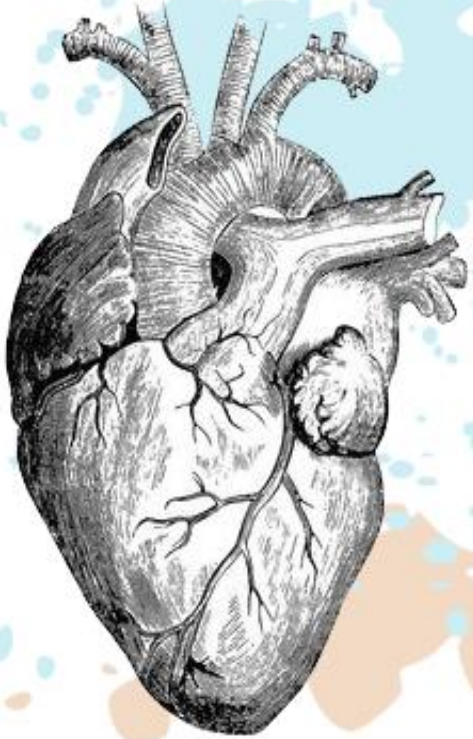


Very important

Extra information

Physiology

OF THE CARDIOVASCULAR SYSTEM

* Guyton corners, anything that is colored with grey is EXTRA explanation

Cardiac cycle 1

Objectives :

- 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.

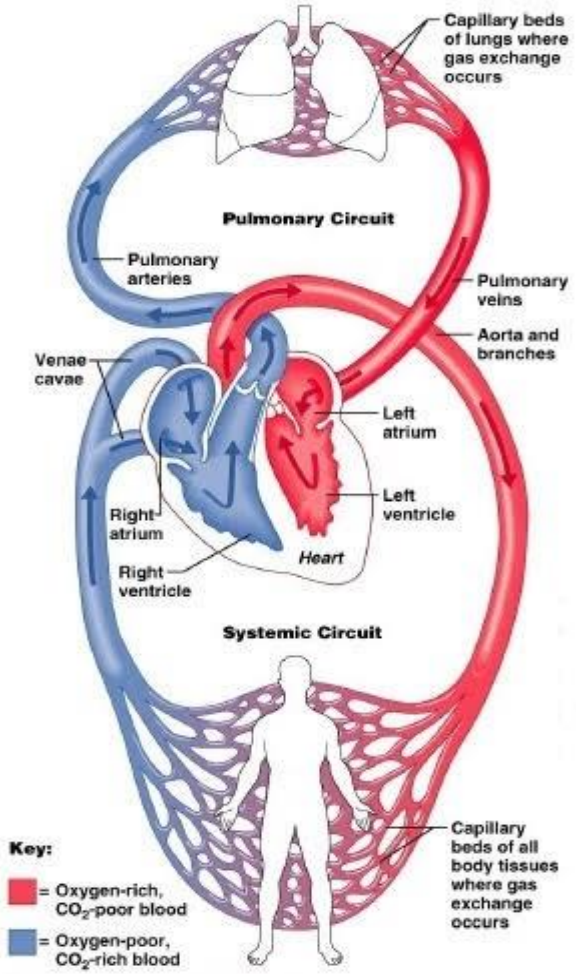
***we recommend studying the anatomy of the heart first.**

Contact us : Physiology435@gmail.com

Introduction

- The main function of the heart is to pump blood throughout the body by **pulmonary** and **systemic** circulations that work together .

More explanation : heart has two pump "double",
one of them called pulmonary → from the heart to the lung
The other one called Systemic → from the heart to the whole body
- Both of them work together.
- Pulmonary carries deoxygenated blood
- Systemic carries oxygenated blood
Any vessel goes out from the heart called **artery**, and any one enter the heart called **vein**.

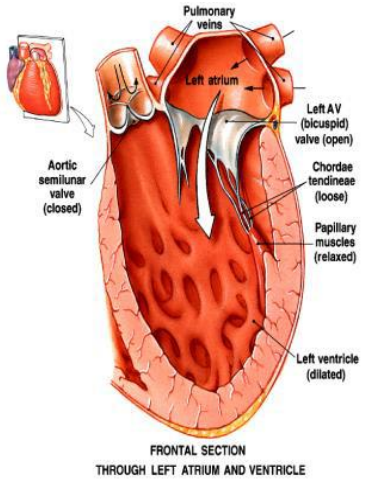


- **Guyton corner :**

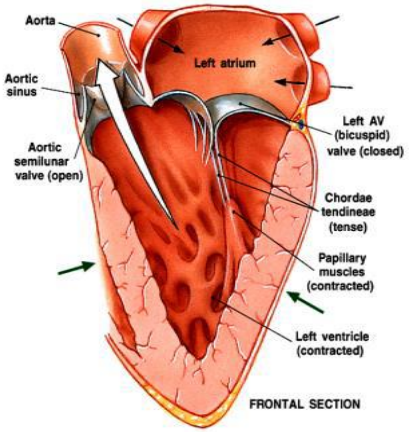
The heart is actually two separate pumps: a right heart that pumps blood through the lungs, and a left heart that pumps blood through the systemic circulation that provides blood flow to the other organs and tissues of the body. In turn, each of these hearts is a pulsatile two-chamber pump composed of an atrium and a ventricle. Each atrium is a weak primer pump for the ventricle, helping to move blood into the ventricle. The ventricles then supply the main pumping force that propels the blood either through the pulmonary circulation by the right ventricle or through the systemic circulation by the left ventricle.

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



FRONTAL SECTION
THROUGH LEFT ATRIUM AND VENTRICLE



FRONTAL SECTION

General Principles

Contraction of the heart generates pressure changes, & results in orderly blood movement.

(مما يعني أن كمية الدم التي تُضخ يحددها الانقباض نفسه)

-Blood flows from an area of high pressure to an area of low pressure.

(**Pressure gradient** controls the opening and closure of the cusps.)

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

Cardiac cycle

Definition:

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

Events:

I: Mechanical events

II: Volume changes

III: Pressure changes

IV: Heart sounds

V: Electrical events (ECG)

Duration:

- Cardiac cycle duration = 0.8 sec when HR (heart rate) = 72 bpm (beats per min)
- The duration is **shortened** when HR becomes **higher**

75 bpm
In some reference

- **Guyton corner :** The total duration of the cardiac cycle, including systole and diastole, is the reciprocal of the heart rate. For example, if heart rate is 72 beats/min, the duration of the cardiac cycle is 1/72 min/beat—about 0.0139 minutes per beat, or 0.833 second per beat.
- Increasing Heart Rate Decreases Duration of Cardiac Cycle. When heart rate increases, the duration of each cardiac cycle decreases, including the contraction and relaxation phases. The duration of the action potential and the period of contraction (systole) also decrease, but not by as great a percentage as does the relaxation phase (diastole).

I: Mechanical Events

- **Each** heart beat consists of **2 major periods**:
  - Systole (contraction)
  - Diastole (relaxation)
- **Systole** and **diastole** happen on **each** chamber of the heart so there is:
  - Atrial systole & diastole
  - Ventricular systole & diastole

Mechanical events:
mechanical means movement itself which follow electrical signal "can't happen by itself without stimulus"

Mechanical events' periods

- Normally diastole is longer than systole.

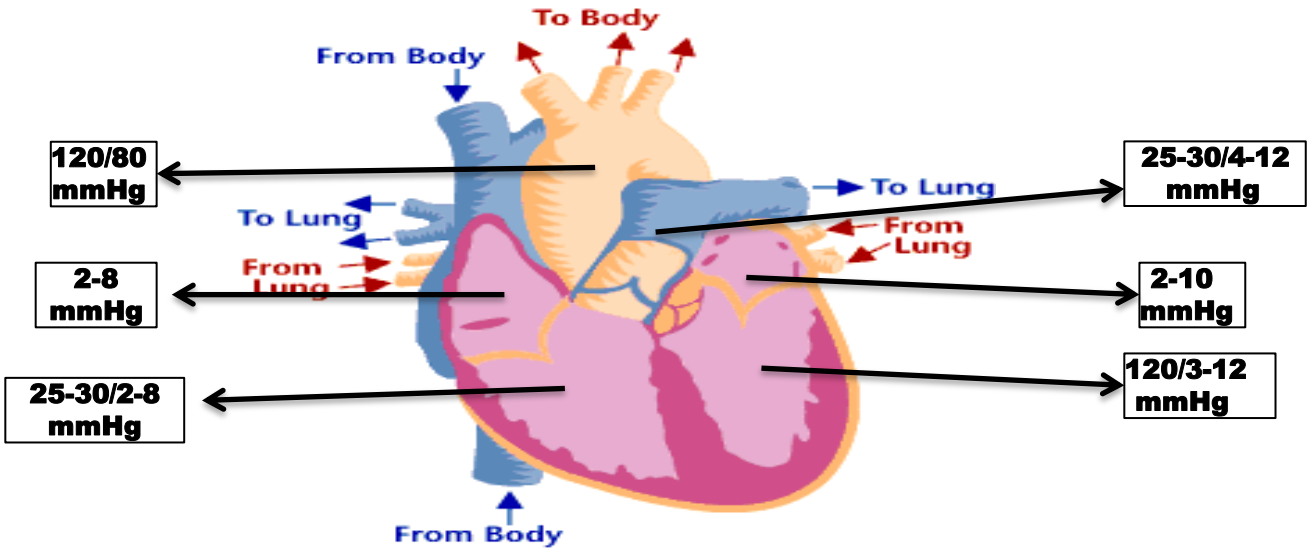
Ventricle	Atrium
Ventricular systole= 0.3 sec	Atrial systole= 0.1 sec
Ventricular diastole= 0.5 sec	Atrial diastole= 0.7 sec

* 0.8 equals the duration of the cardiac cycle

- Importance of long ventricular diastole:
  - Coronary blood flow.
  - Ventricular filling

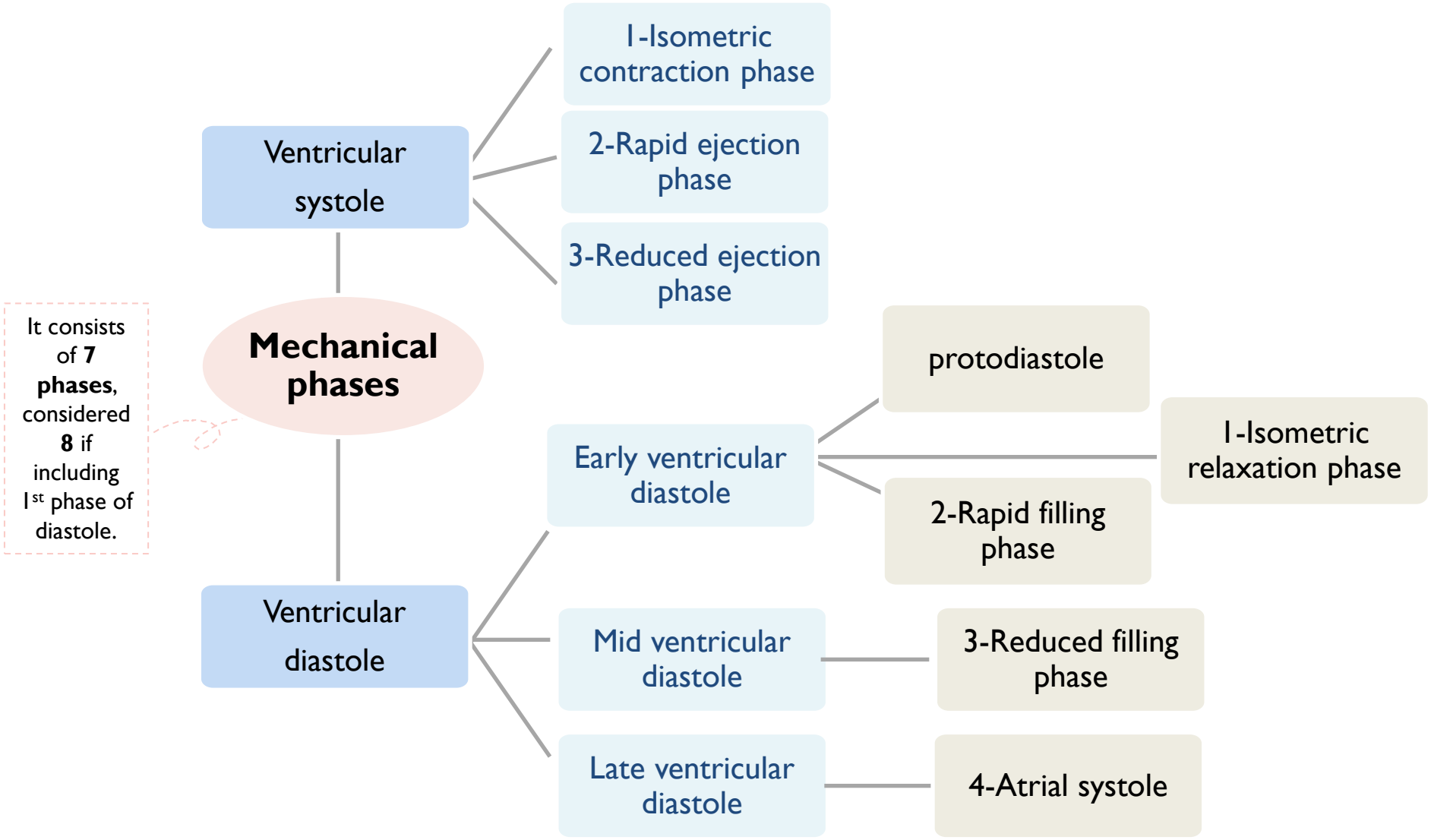
Systole "contraction" is **shorter** while **Diastole** "relaxation" is **longer**, why? Because we need to wait for the heart to be **filled with blood**, another reason is because if you keep the muscle in contraction for a long time this will cause **cutting the blood supply** for the cardiac muscle". So in the **ventricles** the ratio is **0.5 (diastole) + 0.3 (systole) = 0.8** , however in the **atrium** the ratio
0.7 (diastole) + 0.1 (systole)= 0.8

