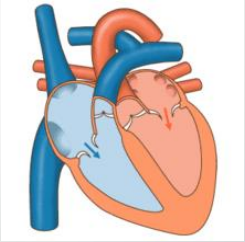



Cardiovascular Physiology

Cardiac Cycle- 1



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 A. Professor,
 Consultant Cardiovascular Physiologist,
 Faculty of Medicine, KSU.



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

- Main function of the heart.
- General principles of the cardiac cycle.
- Function of the atria, ventricles & valves.
- Different events that occur during the cardiac cycle.

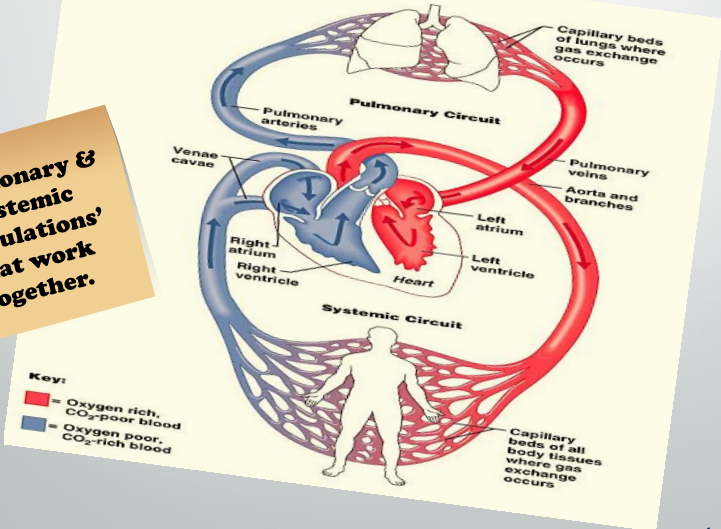
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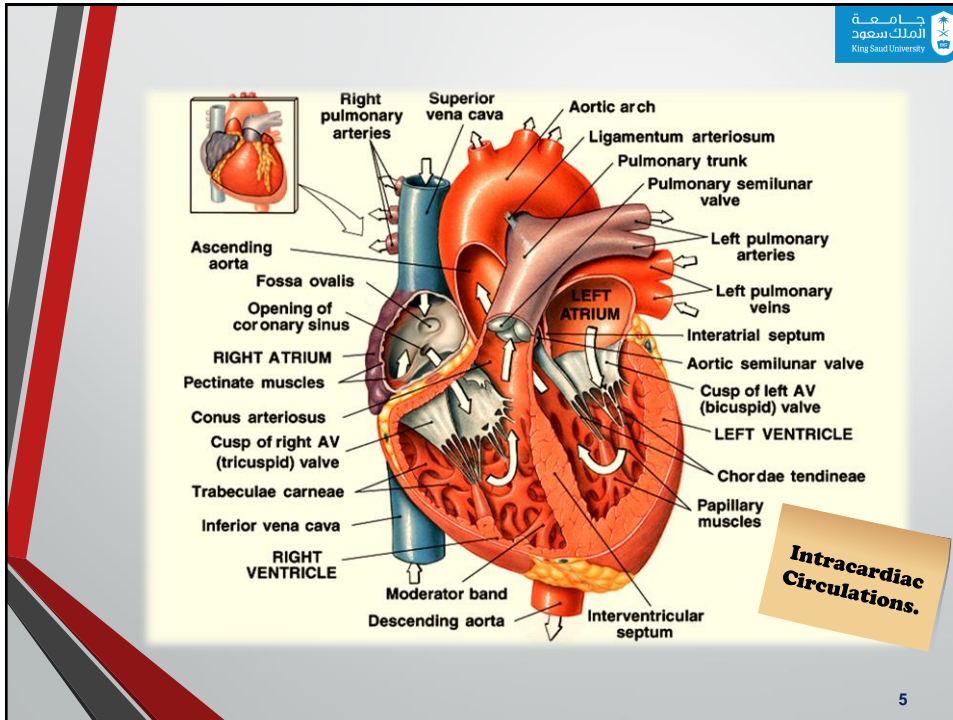
Function of the Heart ?



The Heart is a double pump

'Pulmonary & Systemic' circulations that work together.





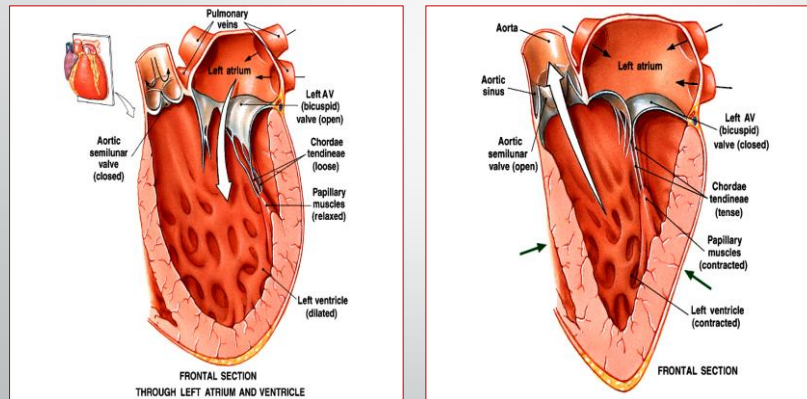
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Valves of the Heart

- 4 valves.
- Found at entry & exit of each ventricle.
- Allow blood to flow in only ONE direction.
- When AV- vs open, semilunar- vs close & vice versa.
- Opening & closure of vs occur as a result of pressure gradient across the vs.
- AV cusps are held by chordae tendinea to muscular projections called Papillary muscles.

6

Function of the Valves



7

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 in the right & left sides of the heart are the same, but with lower pressures in the right side.

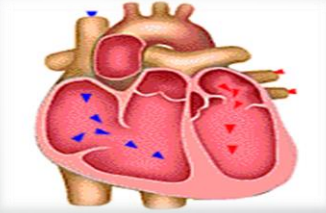
8

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Cardiac Cycle ?

