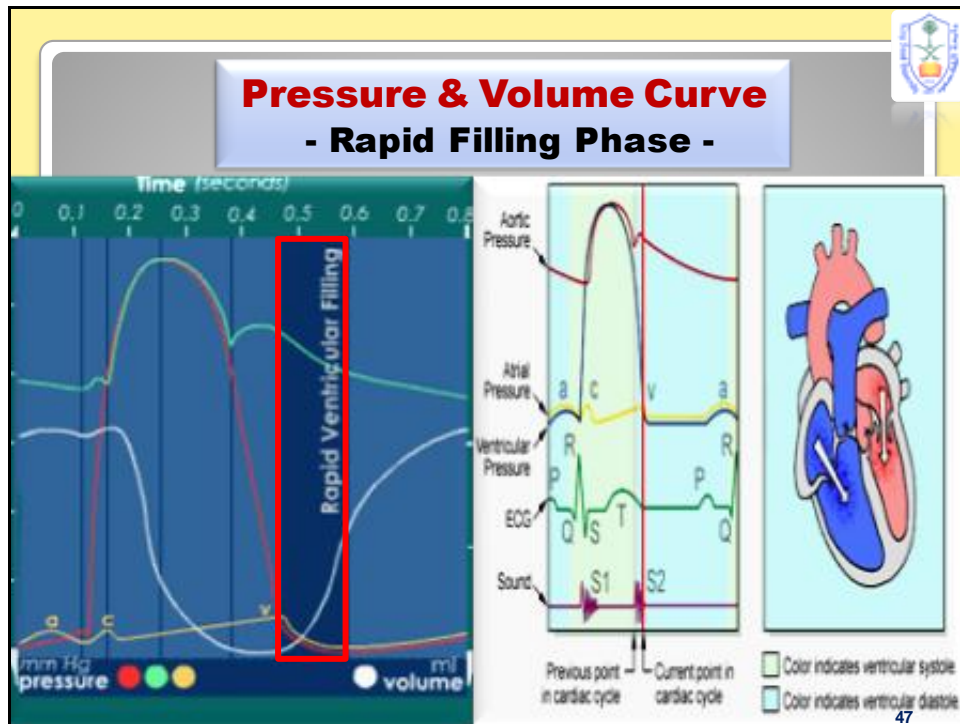
- "v" wave is recorded, due to back flow of blood hitting closed AV v
- Ventricular press continues ↓
- Atrial press ↑ gradually due to continuous VR on top of closed AV v

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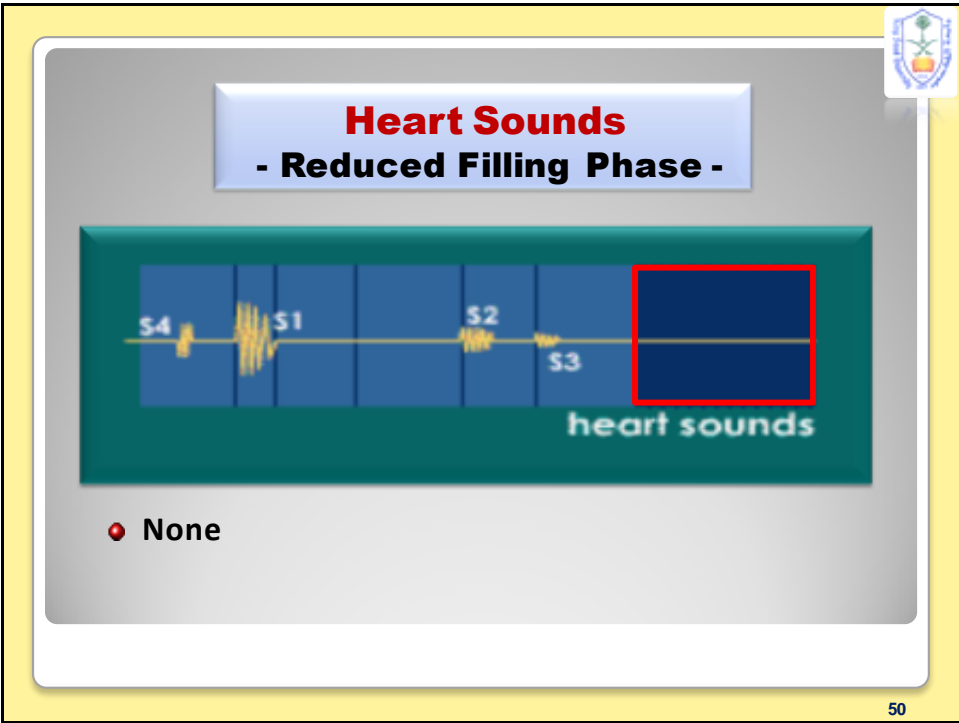
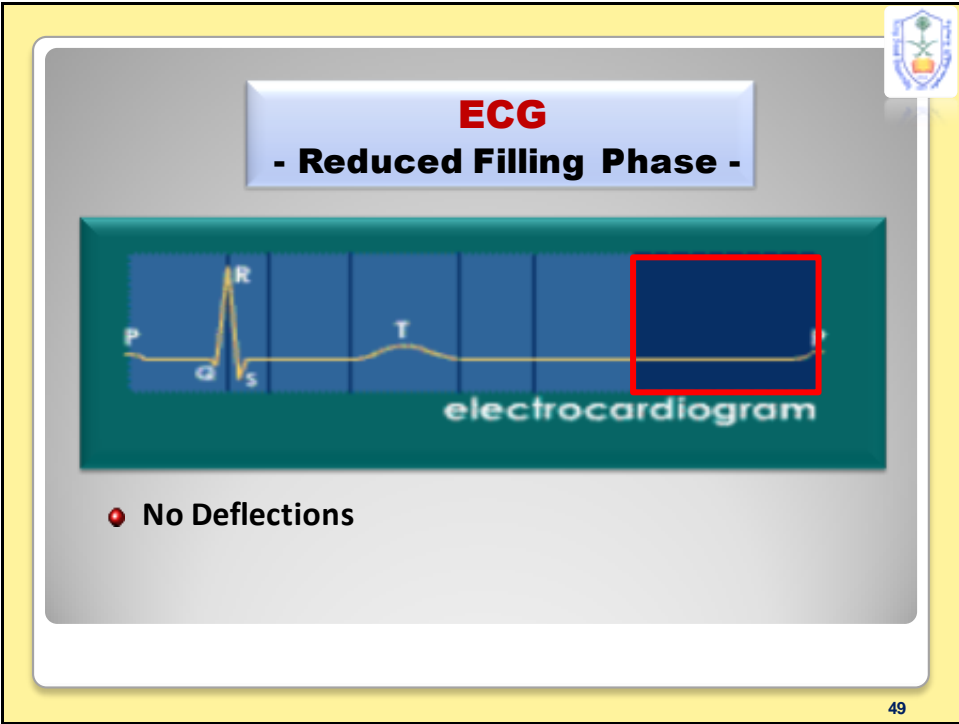