Mechanical events: Intra-cardiac pressures



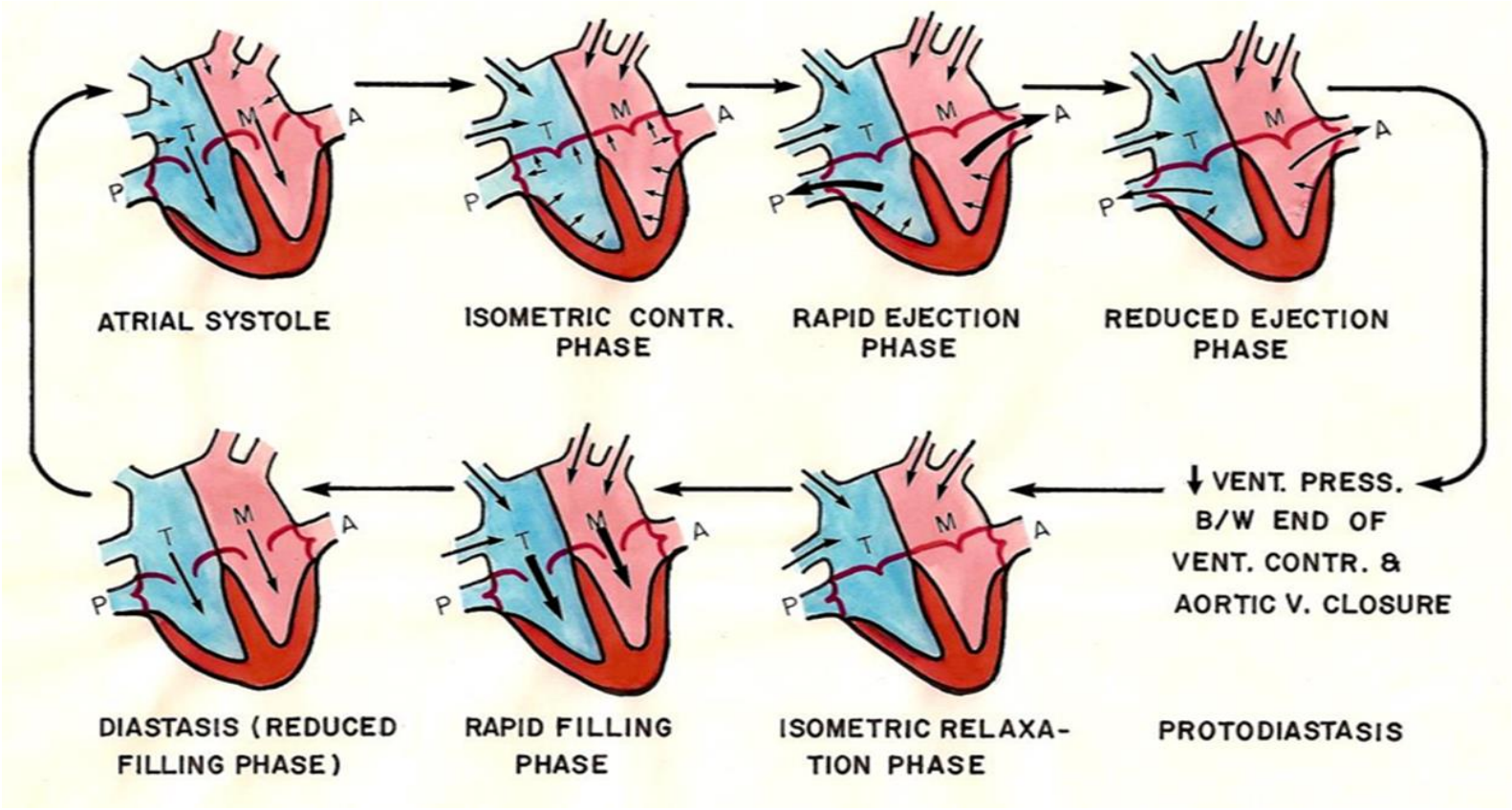
When we read the **pressure** at the **atrium** we figure out that the reading of **right atrium** is almost the **same** as the **left**, and the reading gives us only **one number** which represents the **diastole**,
why does it give us only one reading? Because systole is too short period "0.1" which **can't** be measured.
In the **ventricles** it's different, the reading **changes** from right to left side, the **systole** become measured and it has **higher** reading in the **left ventricles** more than the right side. the **diastole** almost the **same** as in the atrium, but it won't become zero, why? Because it has **never** been empty of blood.

Mechanical phases



It consists of **7 phases**, considered **8** if including 1st phase of diastole.

Mechanical phase



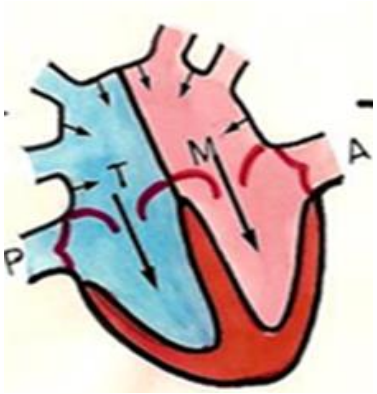
- **PROTODIASTASIS** :Very short Period between the end of ventricular systole and aortic valve closure. (As the ventricle relax the pressure is reduced so the blood tend to flow back from aorta but prevented by closure of aortic valve)

HELPFUL VIDEOS

Mechanical phase

Mechanical Phases of cardiac cycle:

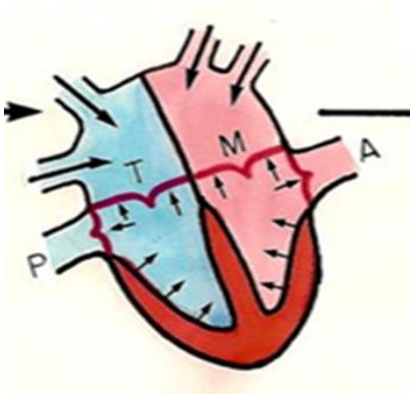
1- Atrial Systole :



- Atrial systole (atrial contraction) is at the end of ventricular diastole .Atrial systole is **Preceded** by **atrial depolarization**.
- **Valves:** AV-vs open (semilunar- vs closed.)
- **Time:** (lasts **0.1** sec.)
- **Pressure changes:** ↑ Atrial pressure.
- **Sounds:** 4th Heart sound (In elderly & pathological conditions)
- **Volume changes:**
  Tops off last 27-30% of ventricular filling. Blood arriving the heart can't enter atria, it flows back up jugular vein.

the muscle in the atrium contract to empty the last 27-30% of blood to ventricle, which mean the atrium become empty , right before this phase atrial depolarization should happen, no Venus return because of contraction, when I contract I'll close the orifices, and I'll notice pulls in the jugular vein "this is a sign for atrial systole", the pressure in the atrium higher than in the ventricle "that's why the AV valves open", this should cause 4th heart sound "caused by contraction of atrium" it's also unheard, may be in elderly.

Mechanical phase



2- Isovolumetric Contraction Phase:

- It is the first phase (beginning) of ventricular systole.
  Period **between** closure of AV- vs & opening of Semilunar- vs.
  It is **Preceded** by ventricular **depolarization**. Ventricle in this phase is a **closed chamber**.
- **Valves:** Starts with closure of **AV- vs**. – Semilunar are already closed.
- **Time:** last **0.04** sec
- **Sounds :** 1st Heart sound heard
- **Volume changes :** - volume of blood in ventricle = **EDV**
  - Ventricle contracts with **no changes** in volume.
- **Pressure changes :** ↑ Ventricular pressure
- Aortic valve **opens** at the **end** of this phase, when left ventricle **exceeds 80 mmHg**

isometric means ventricles are closed chambers, when the chambers are closed it means there's no blood enter or get out of the heart "this blood called end-diastolic volume", this will increase the pressure inside the left ventricles until it's reach the 80 so it will open the aortic valve

Mechanical phase

3- Maximum (Rapid) Ejection Phase:

- This is the second phase of the systole phases "rapid ejection phase", the blood will flow from aorta to the rest of the body which will cause reduction of the ventricle pressure
- **Valves :** Semilunar- vs open at beginning of this phase ,when LV pressure exceeds **80 mmHg**.
- Almost **75%** of ventricular blood is ejected مقذوف, i.e. 75% of **stroke volume**
- Ventricular pressure reaches **120 mmHg**. which equal to aortic pressure.

Then the blood will rapidly be ejected out of the ventricles (eject 75% of the blood of the ventricles), and the pressure will reach 120 which equal to aorta pressure, this is the second phase of the systole phases "rapid ejection phase", the blood will flow from aorta to the rest of the body which will cause reduced of the ventricle pressure

Mechanical phase

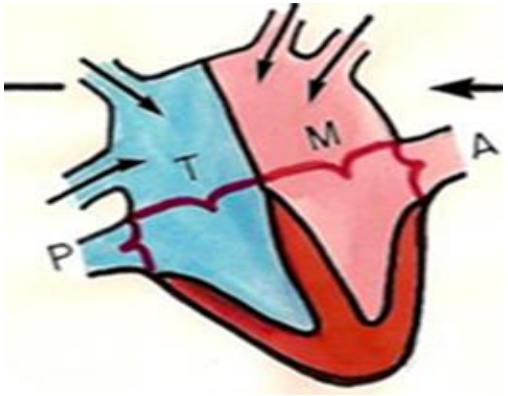
4- Reduced Ejection Phase:

- It is the **End** of **systole**.
- Almost **25%** of ventricular blood is ejected, i.e. 25% of **Stroke volume**
- **Valves:** Aortic- v **closes** at the end of this phase when left ventricle pressure reaches **110 mmHg**.

- It will be reduced until it will reach 110, This reduction will cause the 3rd and last phase of systole phases "reduced ejection phase", at this pressure the semilunar valves will close

Mechanical phase

5- Isovolumetric Relaxation Phase:

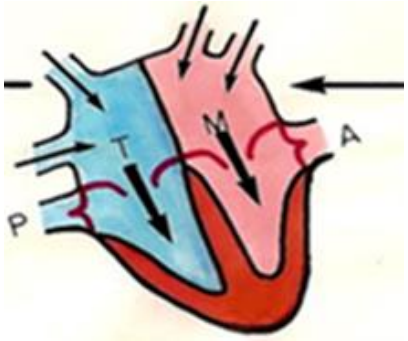


- Period **between** closure of semilunar- vs & opening of AV- vs.
  Happens at the **Beginning** of diastole.
  It is **Preceded** by ventricular **repolarization**.
- **Time :**Lasts **0.04** sec
- **Sounds :** 2nd Heart sound heard .
- **Volume changes :** **-**LV is **a closed chamber,** i.e. relax with **no changes in volume** .
  -Volume of blood in ventricle = **ESV**
- **Valves :** AV- vs **open** at the end of this phase ; semilunar –vs **close**
- When ventricle pressure < arterial pressure → backflow of blood → forces semilunar valves to close.
- **Aortic pressure curve:** INCISURA → when the aortic valve closes.

all the chambers are closed, the blood remaining in the ventricles in this case called end-systolic volume, ventricles keep relaxing and relaxing until the pressure decreased and become higher in atrium more than ventricle.

Mechanical phase

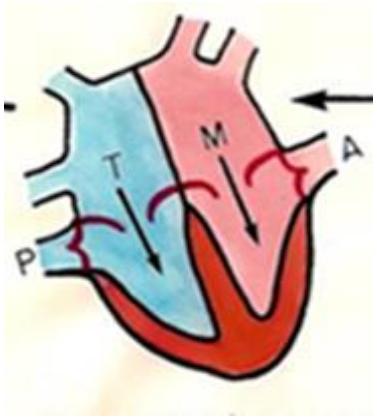
6- Rapid Filling Phase:



- **Pressure changes :** Atrial pressure is higher than ventricular pressure.
- **Valves:** AV- vs open. -Semilunar valves are closed
- From the atrium **60-70%** of blood passes **passively** move to the ventricles along pressure gradient.
- **Sounds :**3rd Heart sound heard. (children only)

Mechanical phase

7- Reduced Filling Phase (Diastasis):



- Remaining atrial blood flows slowly into ventricles.
- **Valves :** AV- vs still open - Semilunar valves are closed

After rapid filling the blood will pass through AV valve passively and this cause the 3rd phase of diastole "diastasis (reduced filling phase)", and this is the last phase in the circulation.
All the sounds of the heart are occurring in the diastole phases.