Sequence of events that take place in the heart in each beat

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

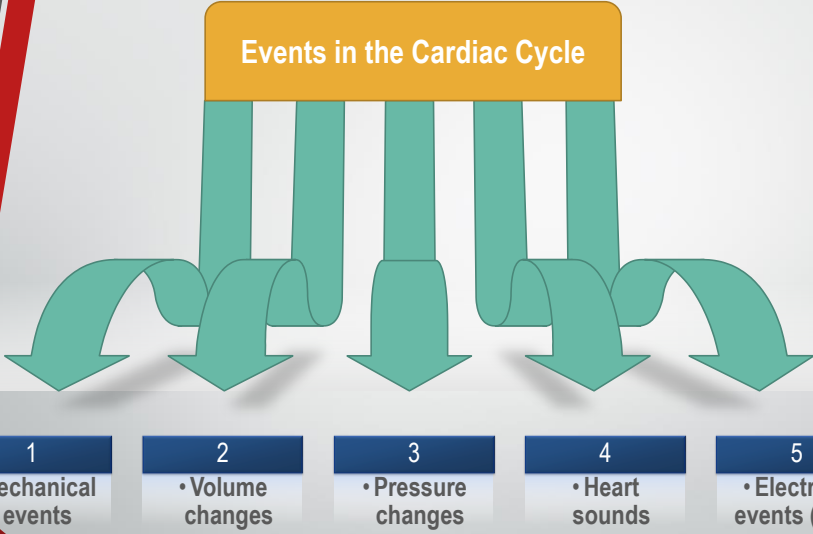


- **Cardiac cycle duration = 0.8 sec ...**
 - When HR 72 bpm
 - Shortened when HR ↑

9

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Events in the Cardiac Cycle



- 1 • Mechanical events
- 2 • Volume changes
- 3 • Pressure changes
- 4 • Heart sounds
- 5 • Electrical events (ECG)

10

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Mechanical Events:

- Each heartbeat consists of 2 major periods:
 - Systole .. (Contraction)
 - Diastole .. (Relaxation)

Ventricular diastole (Relaxation) repeated in next beat Ventricular systole (Contraction)

- Atrial .. systole & diastole
- Ventricular .. systole & diastole

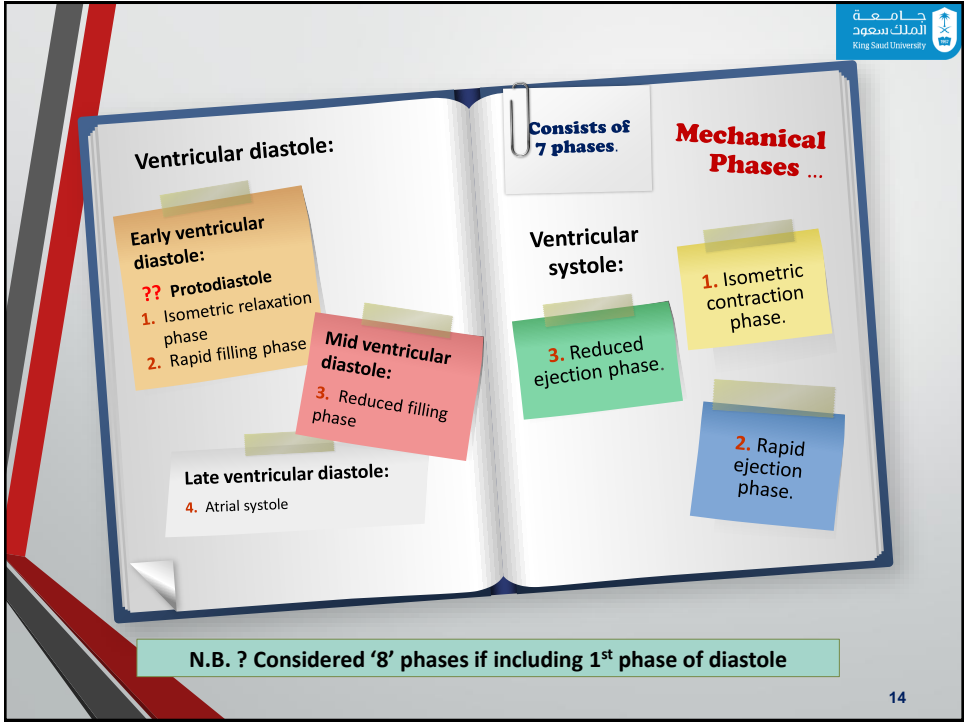
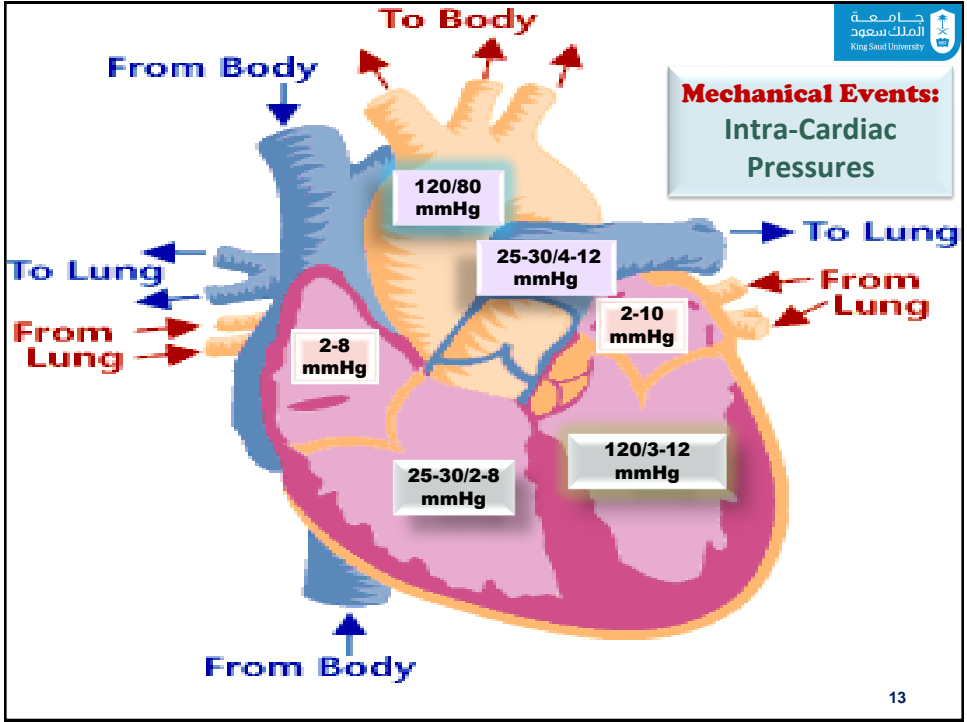
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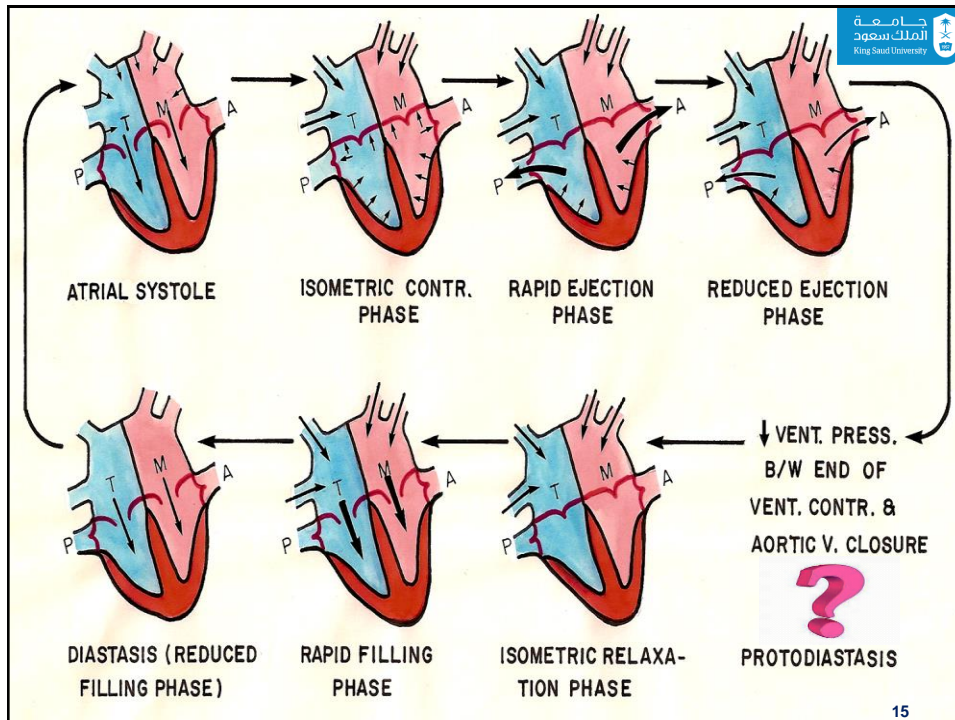
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Mechanical Events' Periods

