Cardiovascular Physiology

Cardiac Cycle- 2

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At end of this lecture you should be able to know:

- ✓ Volume changes that occur during cardiac cycle
- ✓ Pressure changes that occur during cardiac cycle
- ✓ Electrical changes that occur during cardiac cycle
- ✓ Different heart sounds produced during cardiac cycle
- ✓ Correlation of different events that occur during cardiac cycle
- ✓ Volume-Pressure relationship in the left ventricle

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Events in the cardiac cycle ?

I: Mechanical events

II: Volume changes

III: Pressure changes

IV: Heart sounds

V: Electrical events (ECG)

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Ventricular Volume Changes During the Cardiac Cycle

Ventricular Volume Changes

Phases	Ventricular volume
1. Atrial systole	↑
2. Isometric contraction phase	Constant
3. Rapid ejection phase	↓ rapidly
4. Reduced ejection phase	↓ slowly
5. Protodiastole	Constant
6. Isometric relaxation phase	Constant
7. Rapid filling phase	↑ rapidly
8. Reduced filling phase	↑ slowly

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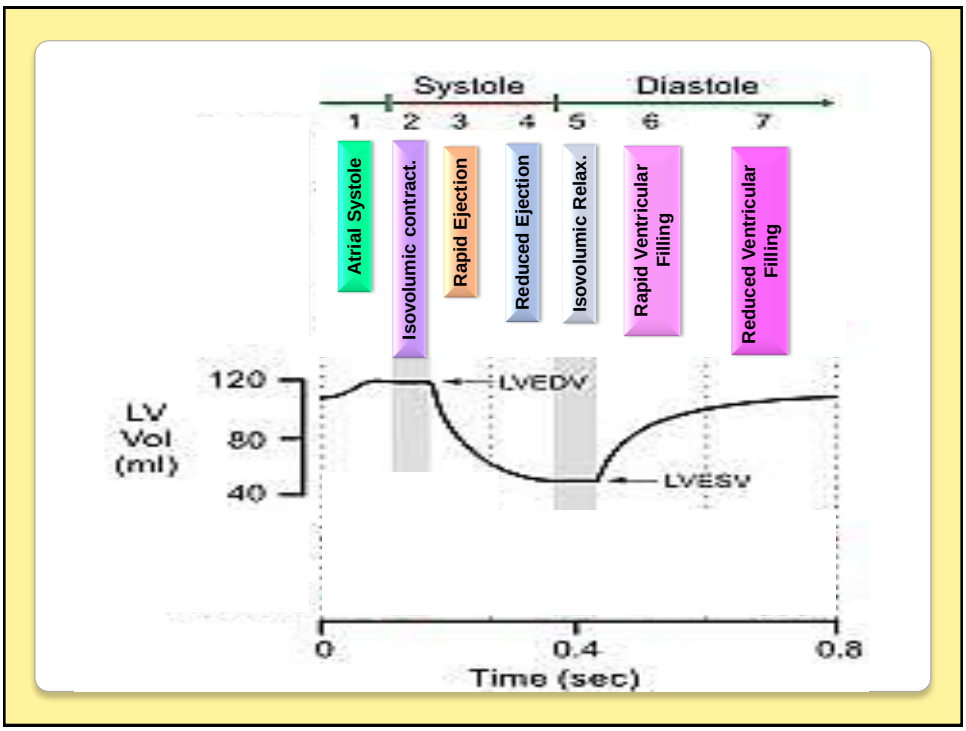

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Pressure Changes During the Cardiac Cycle

Pressure Changes:

- Ventricular pressure
- Aortic pressure
- Arterial pressure waves
- Pulmonary artery pressure
- Atrial pressure
- Jugular venous pulse wave