Video

Definitions

End-diastole volume (EDV)

- Volume of blood in ventricles at the end of diastole.
- ≈ **110-130**ml

End-systolic volume (ESV)

- Amount of blood left in ventricles at the end of systole.
- ≈ **40-60**ml

Stroke volume (SV)

- Amount of blood ejected from ventricles during systole.
- ≈ **70**ml/beat
- SV = EDV - ESV

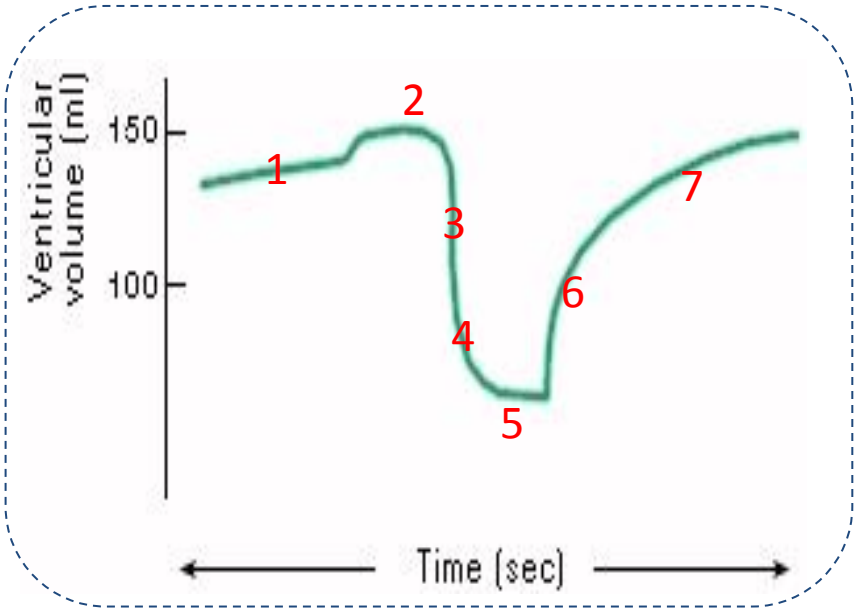
Ejection fraction (EF)

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

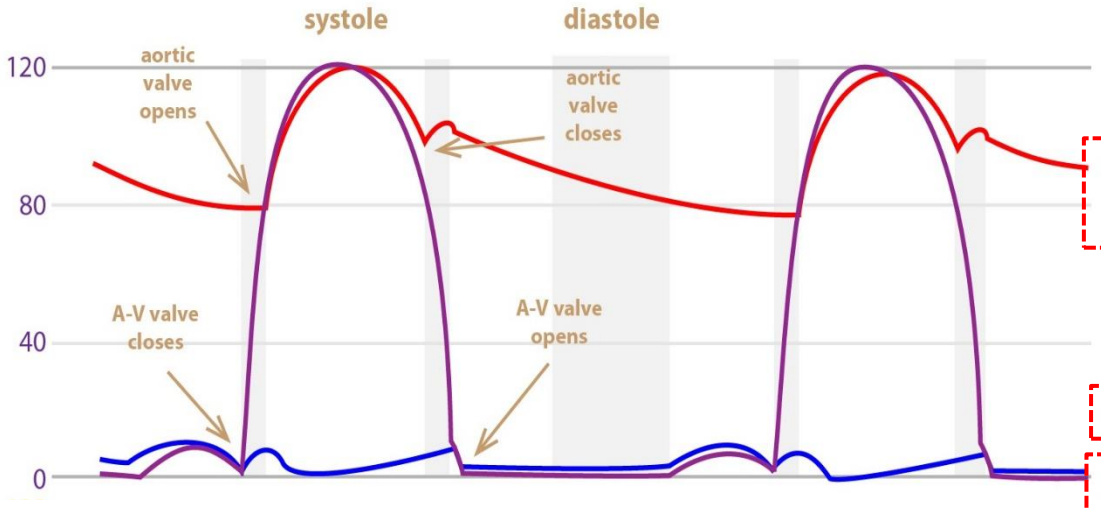
$$EF = \frac{SV\ (EDV - ESV)\ \times 100}{EDV}$$

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



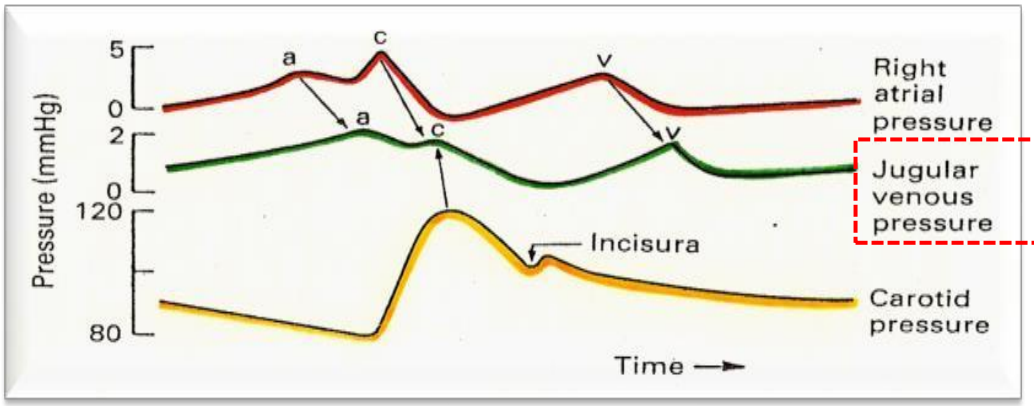
Pressure changes



aortic pressure (mm Hg)

ventricular pressure

atrial pressure



Aortic pressure :

- Arterial pressure waves
- Pulmonary artery pressure

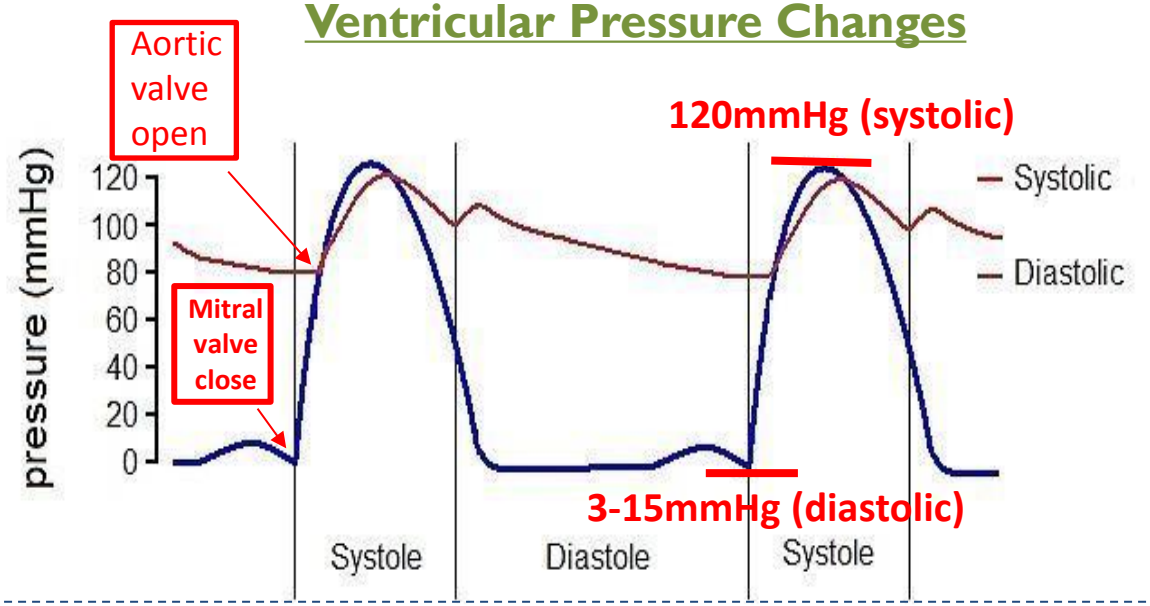
Ventricular pressure

Atrial pressure:

- Jugular venous pressure

Pressure changes

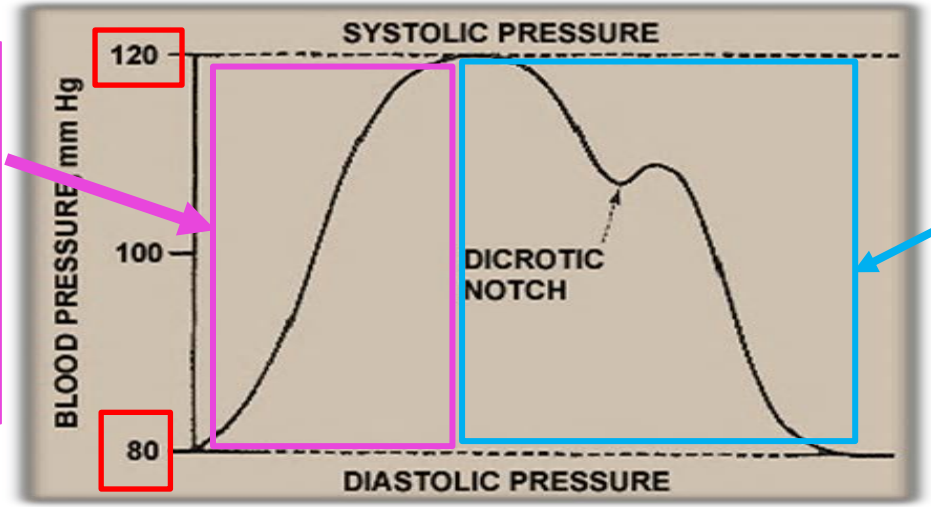
Ventricular Pressure Changes



Aortic pressure changes

Ascending or anacrotic limb:

- With rapid ejection phase.
- Aortic press ↑ up to 120 mmHg.



Descending or catacrotic limb:

- Passes in 4 stages

PHYSIOLOGY TEAM 435

Descending/Catacrotid Limb

Occur in 4 stages:

1 ↓ in Aortic pressure:

- In reduced ejection phase.
- When amount of blood that enters aorta is less than the blood that leaves it

2 Incisura (dicrotic notch):

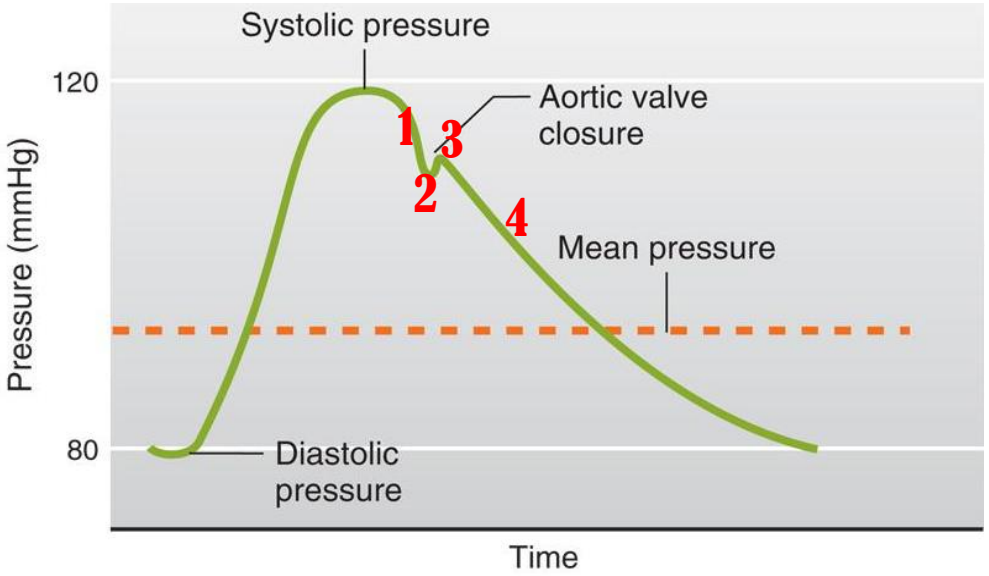
- **"Due to closure of aortic valve"**
- **Causes sudden drop in aortic pressure.**
- **Happens at the end of ventricular systole.**

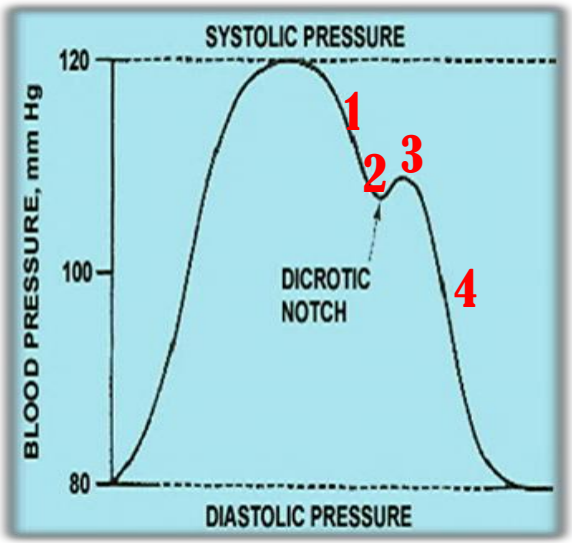
3 Dicrotic wave:

- **"Due to elastic recoil of aorta"**
- **Causes slight increase in aortic pressure.**