- 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

12





Mechanical Phases of cardiac cycle:

1. Atrial Systole:

- At 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.
- **Pressure changes:** ↑ Atrial pressure.
- **4th Heart sound heard.**
- Blood arriving the heart can't enter atria, it flows back up jugular vein.

16

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Mechanical Phases of cardiac cycle:

2. Isovolumetric Contraction Phase:

- At beginning of ventricular systole ... (Lasts \approx 0.04 sec.)
- Period between closure of AV- vs & opening of Semilunar- vs.
- Preceded by ventricular depolarization.
- Starts with closure of AV- vs.
- **1st Heart sound heard.**
- **Ventricle is a closed chamber.**
 - Volume in ventricle = EDV
 - Ventricle contracts with no changes in volume.
- Ventricular pressure \uparrow
- Aortic v opens at the end of this phase, when LV exceeds 80 mmHg.

17

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Mechanical Phases of cardiac cycle:

3. Maximum (Rapid) Ejection Phase:

- Semilunar- vs open at beginning of this phase:
 - When LV pressure exceeds 80 mmHg.
- Almost 75% of ventricular blood is ejected, i.e. 75% of **SV**.
- Ventricular pressure reaches 120 mmHg.

4. Reduced Ejection Phase:

- End of systole.
- Almost 25% of ventricular blood is ejected, i.e. 25% of **SV**.
- Aortic- v closes at the end of this phase when LV pressure reaches 110 mmHg.

18

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Mechanical Phases of cardiac cycle:

5. Isovolumetric Relaxation Phase:

- Period between closure of semilunar- vs & opening of AV- vs.
- Beginning of diastole ... (Lasts \approx 0.04 sec.)
- Preceded by ventricular repolarization.
- **2nd Heart sound heard .**
- **LV is a closed chamber**, i.e. relax with no changes in volume.
- Volume of blood in ventricle = **ESV**.
- AV- vs open at the end of this phase.

19

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Mechanical Phases of cardiac cycle:


6. Rapid Filling Phase:

- Atrial pressure > ventricular pressure.
- AV- vs open.
- \approx 60-70% of blood passes passively to the ventricles along pressure gradient.
- **3rd Heart sound heard.**

7. Reduced Filling Phase (Diastasis):

- Remaining atrial blood flows slowly into ventricles.
- AV- vs still open.