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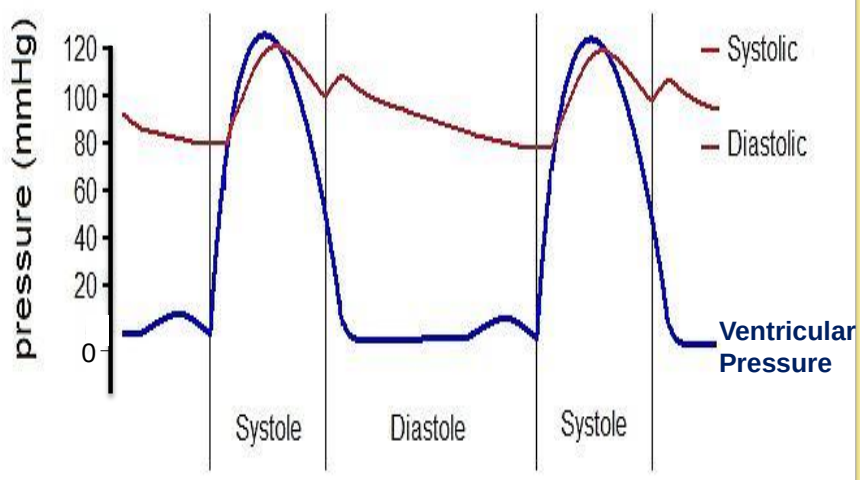
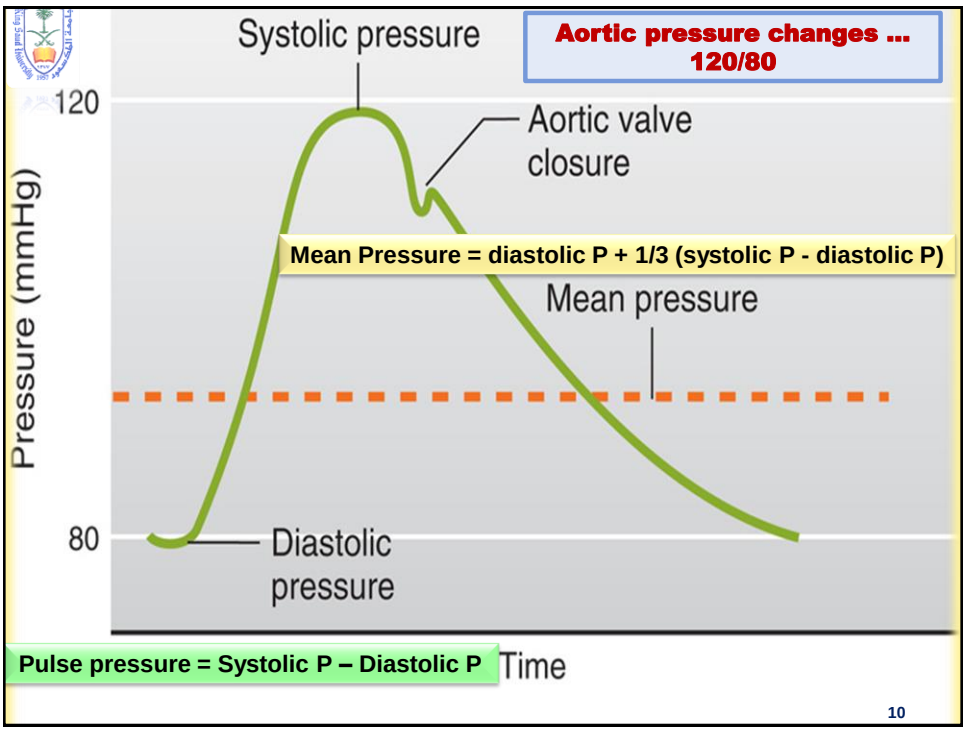
Ventricular Pressure Changes … 120/3-12





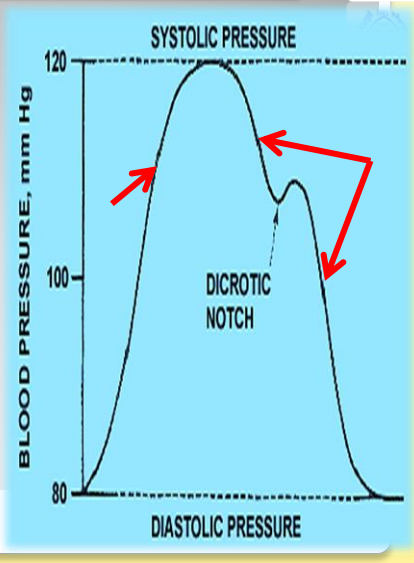
Aortic Pressure Changes … 120/80

a. Ascending or Anacrotic limb:

- With 'rapid ejection phase'
- Pressure ↑ up to 120 mmHg

b. Descending or Catacrotic limb:

- Passes in 4 stages



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Stages of the Descending / Catacrotic Limb:

1. ↓ Aortic press:

- With 'reduced ejection phase'
  (Amount of blood enters aorta < leaves)

2. Dicrotic Notch (Incisura):

Due to closure of aortic- v

- Sudden drop in aortic pressure
- At end of ventricular systole

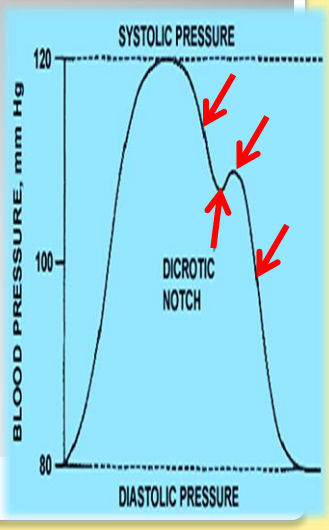
3. Dicrotic Wave:

Due to elastic recoil of the aorta

- Slight ↑ in aortic pressure

4. Slow ↓ aortic press: up to 80 mmHg

Due to continued flow of blood from aorta → systemic circulation



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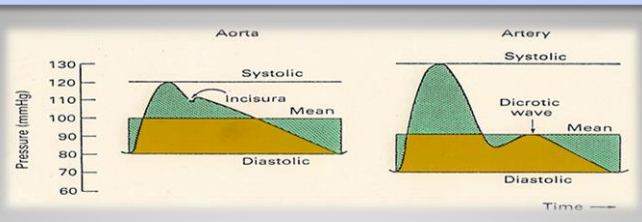
Arterial Pressure Changes … 110-130/70-90



- Similar to aortic pressure waves but **sharper**
- Reflects a systolic peak pressure of 110-130 mmHg & a diastolic pressure of 70-90 mmHg

Pulmonary Artery Pressure Changes … 25-30/4-12

- Similar to aortic pressure changes but with **difference in magnitude**

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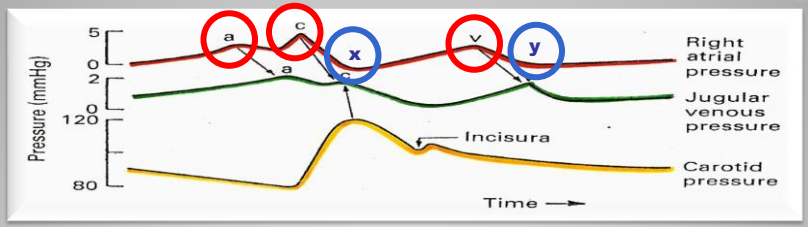
Atrial Pressure Changes



- **Results in:**
  - **3 upward deflection → a, c, & v**
    - 2 components in each wave: +ve (↑ press), -ve (↓ press)
  - **2 downward deflection → x & y**
- The 3 wave (a, c, & v) are equal to ONE cardiac cycle = 0.8 sec

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Causes of atrial pressure waves

- **'a' wave: Atraial systole**: ↑ atrial pressure during atrial contraction
- **'c' wave: Ventricular systole**
  - **+ve** → bulging of AV- vs into the atria during 'isovolumetric contraction phase'
  - **-ve** → pulling of the atrial muscle & AV cusps down during 'rapid ejection phase', resulting in ↓ atrial pressure
- **'v' wave: Atrial diastole or ↑ venous return (VR)**
  …Atrial pressure ↑ gradually due to continuous VR

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Causes of atrial pressure waves … (Cont.)

- **'x' descent:**
  Downward displacement of AV- vs during 'reduced ejection phase'
- **'y' descent:**
  ↓↓ atrial pressure during 'rapid filling phase' as a result of rapid emptying of blood from atria to ventricles

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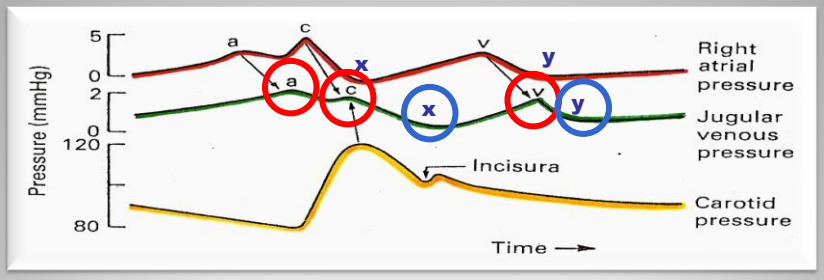
Jugular venous pulse changes



- **Also results in recording of transmitted atrial waves:**
  - 3 upward waves: a, c, & v
  - 2 downward waves: x & y

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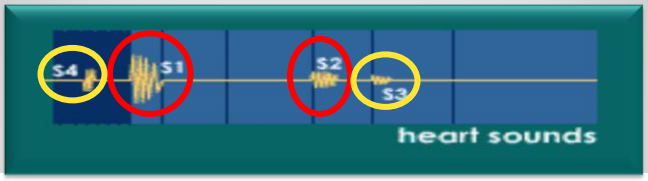
Heart Sounds Recorded During the Cardiac Cycle

Heart Sounds:

- **'4' heart sounds can be detected:**
  - 1st & 2nd ht sounds … (usually audible)
  - 3rd & 4th ht sounds … (sometimes detected)
- **Important for diagnosis of valvular heart diseases (murmurs)**



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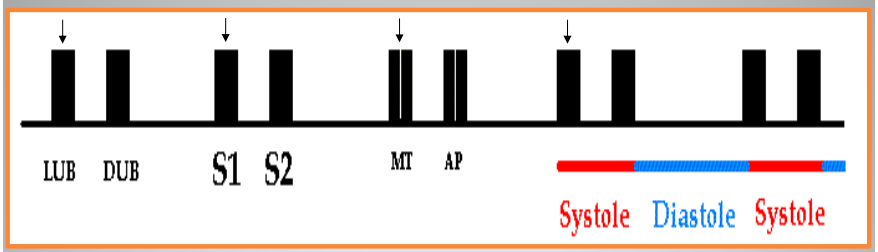
(S1)