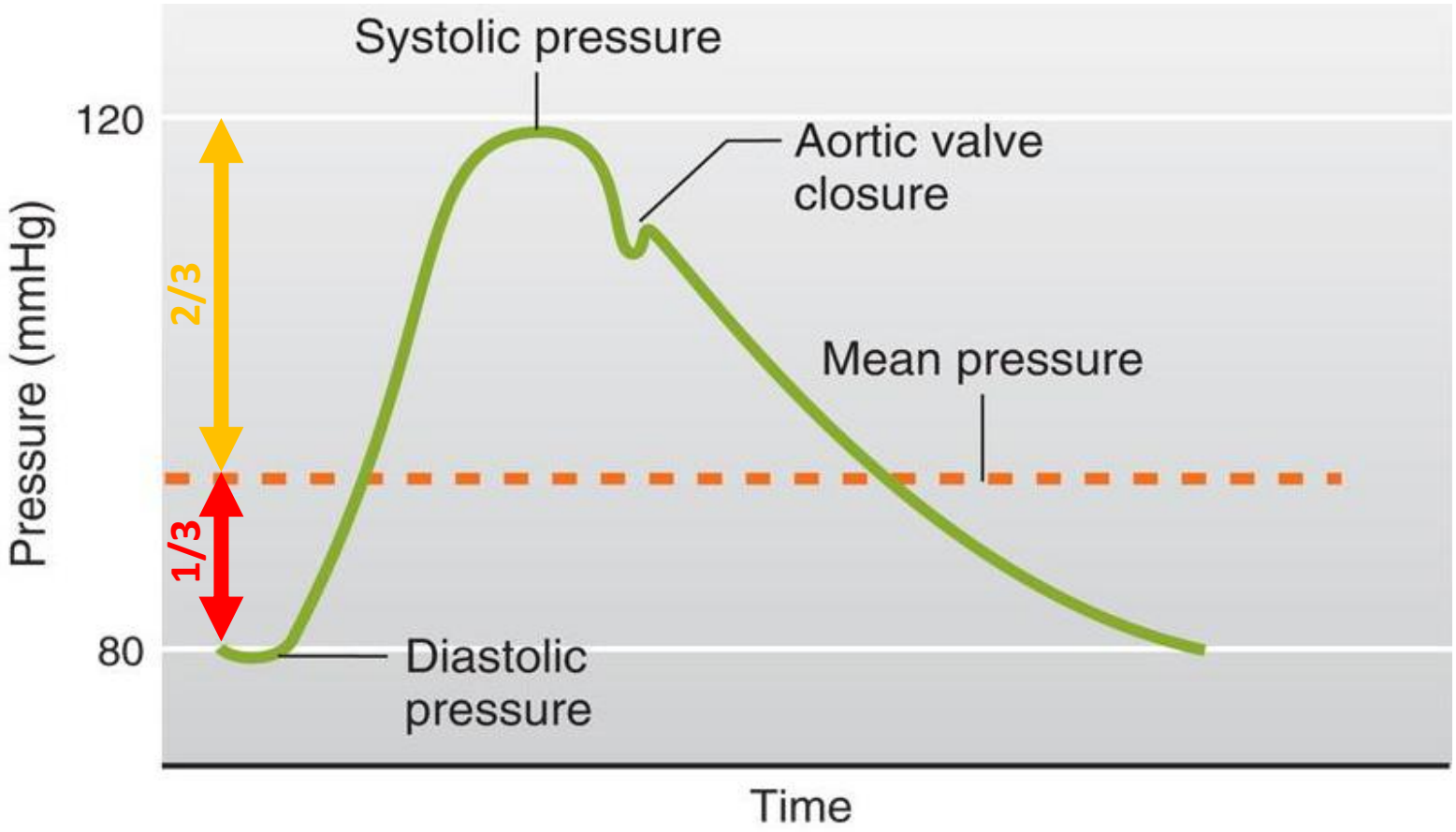
4 Slow decrease of aortic pressure:

- **up to 80 mmHg.**
- **"due to continued flow of blood from aorta to systemic circulation.**





Pressure changes



- **Mean pressure : Diastolic pressure + 1/3 (systolic pressure – diastolic pressure)**
- **Pulse pressure : systolic pressure – diastolic pressure**
- **Aortic pressure : is 120/80**

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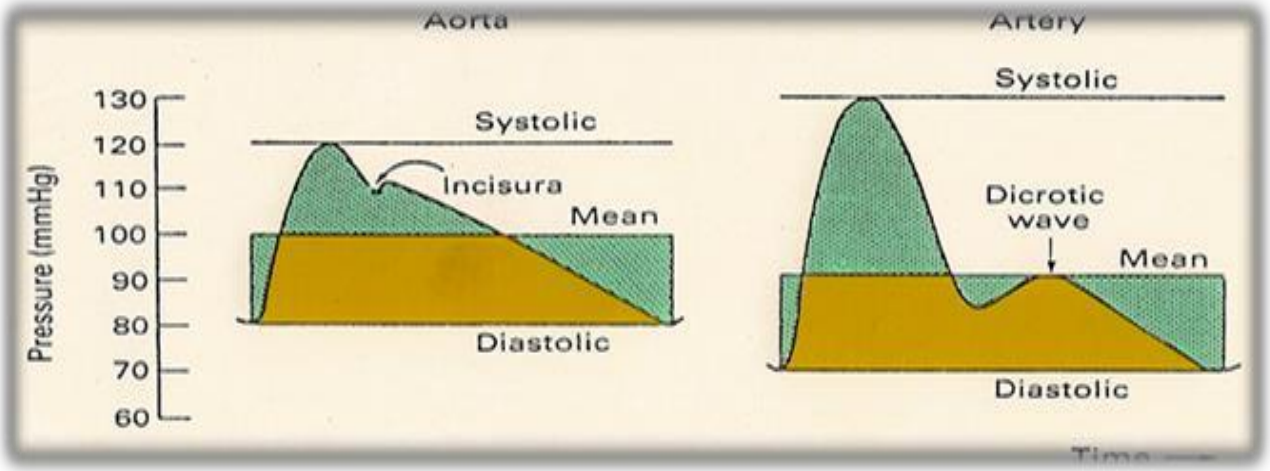
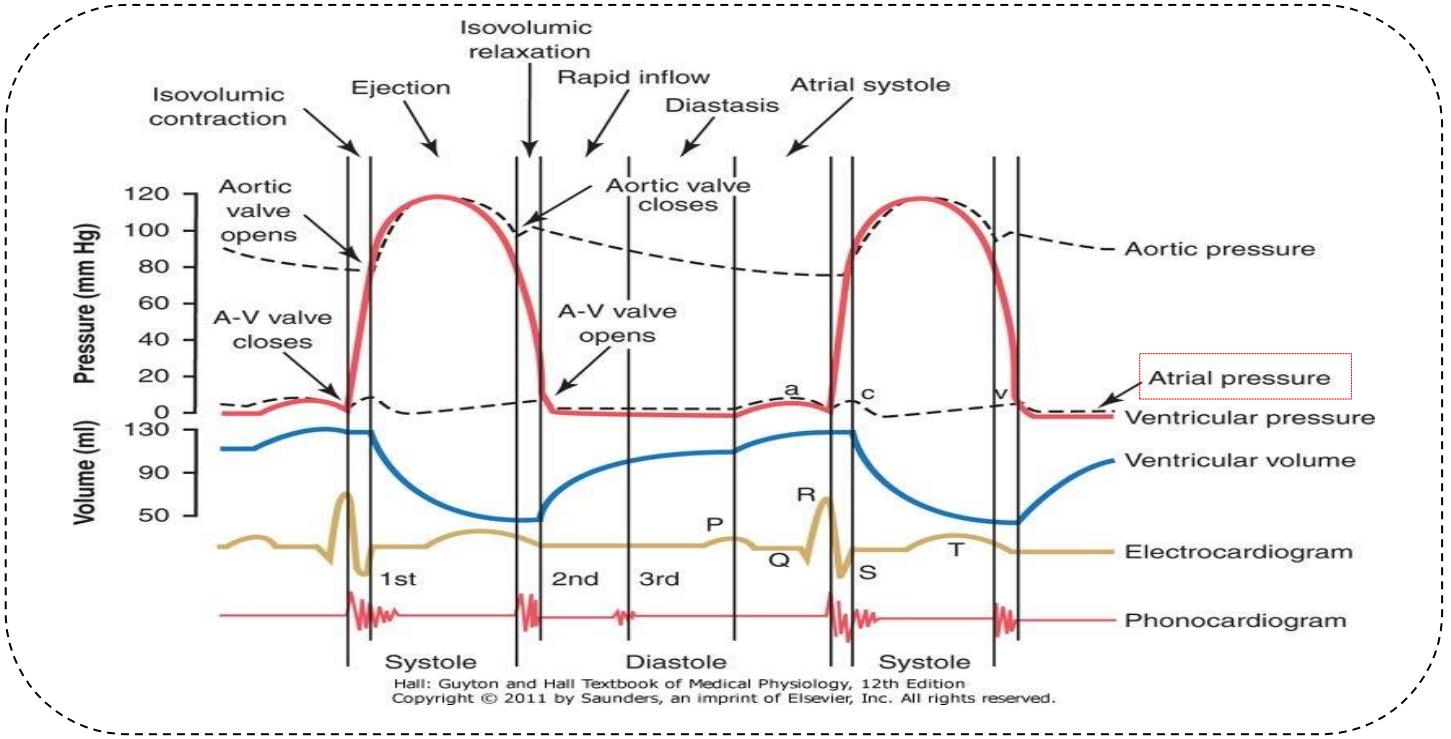
Differences between arteries and aorta

Arterial pressure changes	Pulmonary artery pressure changes
- **110-130/70-85** - Similar to aortic pressure waves, but **sharper.** - (Its waves are Sharper than aortic pressure waves.) - Reflects a systolic peak pressure of **110-130 mmHg** & a diastolic pressure **70-85 mmHg**.	- **25-30/4-12** - Similar to aortic pressure changes, but **with difference in magnitude.** - (Differs from aortic pressure changes by magnitude)



Atrial pressure changes



- **Guyton corner :**

a wave is caused by atrial contraction.

c wave occurs when the ventricles begin to contract; it is caused partly by slight backflow of blood into the atria at the onset of ventricular contraction but mainly by bulging of the A-V valves backward toward the atria because of increasing pressure in the ventricles.

v wave occurs toward the end of ventricular contraction; when blood flows into the atria from the veins while the A-V valves are closed during ventricular contraction.

Causes of Atrial pressure waves

3 Upward deflection

a wave:
(atrial systole)
-Increase in atrial pressure during atrial systole.

c wave:
(ventricular systole)
+ve → bulging of AV valves into atria during "isovolumetric contraction phase"
-ve → pulling of the atrial muscle & AV cusps down during "rapid ejection phase",

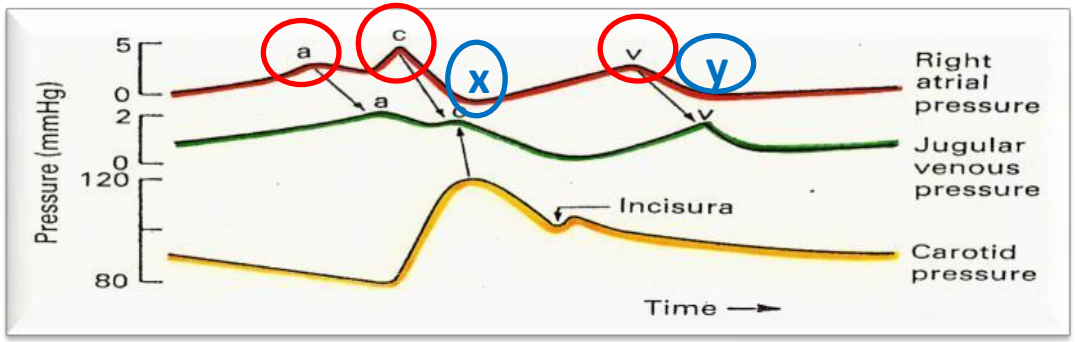
v wave:
+ve: increase in atrial pressure due to the increase in venous return during "atrial diastole".
-ve: decrease in atrial pressure during "rapid filling phase"

2 Downward deflection

x decent:
Downward displacement of AV valves during "reduced ejection phase"

y decent:
Decrease in atrial pressure during "reduced filling phase"

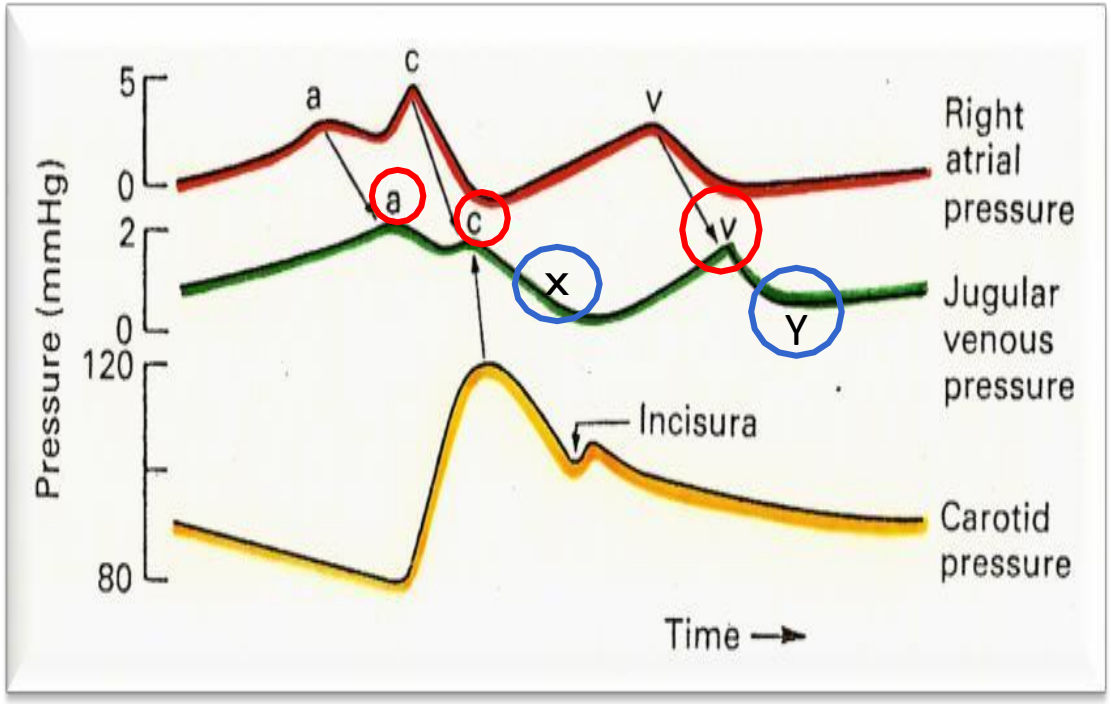
- +ve = **increase** in pressure
- -ve = **decrease** in pressure
- The 3 waves a,c&v are equal to **ONE cardiac cycle = 0.8 sec.**



- **Guyton corner :**

When ventricular contraction is over, the A-V valves open, allowing the stored atrial blood to flow rapidly into the ventricles and causing the v wave to disappear.