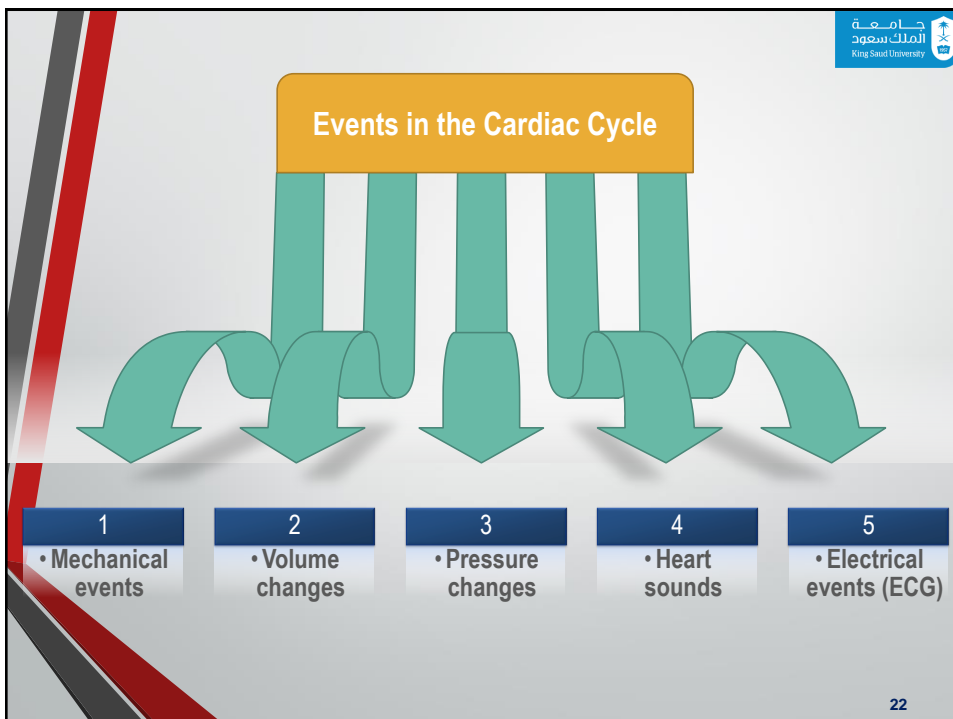
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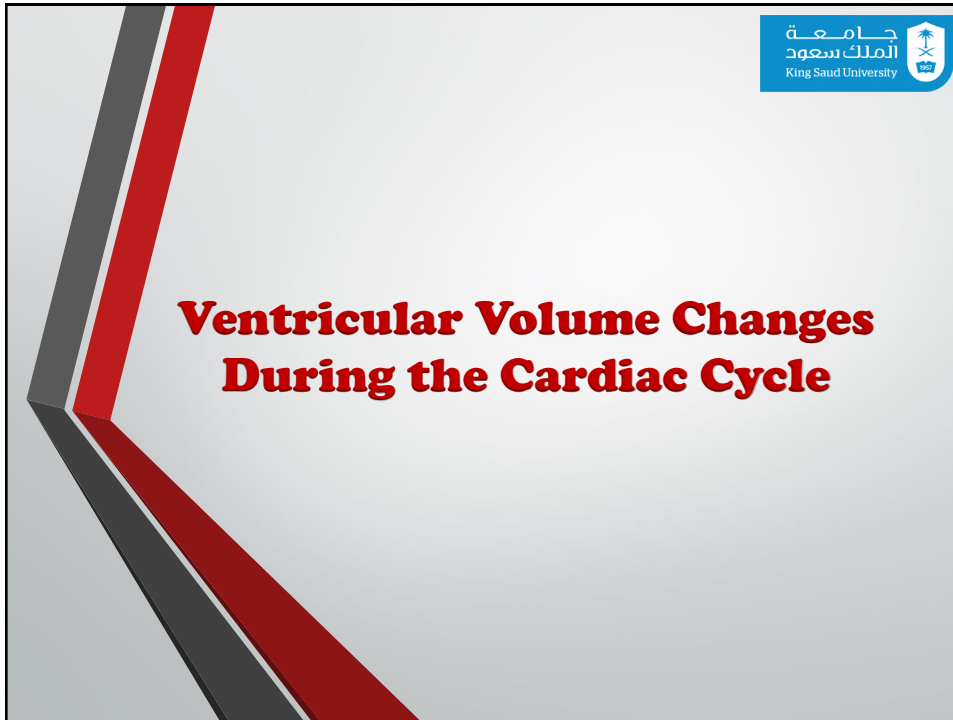


Definitions

- **End-diastolic volume (EDV):**
 - Volume of blood in ventricles at the end of diastole.
 - $\approx 110-130$ 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.
 - $\approx 40-60$ mL.
- **Ejection fraction (EF):**
 - Fraction of end-diastolic volume that is ejected.
 - $\approx 60-65$ %.

21



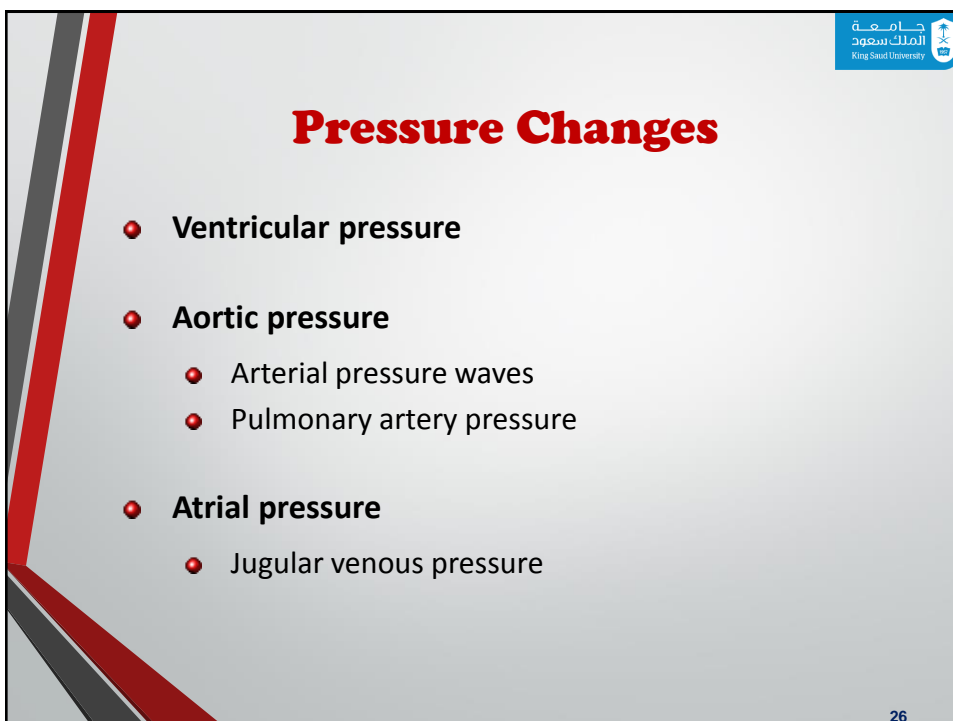
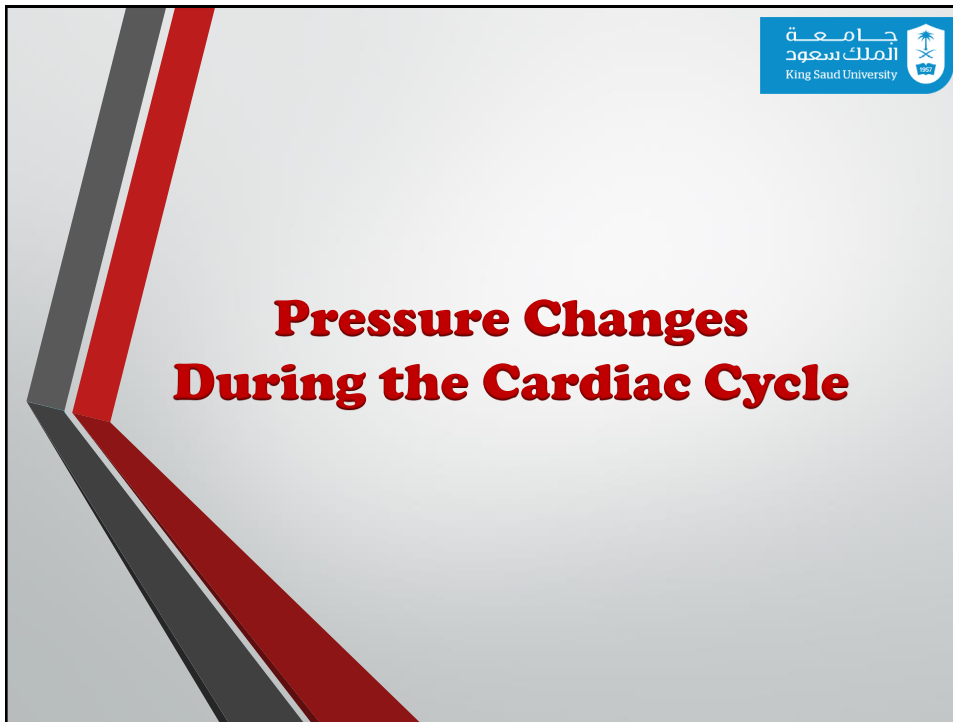