- Due to closer of the AV- vs
- Recorded at the beginning of the the 'isovolumetric contraction phase'
- It marks beginning of ventricular systole

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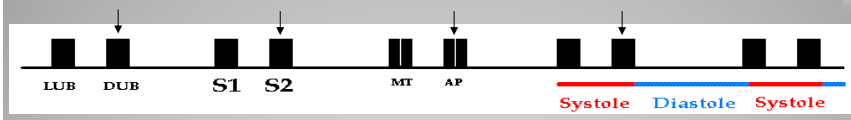
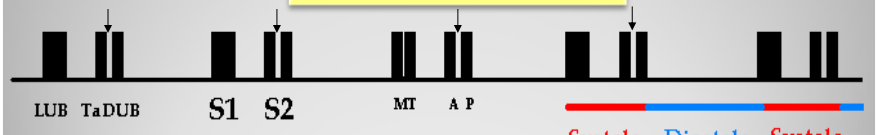
(S2)



- Due to closure of semilunar- vs
- Recorded at the beginning of the 'isovolumetric relaxation phase'
- Marks the beginning of ventricular diastole

Physiological splitting during INSPIRATION



- S2 splits physiologically during inspiration:
  - aortic v closes slightly earlier than pulmonary v

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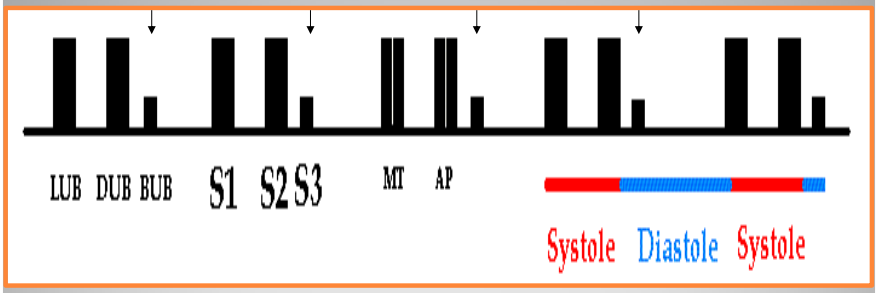
(S3)



- Recorded during the 'rapid filling phase'
- S3 is usually not audible
- ? heard in children

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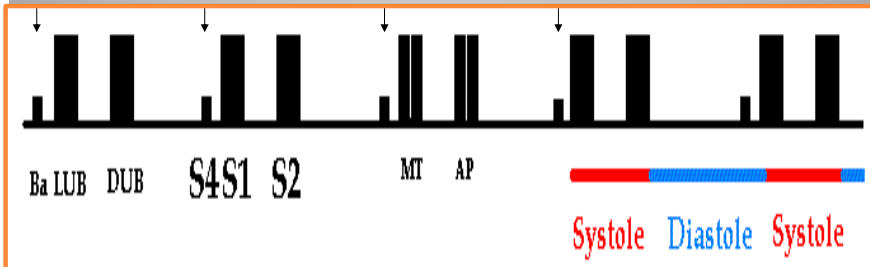
(S4)



- Recorded during 'atrial systole'
- S4 is usually not audible
- ? heard in elderly