Jugular venous pressure (JVP) changes



Note that it has similar recordings of transmitted delayed **atrial** waves:

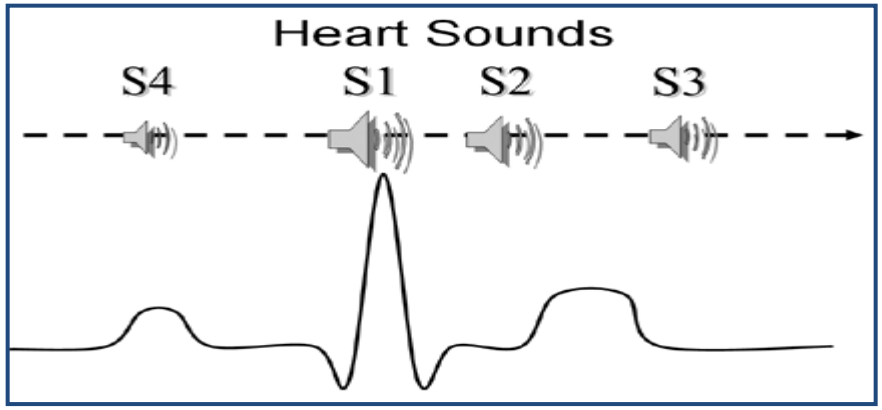
- **3 upward** waves: **a, c, & v**
- **2 downward** waves: **x & y**

Heart Sounds Recorded During the Cardiac Cycle

These sound can be detected either by :

- **Auscultation** (using a Stethoscope)
- **Phonocardiography** (using a sound recording device)

- Why should we care ? By listening with a stethoscope we should be able to tell if there's any abnormality in the heart.
- The murmurs are important for diagnosing valvular heart disease.
- (will be discussed thoroughly in a separate lecture)



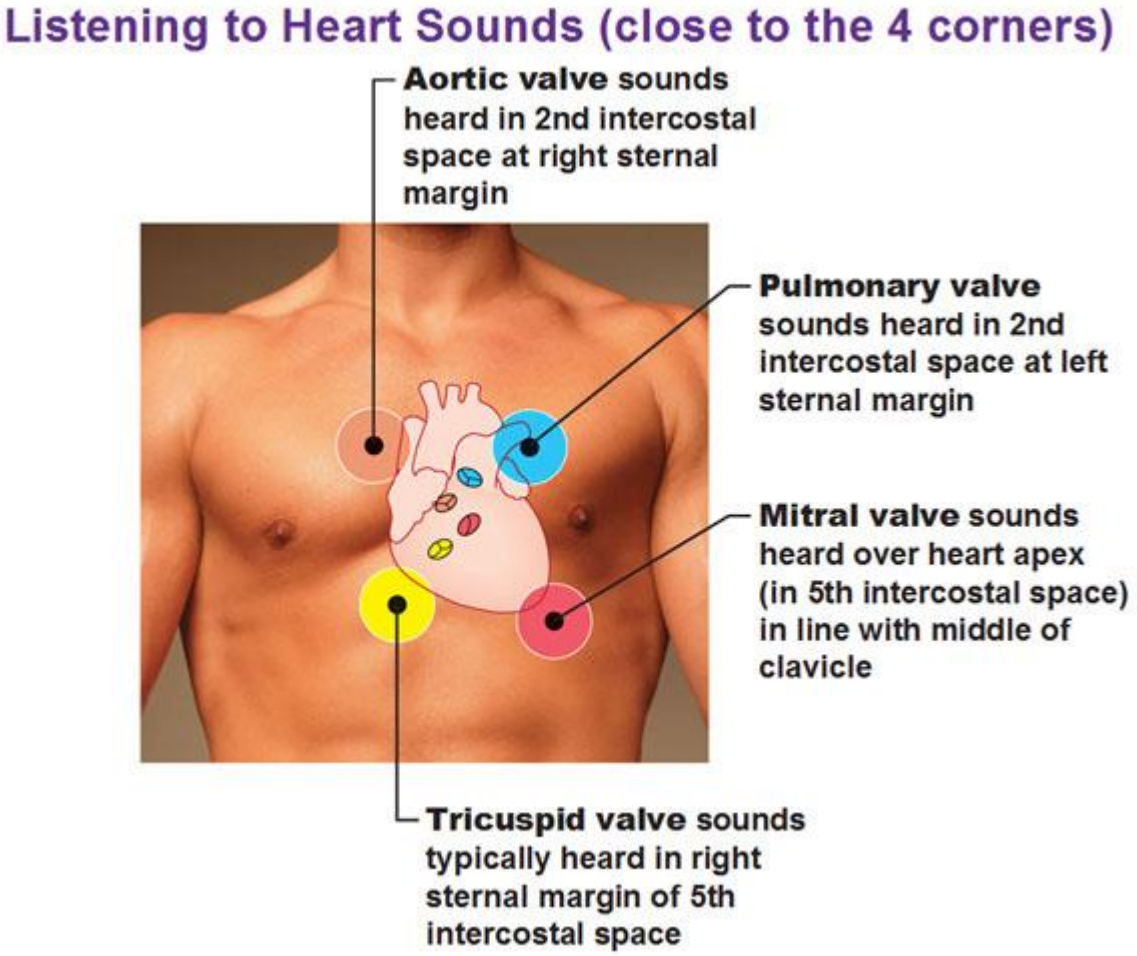
S1 & S2 are Audible, the rest are usually not audible (of low pitch)

Heart Sounds' Windows

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

Pulmonary area	2nd left intercostal space.
Aortic area	2nd right costal cartilage.
Mitral area	5nd left intercostal space crossing mid-clavicular line, or 9 cm (2.5-3 in) from sternum.
Tricuspid area	lower part of sternum towards right side.

Heart sound windows



I can hear the heart sound from any area of the heart, but there are 4 best areas, which are:
-Pulmonary -Aortic -Mitral -Tricuspid

Normal heart sounds

S1	S2	S3	S4
Due to closure of the AV-vs.	Due to closure of semilunar- vs.	S3 is usually not audible (very low pitch.)	S4 is usually not audible (very low pitch.)
Recorded at the beginning of the 'isovolumetric contraction phase.'	Recorded at the beginning of the 'isovolumetric relaxation phase.'	Recorded during the ' rapid filing phase ' due to rush of blood into the ventricle.	Recorded during 'atrial systole.'
It marks beginning of ventricular systole.	Marks the beginning of ventricular diastole.	It can be heard in children.	It can heard in elderly.
Long in duration 0.15 sec	Short in duration 0.11-0.125 sec	0.05 sec.	0.04 sec.
Of low pitch (LUB), Loud.	Of high pitch (DUB) Soft & Sharp.	-	-
25-35 Hz.	50 Hz.	-	-
Best heard at Mitral & Tricuspid areas.	Best heard at Aortic & Pulmonary areas.	Best heard at Mitral area.	Best heard at Mitral area.
-	S2 splits physiologically into 2 sounds during inspiration due to delay closure of pulmonary valve = physiological splitting	-	-

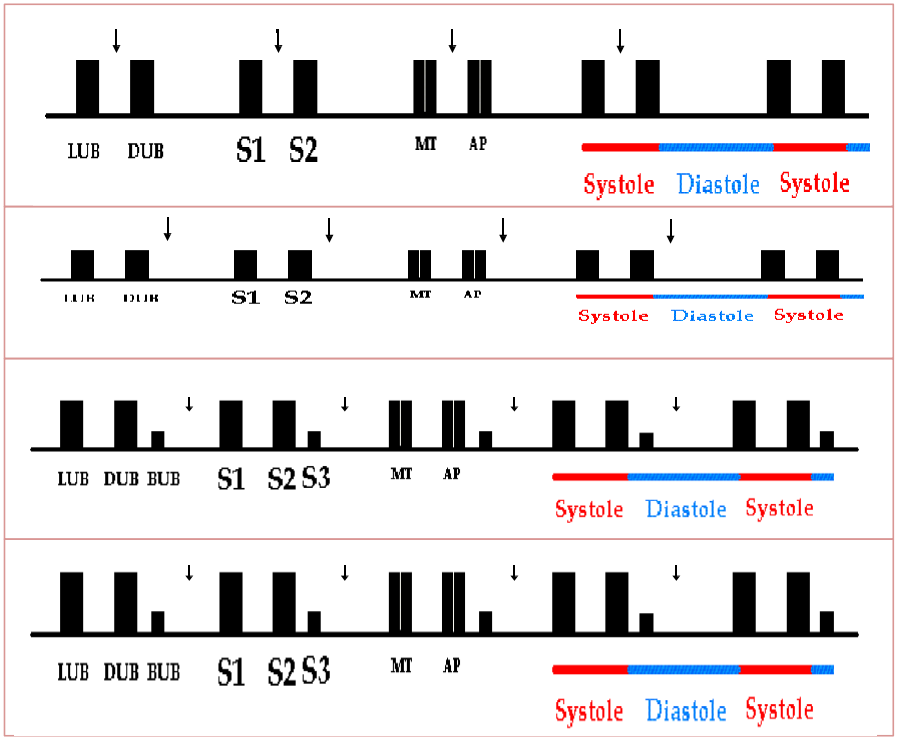
Heart sounds

- **Guyton corner :**

Relationship of the Heart Sounds to Heart Pumping

When listening to the heart with a stethoscope, one does not hear the opening of the valves because this is a relatively slow process that normally makes no noise. However, when the valves close, the vanes of the valves and the surrounding fluids vibrate under the influence of sudden pressure changes, giving off sound that travels in all directions through the chest.

When the ventricles contract, one first hears a sound caused by closure of the A-V valves. The vibration pitch is low and relatively long-lasting and is known as the first heart sound. When the aortic and pulmonary valves close at the end of systole, one hears a rapid snap because these valves close rapidly, and the surroundings vibrate for a short period. This is sound is called the second heart sound. The precise causes of the heart sounds are discussed more fully in Chapter 23, in relation to listening to the sounds with the stethoscope.



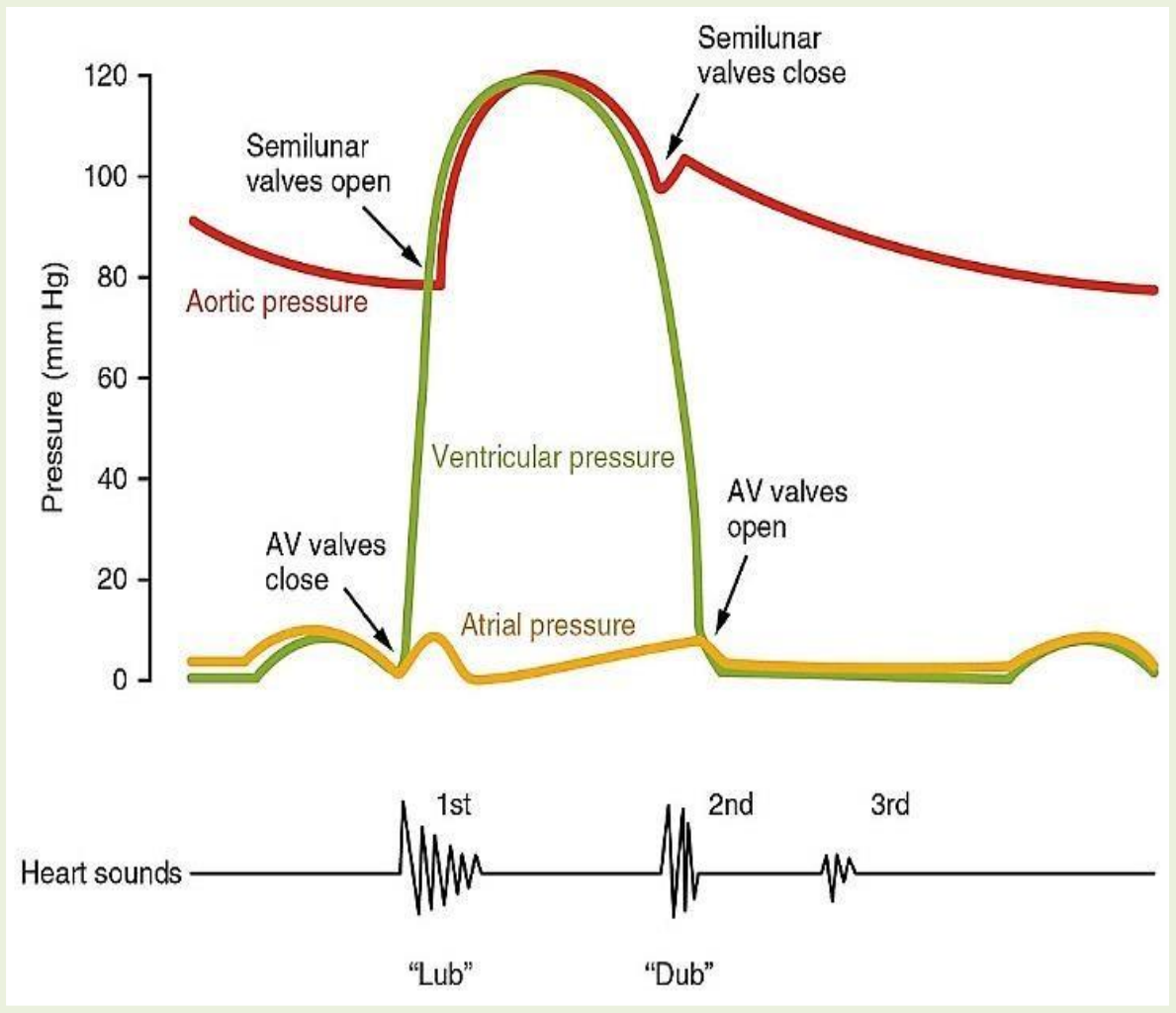
1st sound "**lub**"> Long, Low, Loud > best heard at mitral & tricuspid

2nd sound "**dub**"> Short, Soft, Sharp > best heard at aortic & pulmonary

If we ask the patient to take deep inspiration and hold it, then hear his heart sound we'll hear splitting "**lub tadub**" in the 2nd sound, and this is **normal**, but if it occurs in other than deep inspiration then this is **abnormal**.

