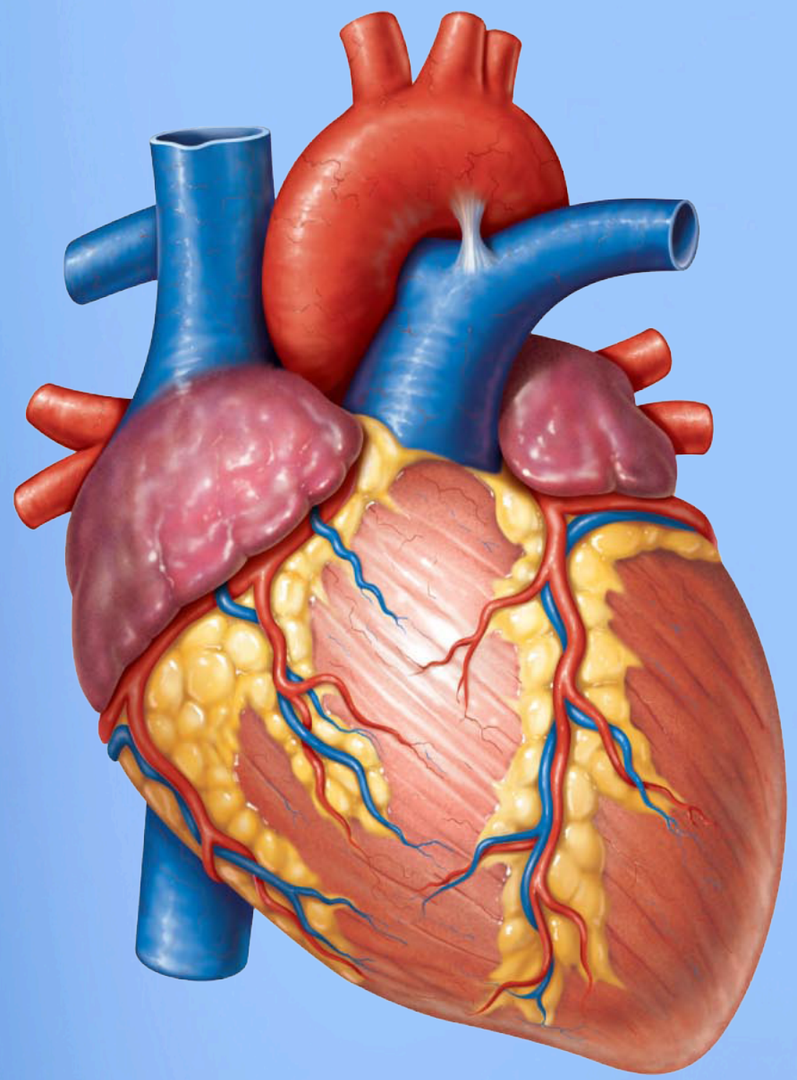
3

CARDIAC CYCLE



Cardiovascular Block

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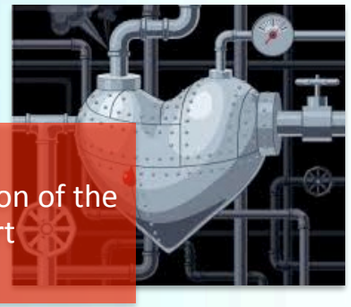
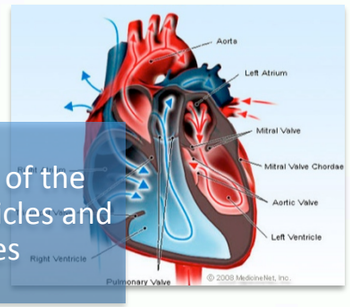
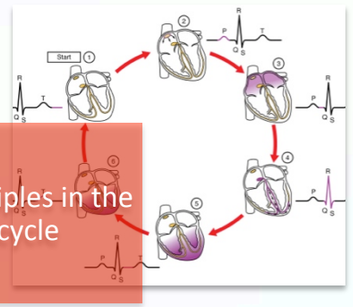
OBJECTIVES