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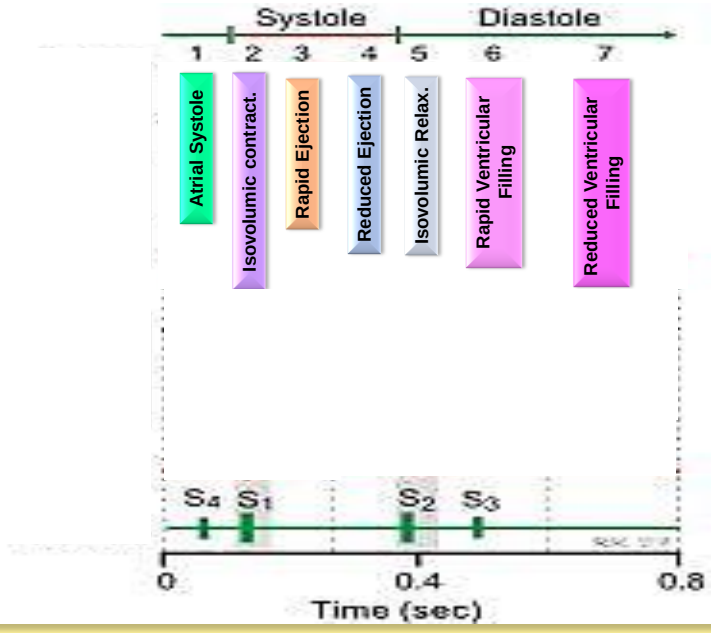
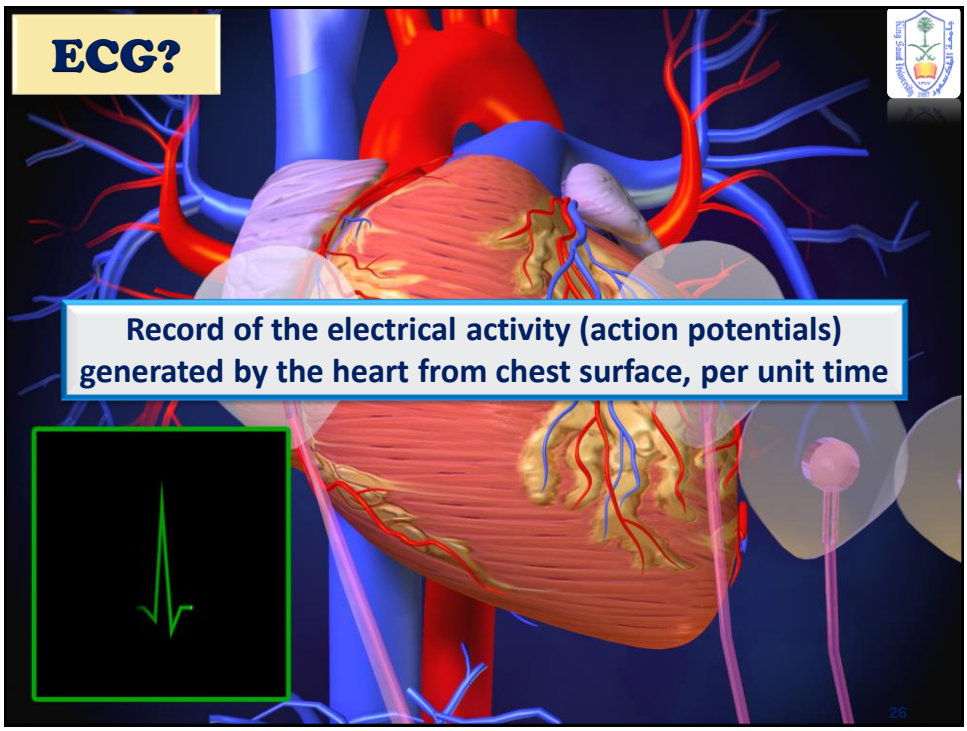
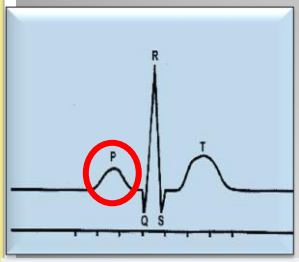
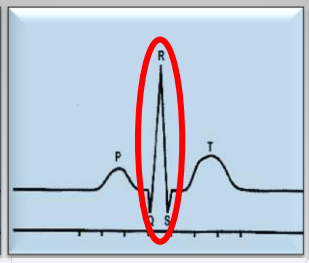


Electrical Changes (ECG) During the Cardiac Cycle

ECG?



P- Wave	QRS- Complex	T- Wave
		
• Due to atrial depolarization • P- wave is recorded before the onset of the atrial systole	• Due to ventricular depolarization • QRS complex is recorded before the onset of ventricular systole (isovolumetric contraction phase)	• Due to ventricular repolarization • T- wave is recorded before the onset of ventricular diastole