PHYSIOLOGY TEAM 435

Cardiac Cycle Vs Heart Sounds



Cardiac Cycle 2

Objectives :

- Electrical changes that occur in the cardiac cycle.
- Identify the systolic and diastolic period.
- Discuss the volume-pressure relationship in the left ventricle.
- Pressure Volume Curve and Pressure Volume loop.

Contact us : Physiology435@gmail.com

Electrocardiogram (ECG)

What is it?

Record of the electrical activity (**Action Potentials**) generated by the heart from chest surface per time unit. It displayed on graph paper as **waves**.

Calibration: Time and voltage

-The axises of ECG graph:

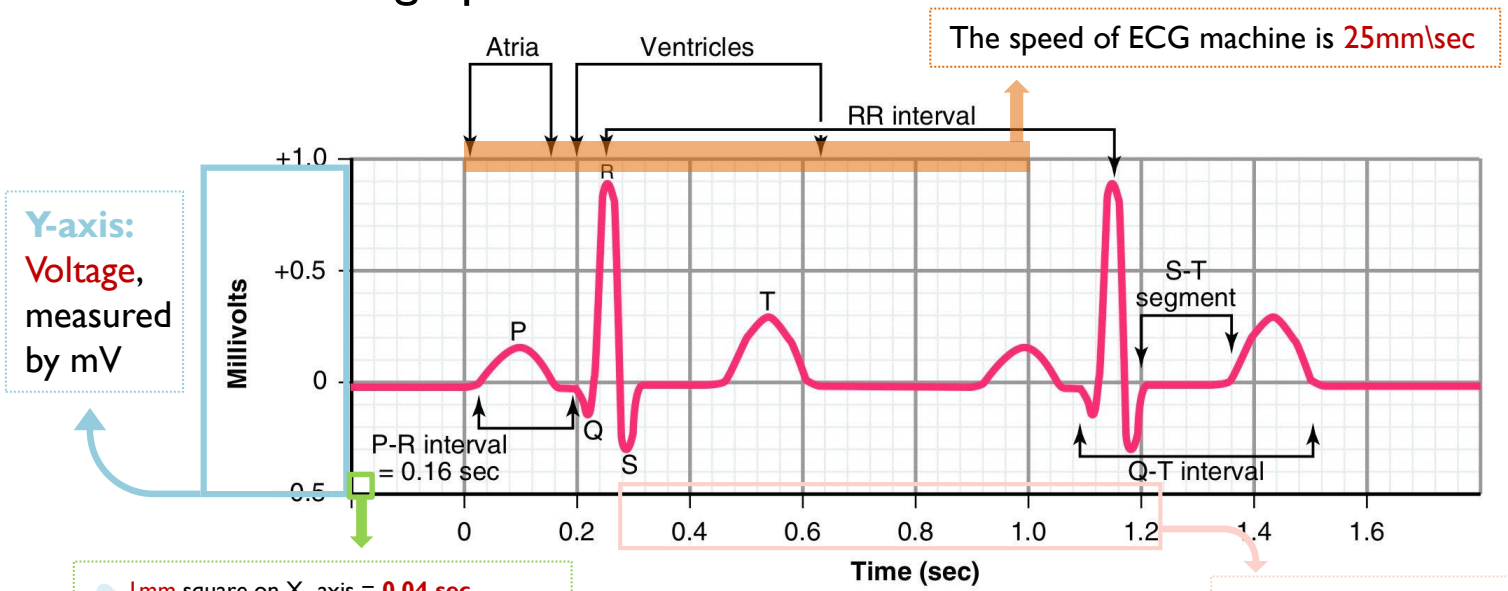


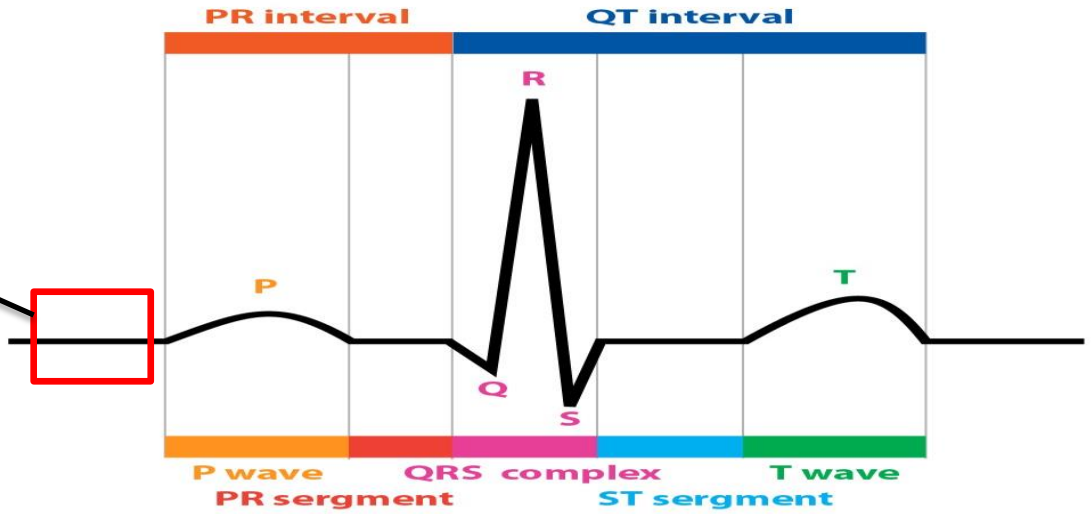
Figure 11-1. Normal electrocardiogram.

ECG Waveforms

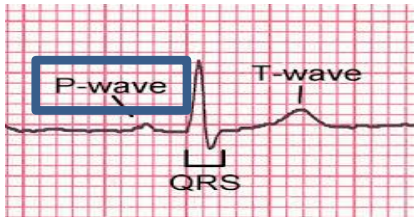
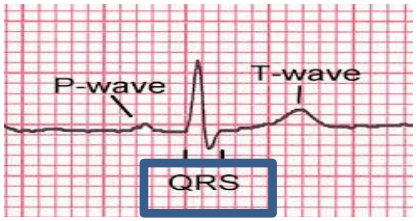
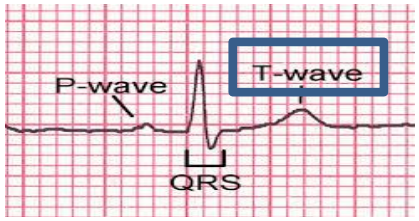
One heartbeat is normally recorded as:

3 waves		2 interval between waves	2 segments
P-wave		PR interval (stare from the beginning of P to the beginning of Q)	PR segment (start from the end of P to the beginning of QRS)
QRS-complex			
T-wave		QT interval (start from the beginning of Q to the end of T)	ST segment (start from the end of QRS to the beginning of T)
3 (+) waves (P,R,T)	2 (-) waves (Q,S)		

Note :
- Isoelectric line (the muscle is **polarize** means not depolarize or repolarize)
- Any positive deflection is **above** the line
- Any negative deflection is **below** the line



ECG Waves

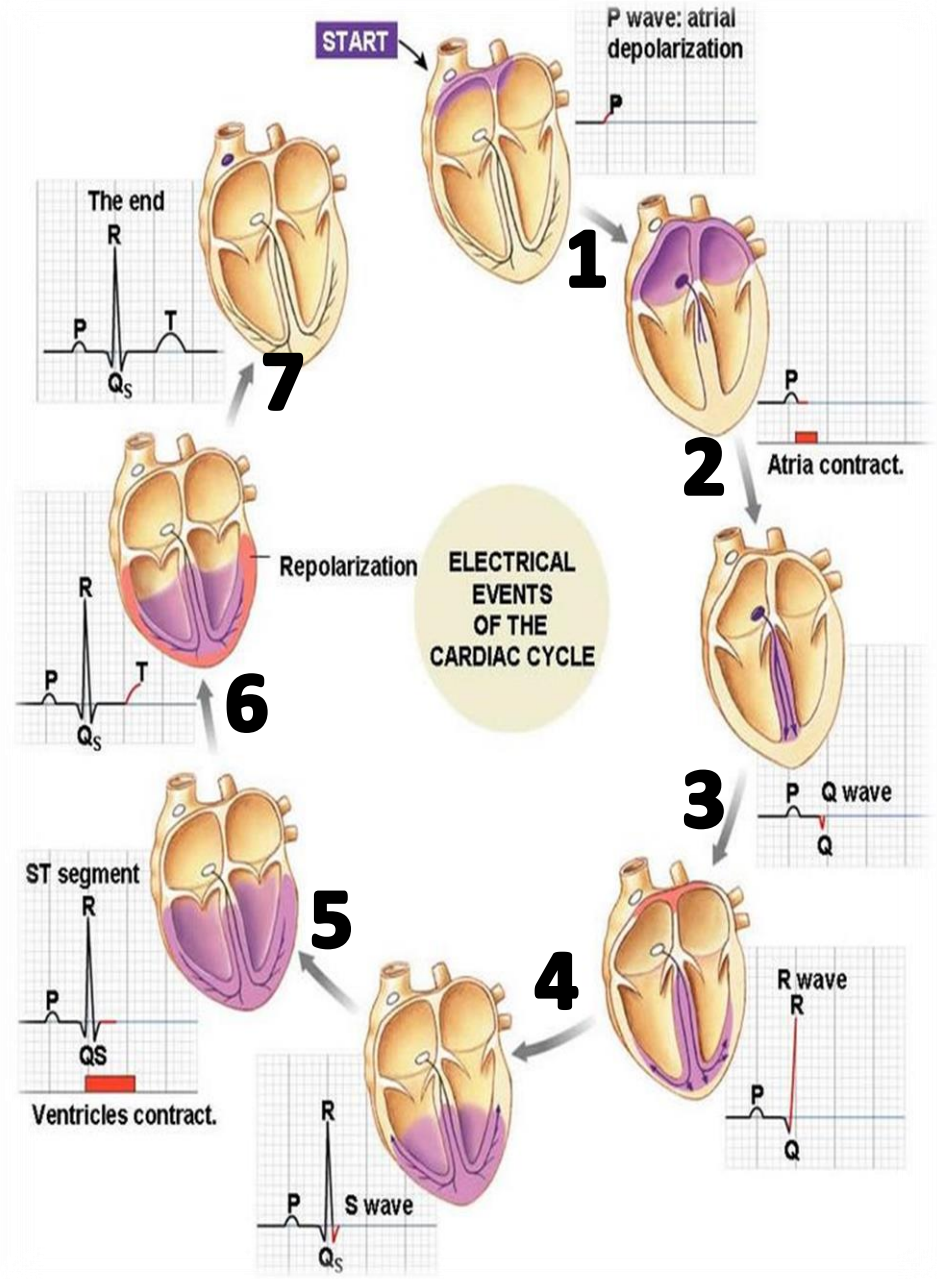
Name of the waves	P-wave	QRS-complex	T-wave
Diagram showing the waves			
Due to	Atrial depolarization	Ventricular depolarization	Ventricular repolarization
Recorded before	The onset of the Atrial systole	The onset of ventricular systole (isometric contraction phase)	The onset of ventricular Diastole (isometric relaxation phase)

Note :
- The impulses from SA node spread in the atrium it gives P wave , it means the P wave is from SA node.
- If you see P wave before QRS complex that mean it is sinus rhythm , it is from SA node.

Video

1	Impulse from SA node spread in the atrium and it give the P wave (Atrial depolarization)
2	it spread to AV node , it means PR interval. PR interval is the conduction between the SA node and AV node , it is critical interval لها مسافة محددة إذا طالت هذه المسافة فهذا يعني أن هنالك خلل في التوصيل بينهما (very important)
3	After AV node it spread to bundle of his and enter the **septum** it give the : Q wave
4	Spread in the **wall** and gives : R wave
5	Spread in the **base** and gives : S wave
6	Ventricular repolarization and gives : T waves

Note :
- QRS complex : Q from septum , R from wall , S from base.