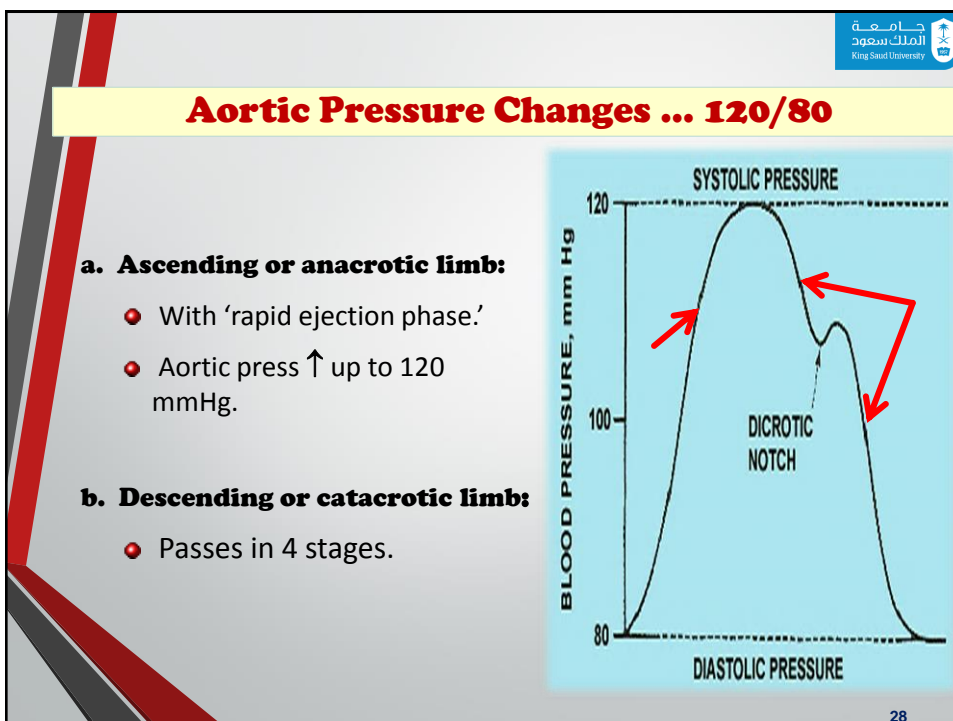
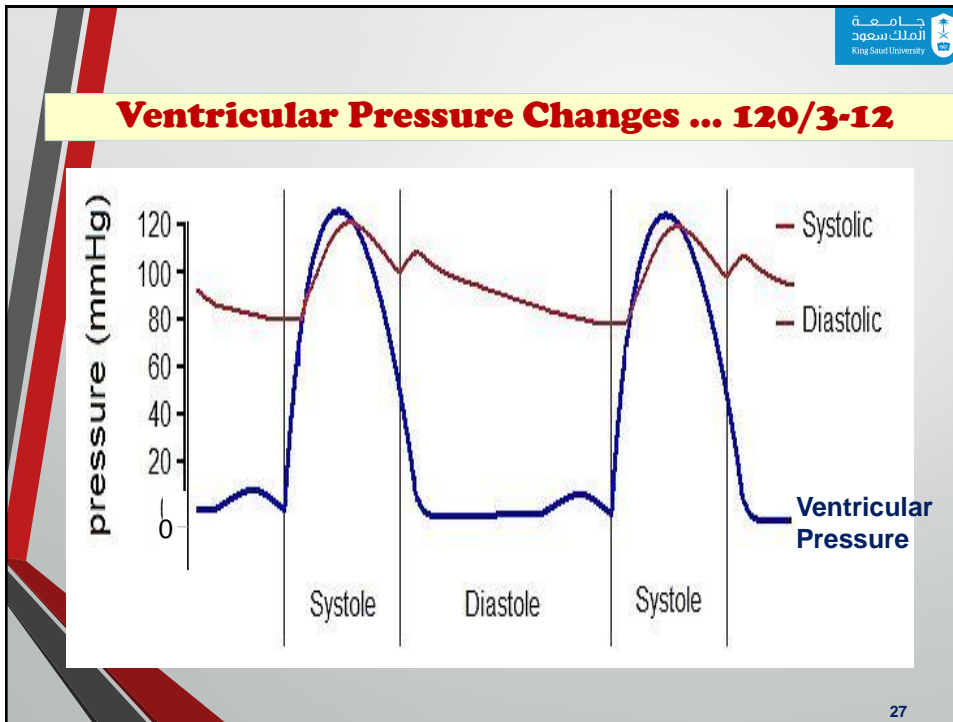
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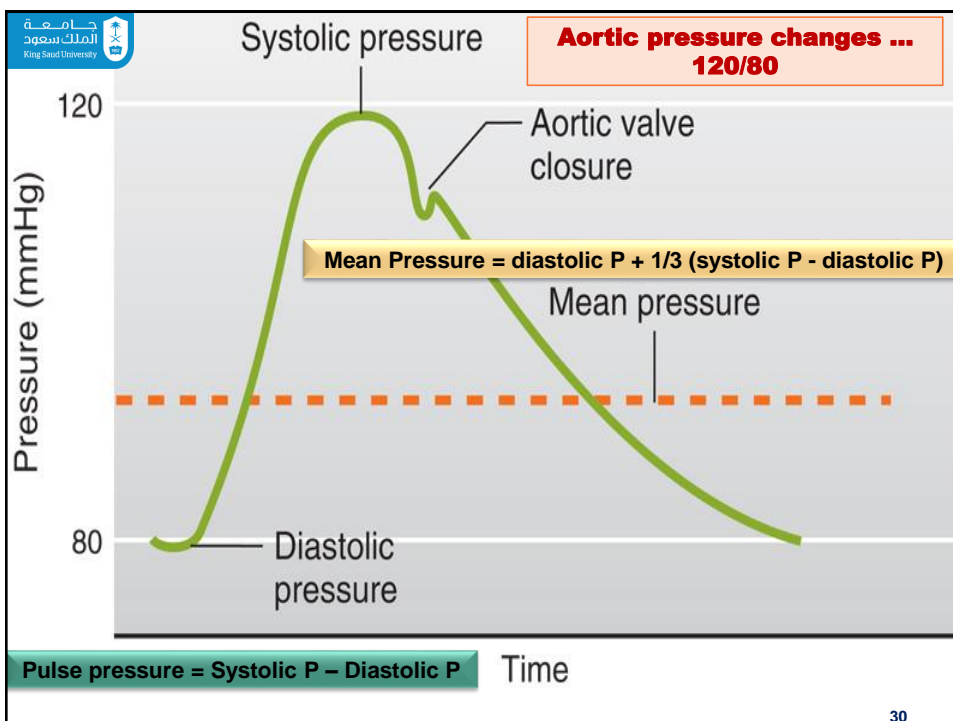
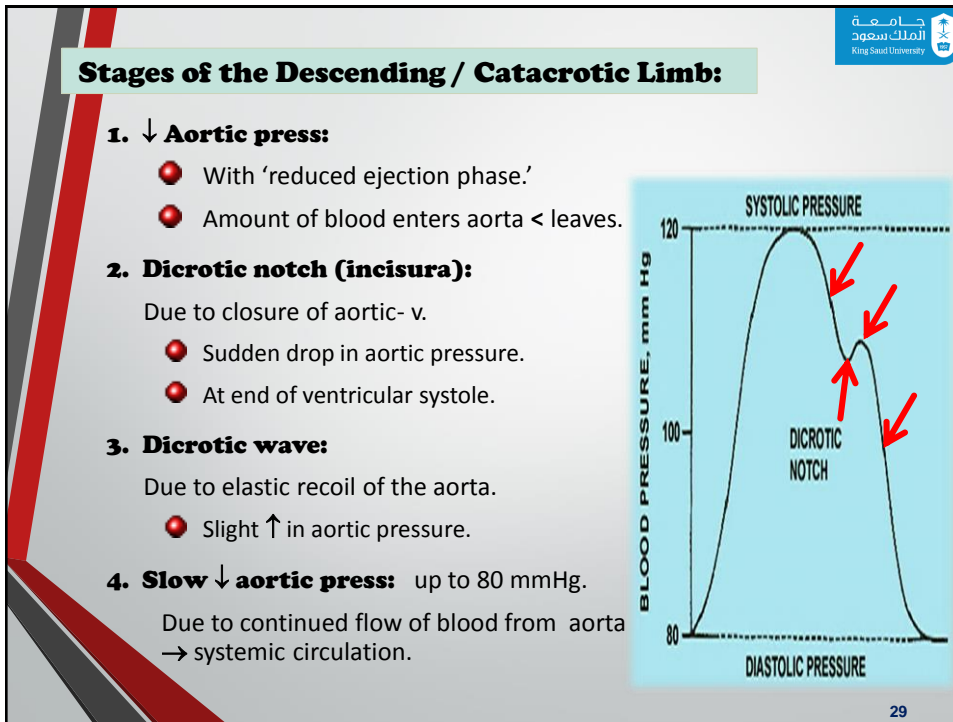
Ventricular Volume Changes