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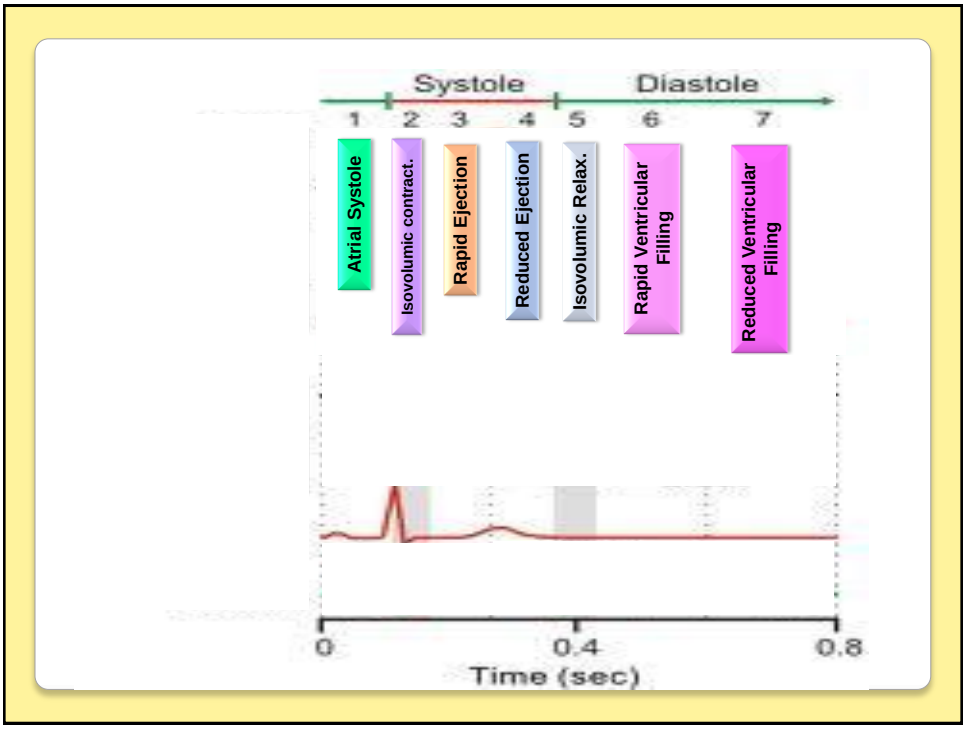
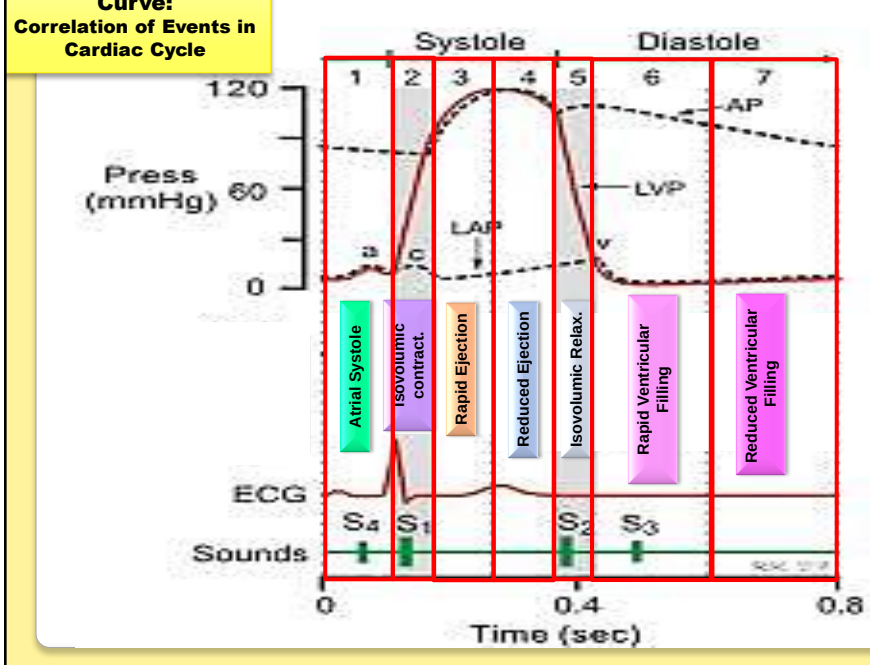
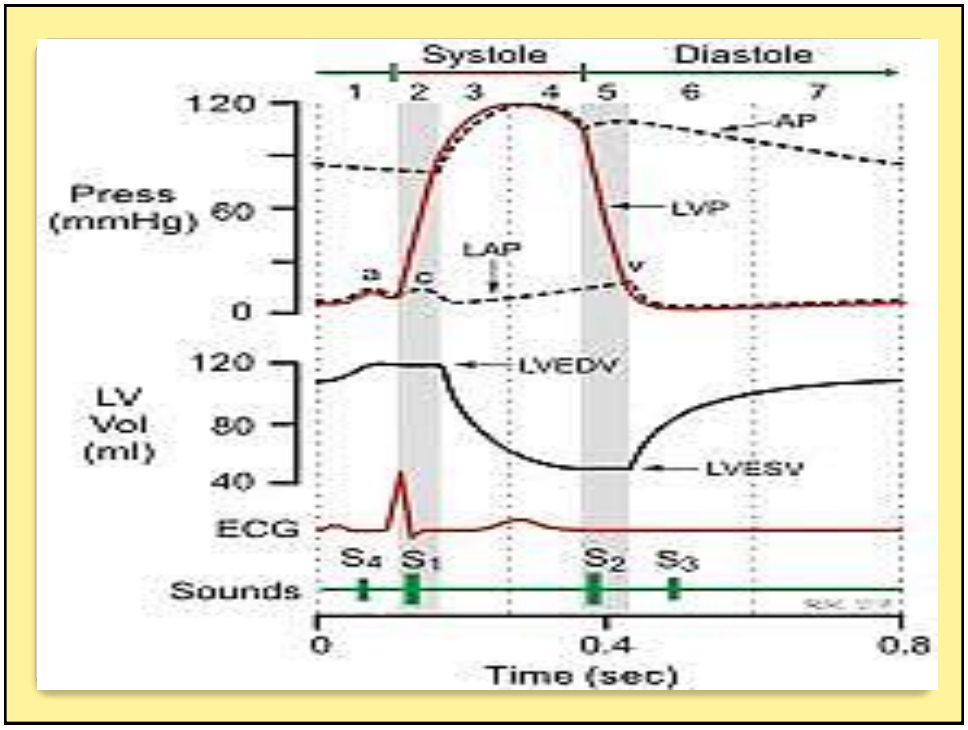
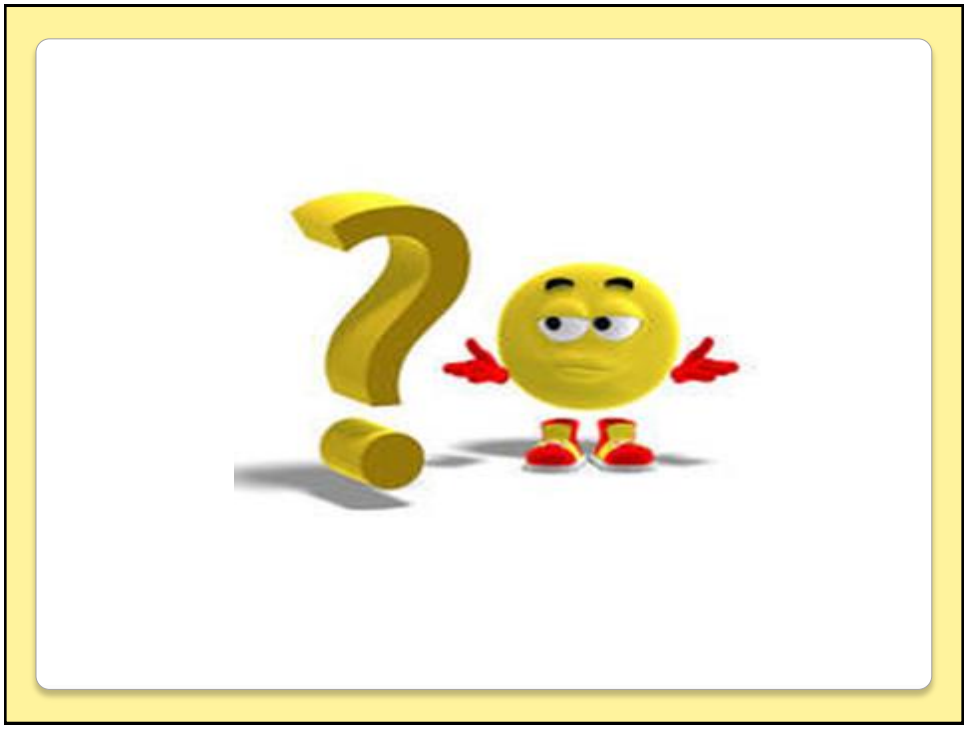