*** This was not written in slides but it is very important to understand the sequence of electrical events.**

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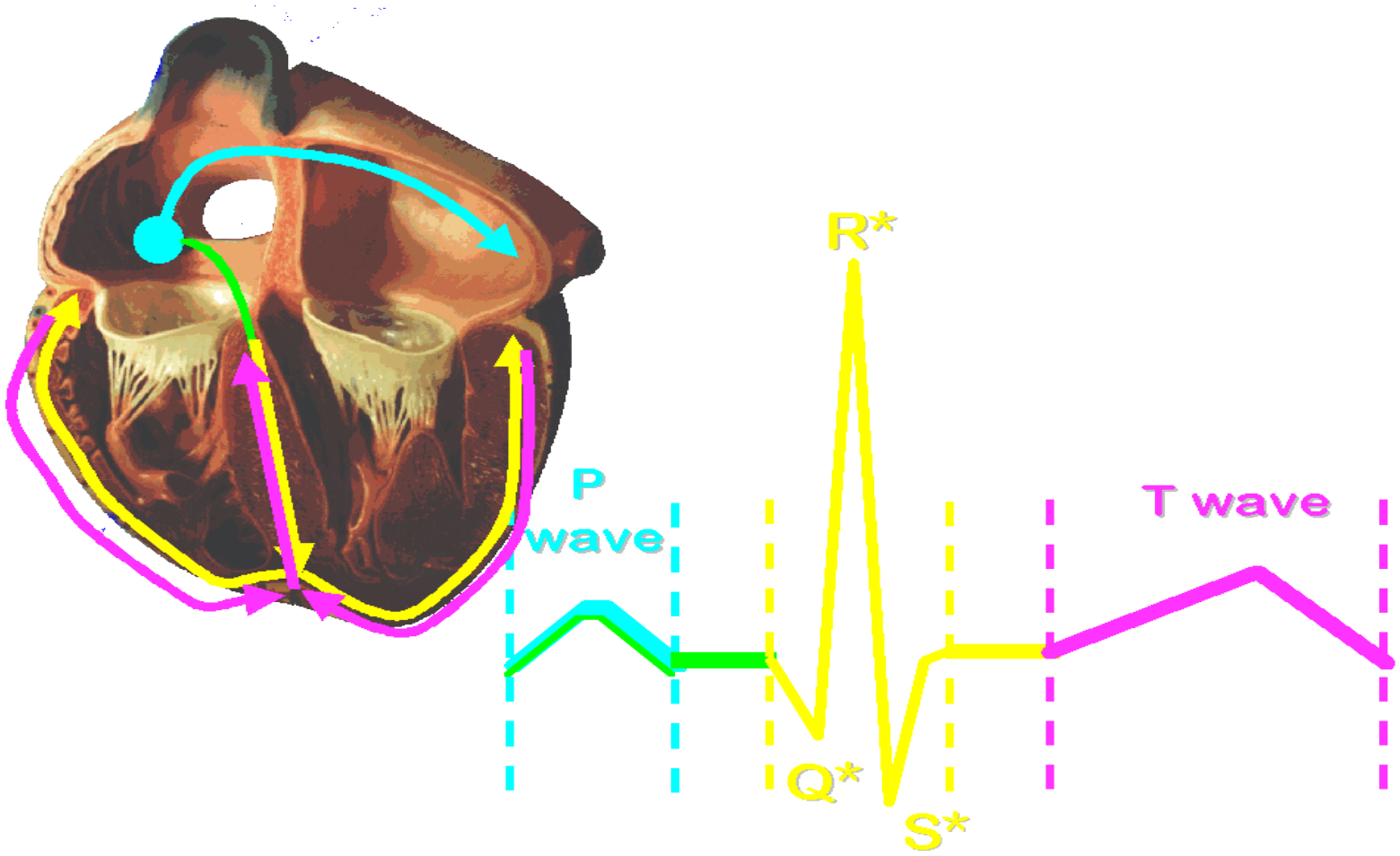
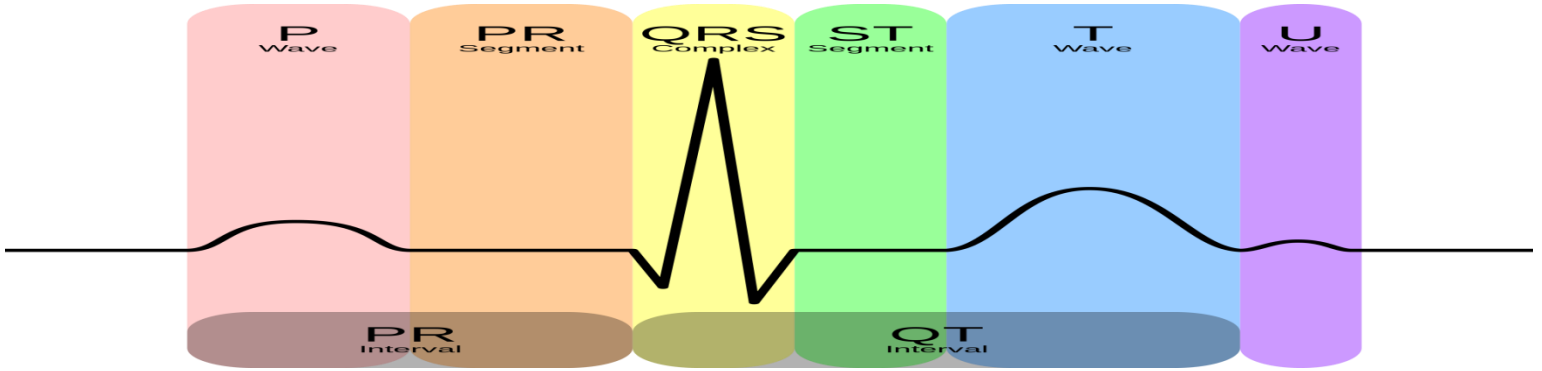
Electrical event of cardiac cycle



Video

ECG cont.



Atrial depolarization (p-wave)	P-R interval	Ventricular depolarization (QRS)	Ventricular repolarization (S-T segment)	Ventricular repolarization (T wave)	Ventricular depolarization and repolarization (Q-T interval)
The depolarization of both atria is represented by the **P** wave , the **P** wave is the first ECG deflection	Electrical transmission from the atria to the ventricles. Including the **P** wave and **PR** segment.	Ventricular depolarization is indicate by the **QRS** complex. The R wave is the initial positive deflection; the negative deflection before the **R** wave is the **Q** ; the negative deflection after the **R** wave is the **S** wave	Earlier phase repolarization of both ventricles extends from the end of the **QRS** to the beginning of the **T** wave. The point at which the **ST** segment joins the QRS is known as the **J** (junction)- point	The repolarization of both ventricles is represented by **T** wave. The **ST** segment and the **T** wave are sensitive indicators of the oxygen demand - oxygen supply status of the ventricular myocardium	Including the **QRS** complex , **ST** segment and **T** wave

Note : ST segment is the distance between ventricular depolarization and repolarization , it is short distance and critical. In ischemia patient the ST segment will not be (Iso-electrical) , rather it will deflect above or below the isoelectric line.

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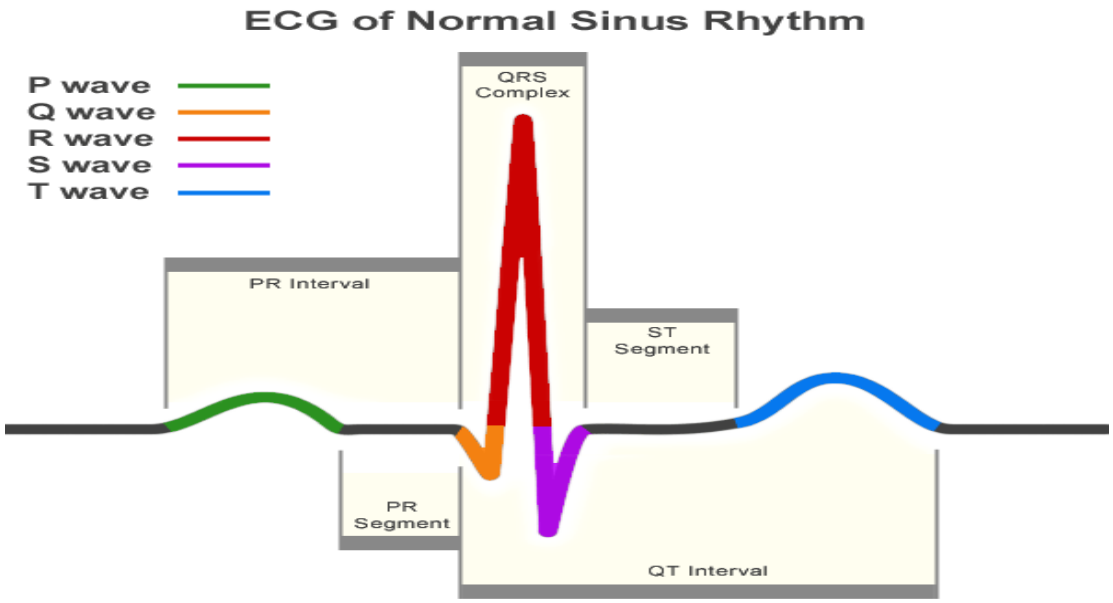
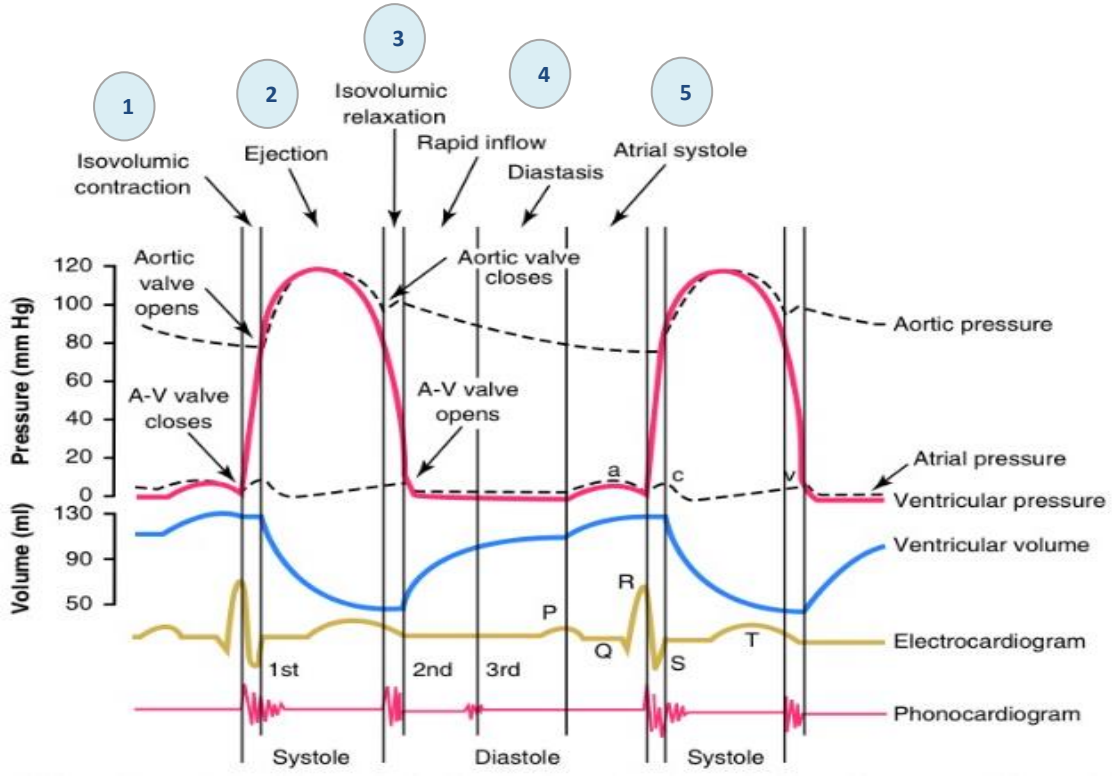
Normal duration of ECG waves and intervals



PR interval	PR segment	QT interval	ST segment	QRS
0.12 - 0.20 sec	0.06 - 0.11 sec	0.35 - 0.45 sec	0.3 - 0.32 sec	<0.10 sec

Left Ventricular Pressure – Volume Curve ‘the Complete picture’



- It consist of the following periods:

1. Period of Isovolumetric (Isometric) Contraction
2. Period of Ejection. “period of rapid ejection, period of slow ejection”.
3. Period of Isovolumetric (Isometric) Relaxation
4. Ventricular diastole” Rapid Filling (Rapid inflow), Reduced Filling (diastasis)”
5. Atrial systole

Video

EXTRA INFORMATION of Left Ventricular Pressure – Volume curve

Period		Pressure / volume changes
Period of Isovolumetric (Isometric) Contraction "systole"		**ventricular pressure :** rises abruptly Immediately after ventricular contraction begins causing the A-V valves to close **ventricular volume :** contraction is occurring in the ventricles, but there is no emptying. So, volume is constant
Period of Ejection.		**ventricular pressure :** rises slightly (above 80 mm Hg) which will push the semilunar valves open **ventricular volume :** rapidly decreases. blood begins to pour out of the ventricles. (with about 70% of the blood emptying occurring during the first third of the period of ejection and the remaining 30% emptying during the next two thirds. Therefore, the first third is called the **period of rapid ejection**, and the last two thirds, the **period of slow ejection**.)
Period of Isovolumetric (Isometric) Relaxation "diastole".		**ventricular pressure :** ventricular relaxation begins suddenly, allowing both the right and left ventricular pressures to decrease rapidly **ventricular volume :** does not change (constant)
Ventricular diastole	**Rapid Filling (Rapid inflow)**	**ventricular pressure :**will slowly rise as they fill with blood from the atria. **ventricular volume :** increases the volume of each ventricle
	Reduced Filling (diastasis)	**ventricular pressure :**As the ventricles continue to fill with blood and expand, they become less compliant and the ventricular pressures rise **ventricular volume :** Blood flows slowly to ventricles causing slowly increases volume.
Atrial systole		**ventricular pressure :** increasing pressure in the ventricles. **ventricular volume :** Ventricles receiving blood resulting in increase volume.