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

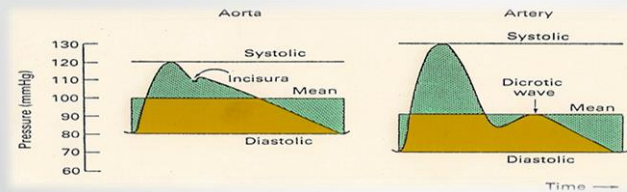
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Arterial Pressure Changes ... 110-130/70-85



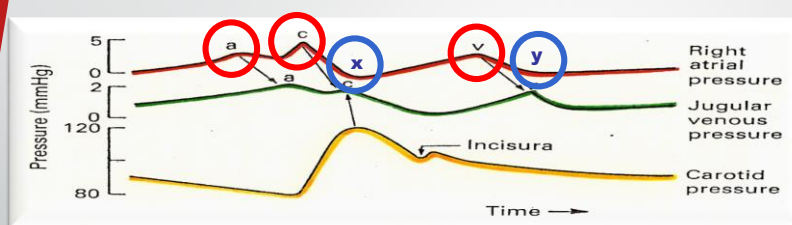
- Similar to aortic pressure waves, but **sharper**.
- Reflects a systolic peak pressure of 110-130 mmHg & a diastolic pressure of 70-85 mmHg.

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

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

31

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

32

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Causes of atrial pressure waves