Pressure – Volume Curve
"The Complete Picture"

Pressure & Volume Curve:
Correlation of Events in Cardiac Cycle




Systole
Diastole
1
2
3
4
5
6
7
120
Press (mmHg)
60
0
AP
LVP
LAP
a
c
v
120
LV Vol (ml)
80
40
LVEDV
LVESV
ECG
S4
S1
S2
S3
Sounds
0
0.4
0.8
Time (sec)



Pressure Versus Volume
Pressure - Volume Loop

Left Ventricular Pressure – Volume Loop

Intra-ventricular changes in volume & pressure that occur during one cardiac cycle

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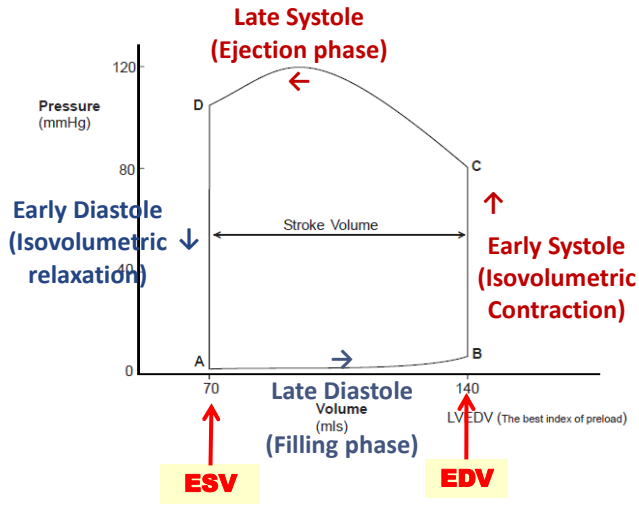
Ventricular Pressure - Volume Loop