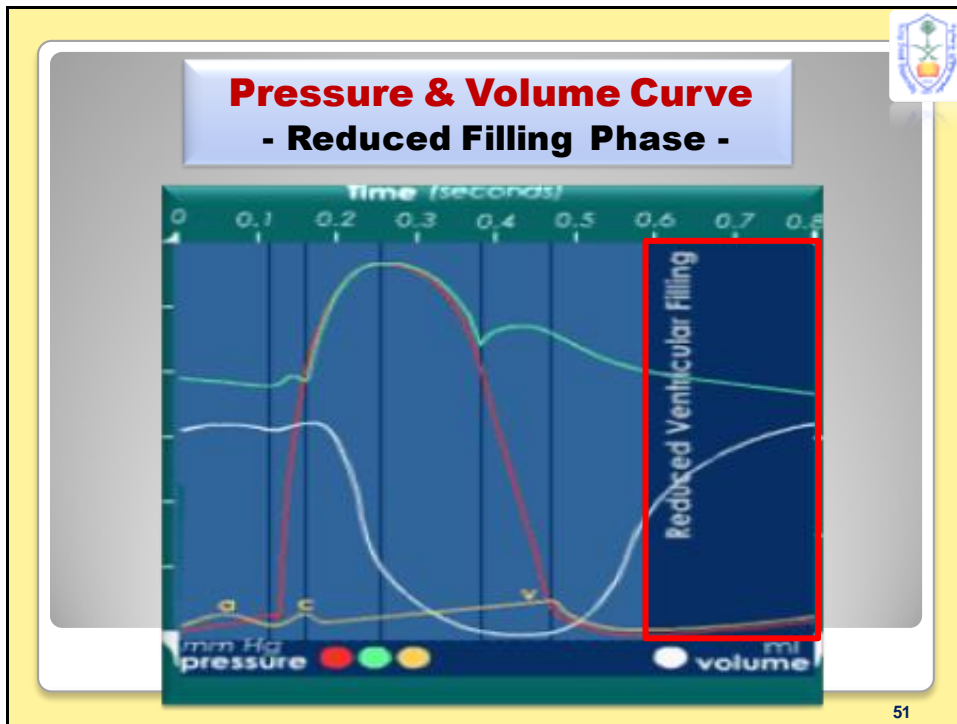












**To Revise:**

Regarding phases of ventricular relaxation:

- 'v' wave in atrial pressure curve occurs during:  
 phase
- heart sound marks the beginning of diastole
- % of blood passes passively during 'rapid filling' phase
- heart sound is recorded during 'rapid filling' phase

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