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

33

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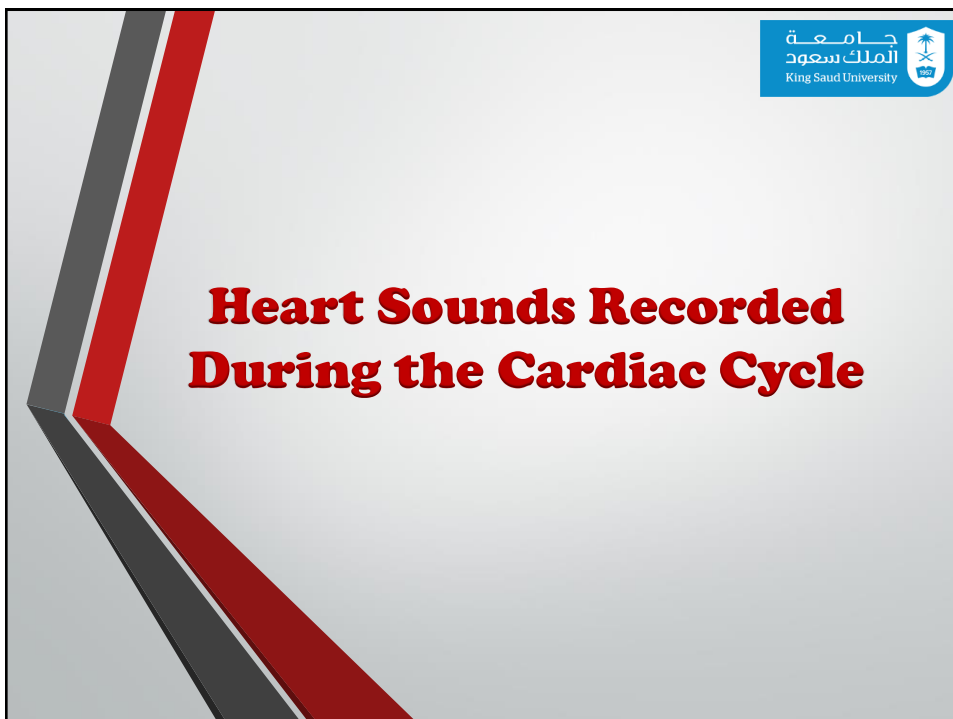
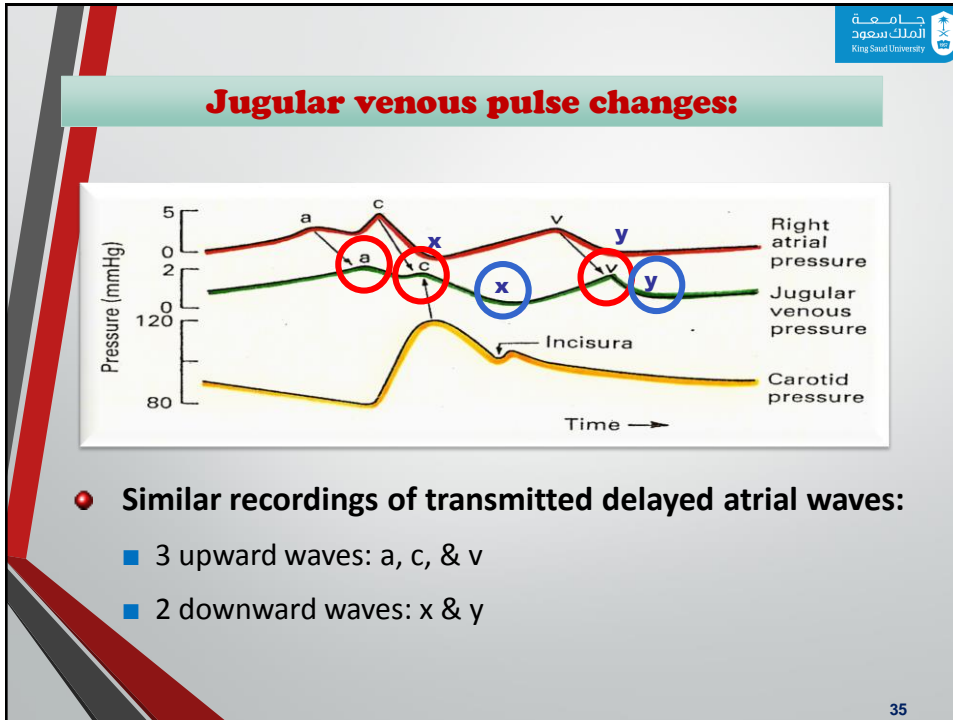
Causes of atrial pressure waves ... (Cont.)


- **'x' descent:**

Downward displacement of AV- vs during 'reduced ejection phase.'
- **'y' descent:**

↓↓ atrial pressure during 'reduced filling phase.'

34

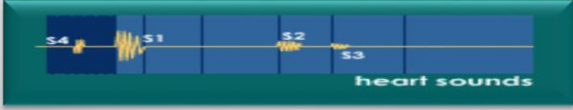




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HEART SOUNDS


- ◆ **Detected over anterior chest wall by:**
 - Auscultation... (Stethoscope.)
 - Phonocardiography... (sound recording device.)
- ◆ **'4' heart sounds can be detected:**
 - 1st & 2nd heart sounds ... (usually audible)
 - 3rd & 4th heart sounds ... (of low pitch, usually not audible)