- Plots LV pressure against LV volume through one complete cardiac cycle
- **Systole:** divided into,
  - Early systole
  - Late systole
- **Diastole:** divided into,
  - Early diastole
  - Late diastole

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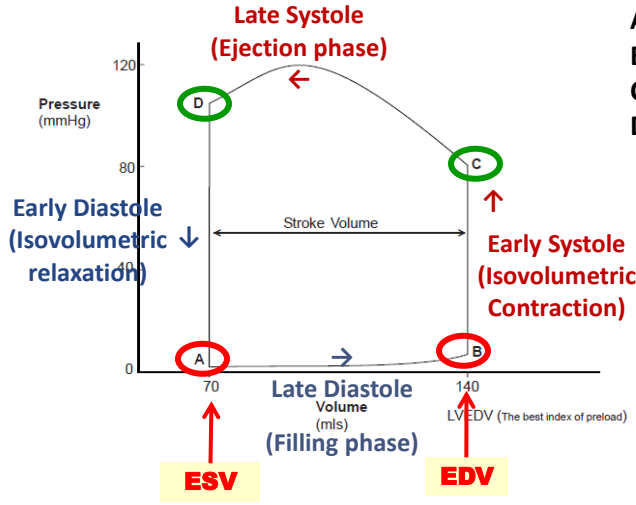
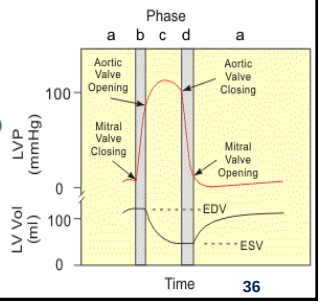
Ventricular Pressure - Volume Loop



A – Mitral valve opens
B – Mitral valve closes
C – Aortic valve opens
D – Aortic valve closes



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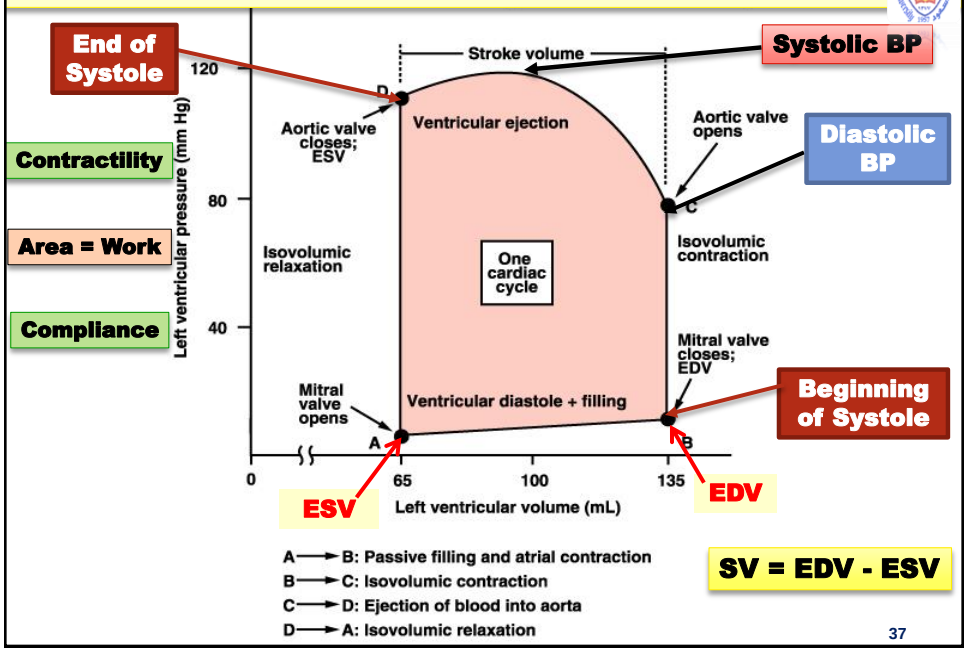
Ventricular Pressure - Volume Loop



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What you should remember about pressure – volume loop?

- Closer & opening of mitral & aortic- vs during each phase
- Beginning of systole (B) & end (D)
- Early & late systolic periods
- Beginning of diastole (D) & end (B)
- Early & late diastolic periods
- Diastolic filling occurs between points A & B
- Ejection occurs between points C & D

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To Revise

To Revise:

Regarding '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

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To Revise:

Regarding 'ventricular contraction' phases:

- During 'isovolumetric contraction' phase, all valves are [ ]
- 'c' wave in atrial pressure curve occurs during: [ ] & [ ] phases
- QRS is reported prior to [ ] 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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To Revise:

Regarding 'ventricular relaxation' phases:

- '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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Thank You