Left Ventricular Pressure - Volume Loop

Left Ventricular Pressure - Volume Loop :

Correlation of intra-ventricular changes in volume & pressure that occur during **ONE** cardiac cycle .

* The cardiac cycle refers to a complete heartbeat from its generation to the beginning of next beat. **[1 cardiac cycle = 1 Heart beat = 1 Loop].**

Both ventricular systole and diastole can be divided into :

	DIASTOLE	SYSTOLE
Early phase	Early diastole : Isovolumetric Relaxation	Early systole Isovolumetric Contraction
Late phase	Late diastole : Isotonic Relaxation *(Filling Phase)*	Late systole : Isotonic Contraction *(Ejection Phase)*

The difference between (isovolumetric) and (isotonic) :
- Isovolumetric there is high tone but no work.
- Isotonic there is work but no tone.

EXTRA

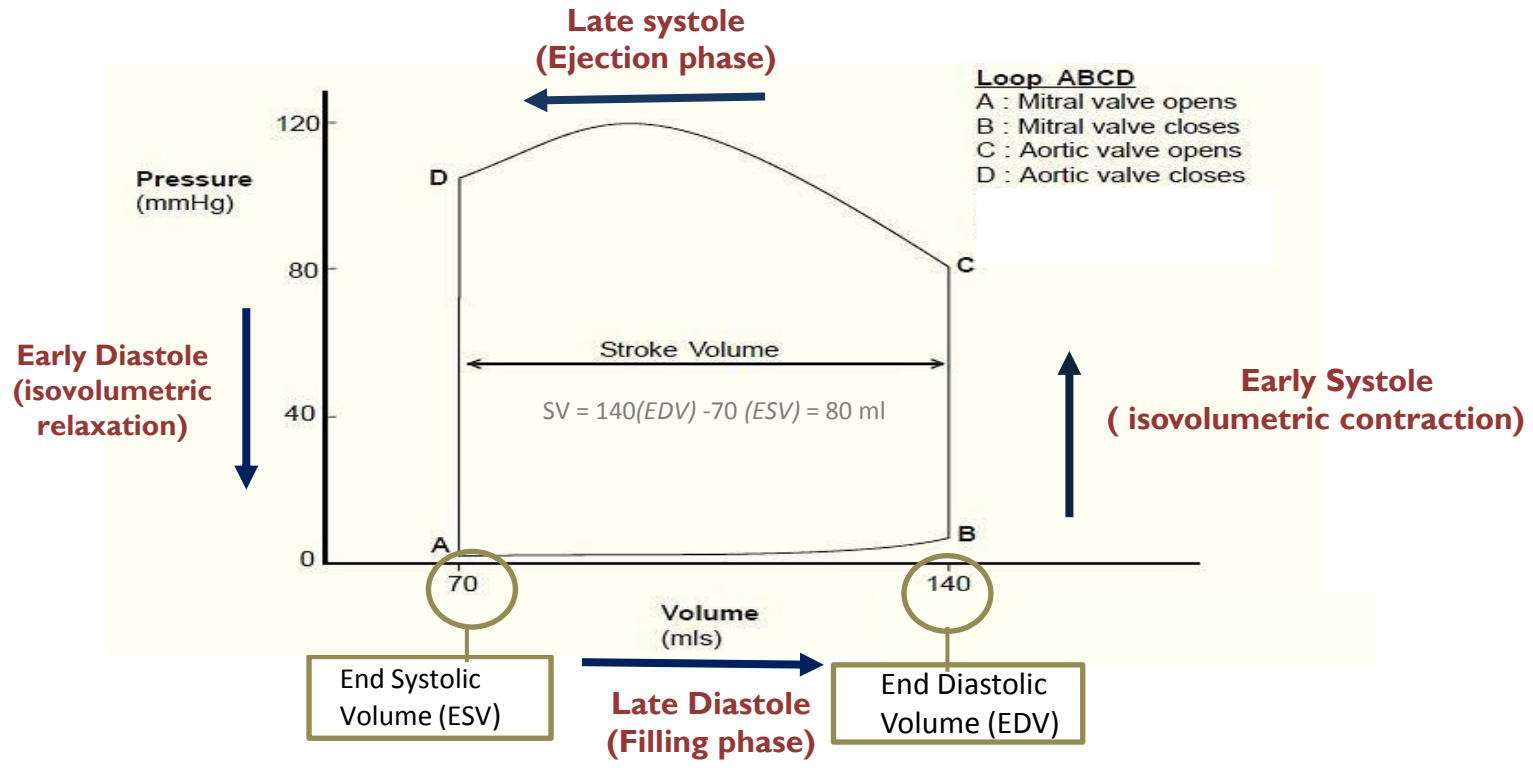
- They divide the (Pressure – Volume Loop) into two stages :

- Early stage
  - it's isovolumetric (there is change in pressure)
    - isovolumetric contraction (systole)
    - isovolumetric relaxation (diastole)
- Late stage
  - it's isotonic (there is work)
    - Ejection phase
    - Filling phase

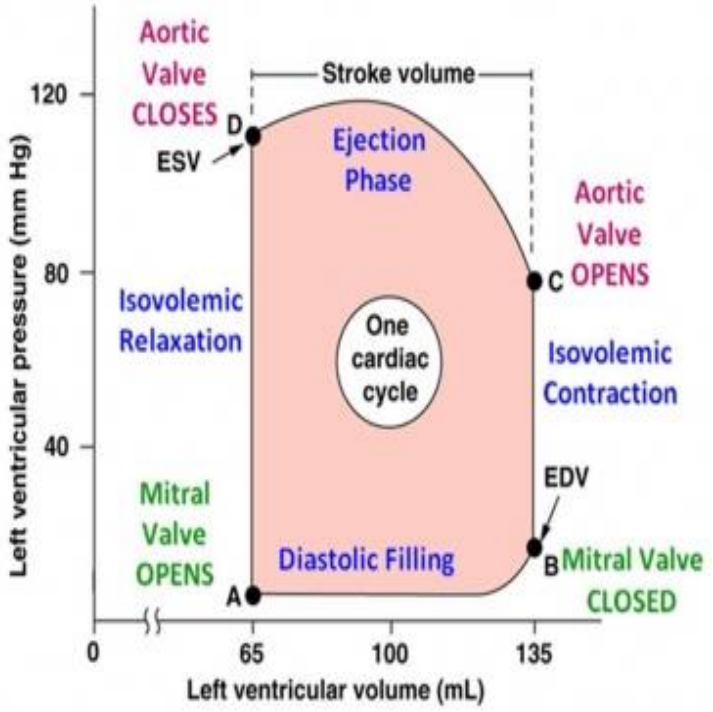
Ventricular Pressure-Volume loop

The following Volume-Pressure loop shows plots of the left ventricle pressure values *(Y-axis)* and volume values *(X-axis)* through one complete cardiac cycle :

- **Systole** is divided into early and late systoles.
- **Diastole** is divided into early and late diastoles.



Left ventricular pressure – volume loop



- **EDV:** End diastolic volume.
- **ESV:** End systolic volume.
- **A→B:** Passive filling and atrial contraction.
- **B→C:** Isovolumetric Contraction.
- **C→D:** Ejection of blood into aorta.
- **D→A:** Isovolumetric relaxation.

* for better understanding : Video

The volume pressure diagram demonstrating changes in the intraventricular volume and pressure during a single cardiac cycle (black line). the red shaded area represent the net external work output by the left ventricle during the cardiac cycle

Left Ventricular Pressure-Volume Loop

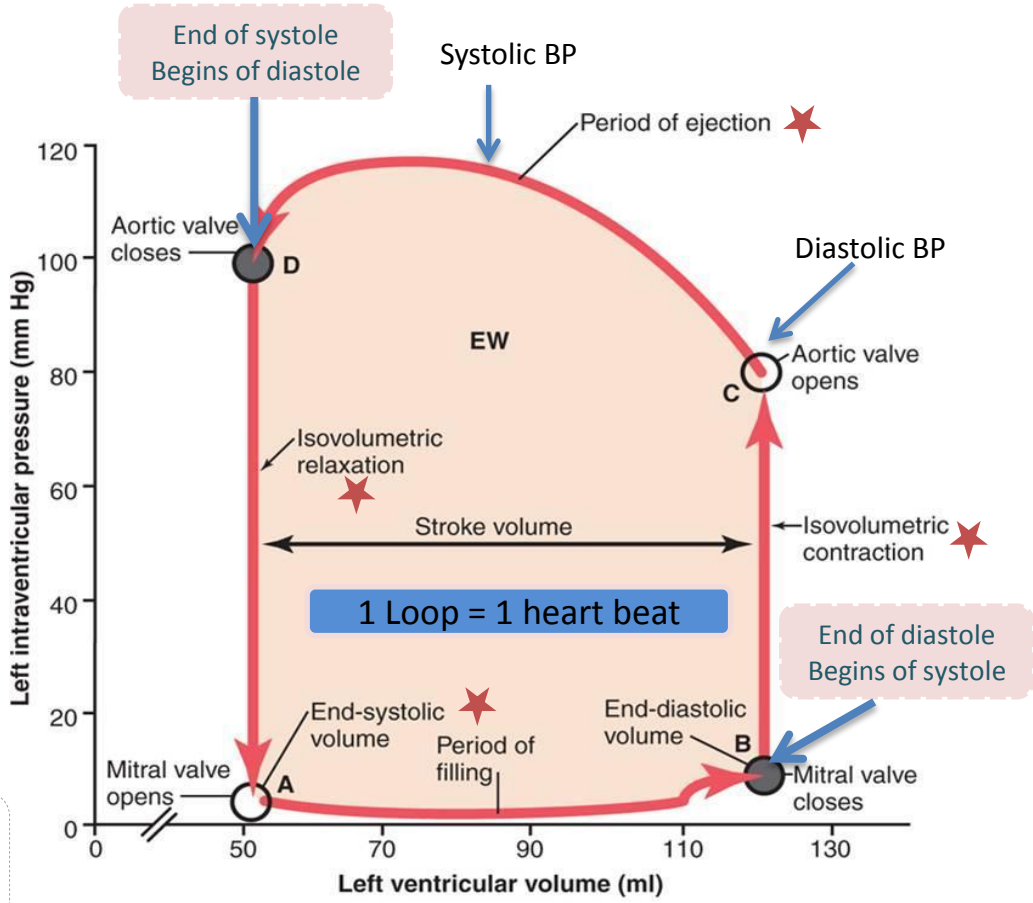
Important to know :

1- At point A the mitral valve opens then it closes at point B between them the diastolic filling occurs (A & B).
2- at point C the aortic valve opens then closes at D point between them ejection phase occurs (C & D).

Systole : begins at B & end at D
Diastole : begins at D & end at B

Stroke Volume: It is the volume of blood pumped from one ventricle of the heart with each beat.
Stroke Volume = End diastolic - End Systolic
SV = EDV - ESV

Note :
- The systole stage is determined by the contractility of the muscle.
- The diastole stage is determined by the compliance of the muscle.



- **Guyton corner :**

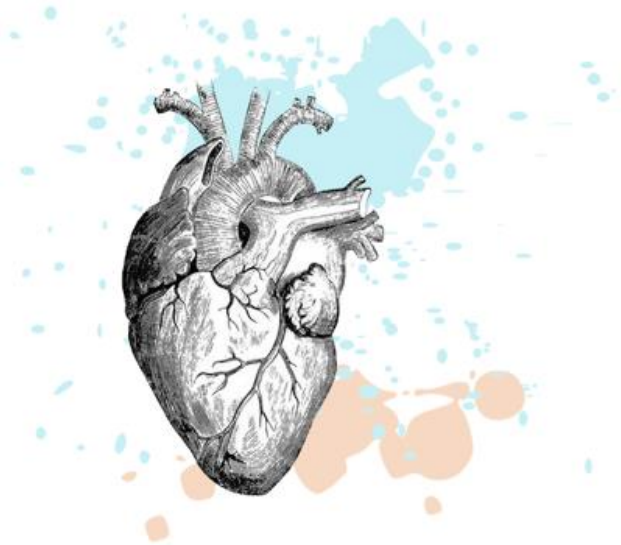
Diastolic BP : increase in the pressure before the end of diastole because of the closed valve.
Systolic BP : increase in the pressure inside the ventricles during ejection.

video

Physiology
OF THE CARDIOVASCULAR SYSTEM

Physiology Leaders :

Khawla Alammari
Nojood Alhaidri
Rawaf Alrawaf



Girls team :

- Atheer Alnashwan
- Asrar Batarfi
- Afnan Almalki
- Alhanouf Aljlaoud
- Deema AlFaris
- Elham Alzahrani
- Johara Almalki
- Lojain alsiwat
- Malak Alsharif
- Monirah Alsalouli
- Monera Alayuni
- Nurah Alqahtani
- Nouf Alabdulkarim
- Nora Albusayes
- Nora Alsomali
- Norah Alakeel
- Reem Alageel
- Rawan Aldhuwayhi
- Reham Al-Obaidan
- Samar AlOtaibi
- Shamma Alsaad

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- Abdullah Aljaafar
- Omar Alotaibi
- Abdulrahman Albarakah
- Adel Alshehri
- Abdulaziz Alghanaym
- Abdulmajeed Alotaibi
- Khalil Alduraibi
- Hassan Albeladi
- Omar Alshehri
- Saleh Alshawi
- Abdulaziz Alhammad
- Faisal Alabdulatif
- Abdulnasser Alwabel
- Saad Almutairy