heart sounds

- ◆ **Important for diagnosis of valvular heart diseases (murmurs)**

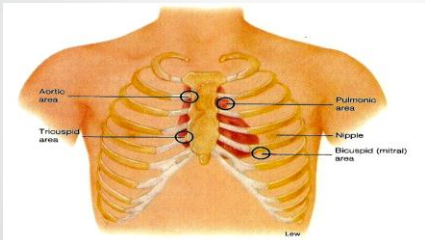
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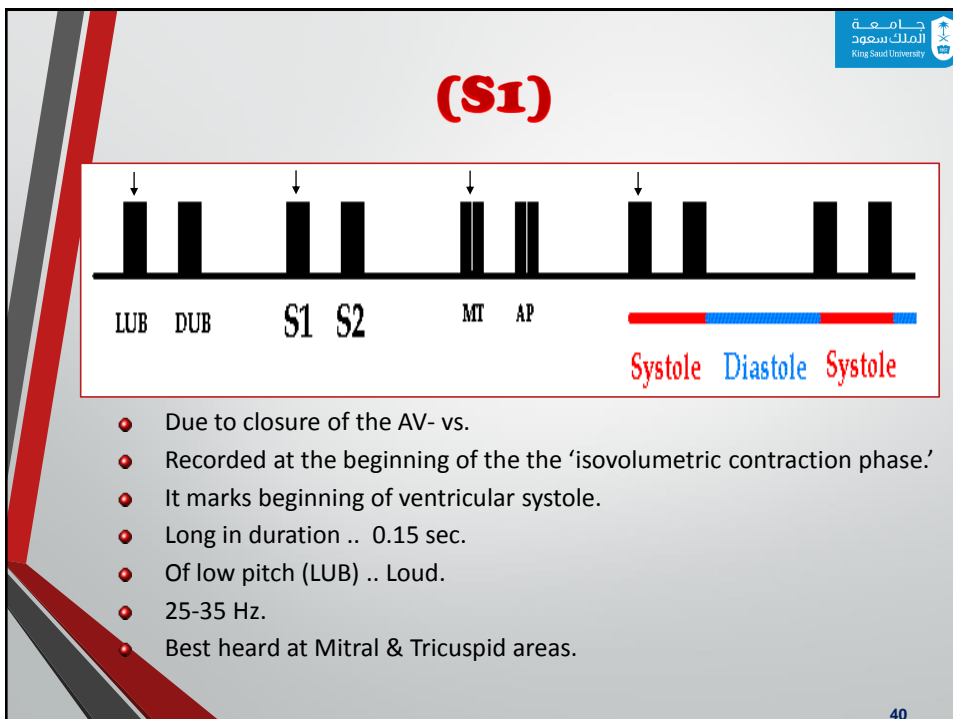
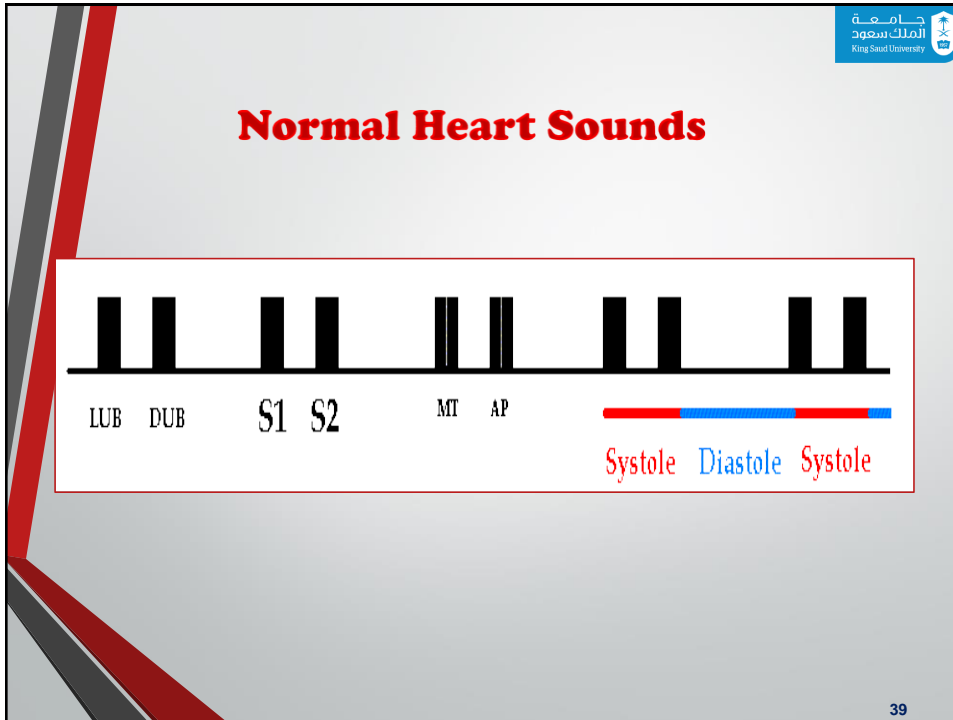
HEART SOUNDS' WINDOWS

- ◆ **Best heard at 4 certain areas:**

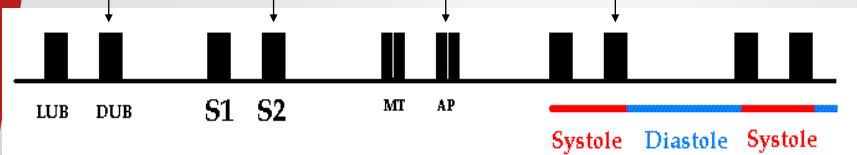


<ul style="list-style-type: none"> ■ Pulmonary area: <ul style="list-style-type: none"> • 2nd Lt intercostal space. ■ Aortic area: <ul style="list-style-type: none"> • 2nd Rt costal cartilage. 	<ul style="list-style-type: none"> ■ Mitral area: <ul style="list-style-type: none"> • 5nd Lt intercostal space crossing mid-clavicular line, or • 9 cm (2.5-3 in) from sternum. ■ Tricuspid area: <ul style="list-style-type: none"> • lower part of sternum towards Rt side.
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38



(S₂)

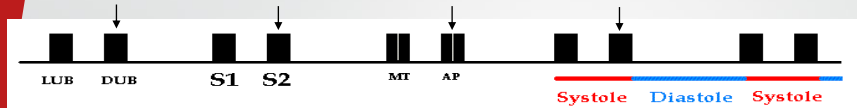


The diagram shows a series of sound waves on a horizontal axis. From left to right, there are two pairs of waves labeled LUB and DUB, followed by two pairs labeled S1 and S2, then two pairs labeled MT and AP. Below the axis, a red bar represents Systole, a blue bar represents Diastole, and another red bar represents Systole. Arrows point from the S1 and S2 labels to their respective sound wave pairs.

- Due to closure of semilunar- vs.
- Recorded at the beginning of the 'isovolumetric relaxation phase.'
- Marks the beginning of ventricular diastole.
- Short in duration .. 0.11-0.125 sec.
- Of high pitch (DUB) .. Soft & Sharp.
- 50 Hz.
- Best heard at Aortic & Pulmonary areas.

41

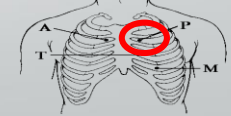
(S₂)



The diagram shows sound waves similar to the previous slide, but with a yellow box above the S2 waves that says "Physiological splitting during INSPIRATION". The S2 waves are split into two distinct sounds. Below the axis, a red bar represents Systole, a blue bar represents Diastole, and another red bar represents Systole. Arrows point from the S1 and S2 labels to their respective sound wave pairs.

- S₂ splits physiologically into 2 sounds during inspiration = Physiological Splitting.

Physiological splitting during INSPIRATION



The diagram shows a simplified anatomical drawing of a human chest with the lungs and heart. A red circle highlights the area between the lungs, indicating the location of the heart and the point of auscultation for the pulmonary valve.

- This splitting occurs due to delay closure of pulmonary valve.

42

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(S3)

LUB DUB BUB S1 S2 S3 MT AP

Systole Diastole Systole

- Recorded during the 'rapid filling phase' due to rush of blood into the ventricle.
- S3 is usually not audible (very low pitch.)
- 0.05 sec.
- ? heard in children.
- Best heard at Mitral area.

43

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(S4)

Ba LUB DUB S4 S1 S2 MT AP

Systole Diastole Systole

- Recorded during 'atrial systole.'
- S4 is usually not audible (very low pitch.)
- 0.04 sec.
- ? heard in elderly.
- Best heard at Mitral area.

44