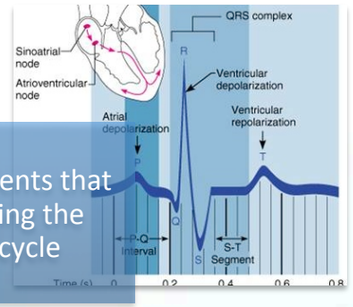
Main function of the heart



Function of the atria, ventricles and valves



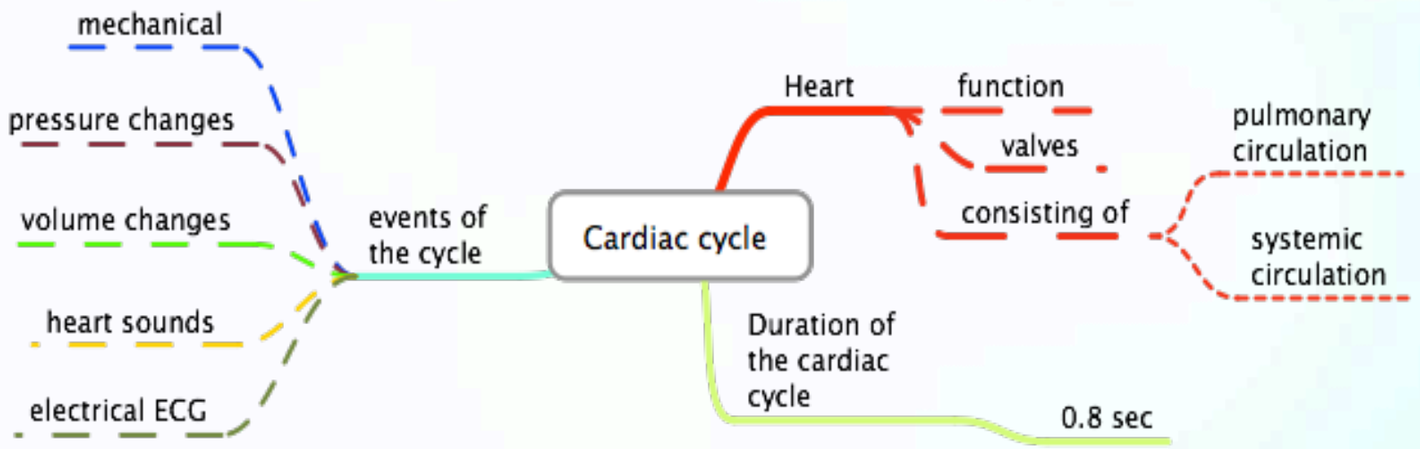
General principles in the cardiac cycle



Different events that occur during the cardiac cycle

abbreviations

- AV=atrioventricular
- VS= Valves
- HR= heart rate
- bpm = beats per minute
- EDV=End-diastolic volume.
- SV= Stroke volume.
- ESV= End-systolic volume.
- EF =Ejection fraction.
- LV= left ventricle



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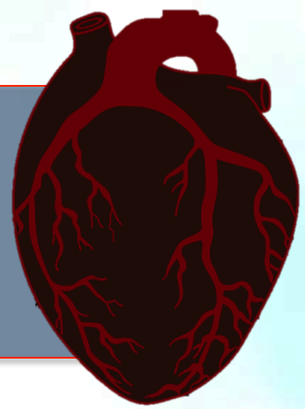
THE HEART



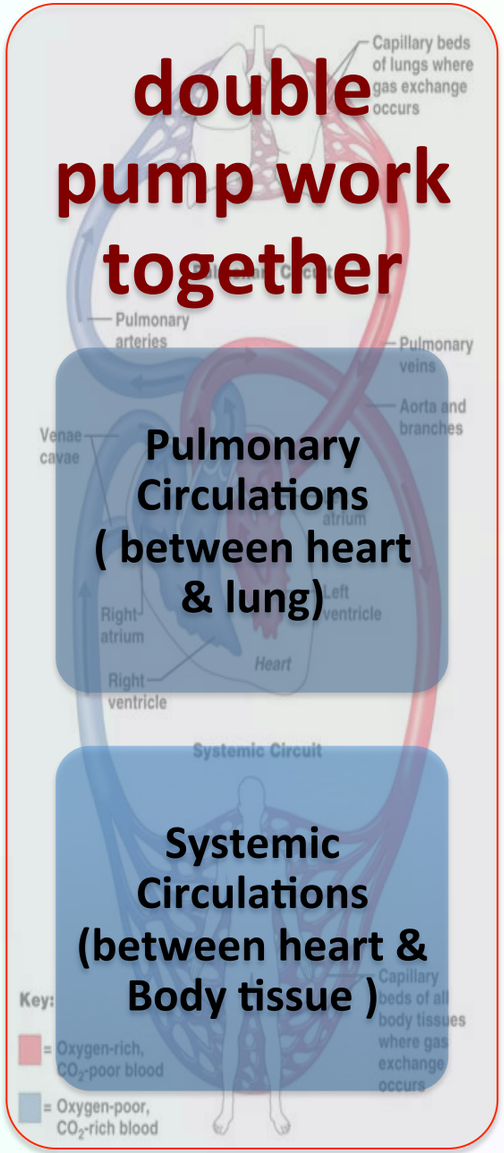
Function

Heart works as a pump

(Contraction of the heart generates pressure changes, resulting in orderly blood movement)

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

double pump work together



Pulmonary Circulations (between heart & lung)

Systemic Circulations (between heart & Body tissue)

Consisting of:

Atria (Primer pump)

Ventricles (Pump)

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 musculr projections called Papillary muscles

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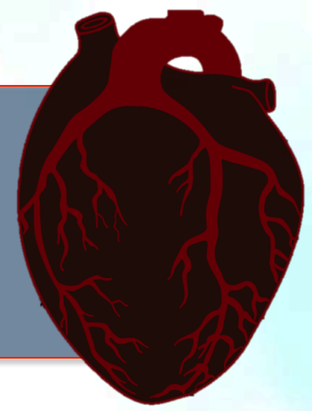
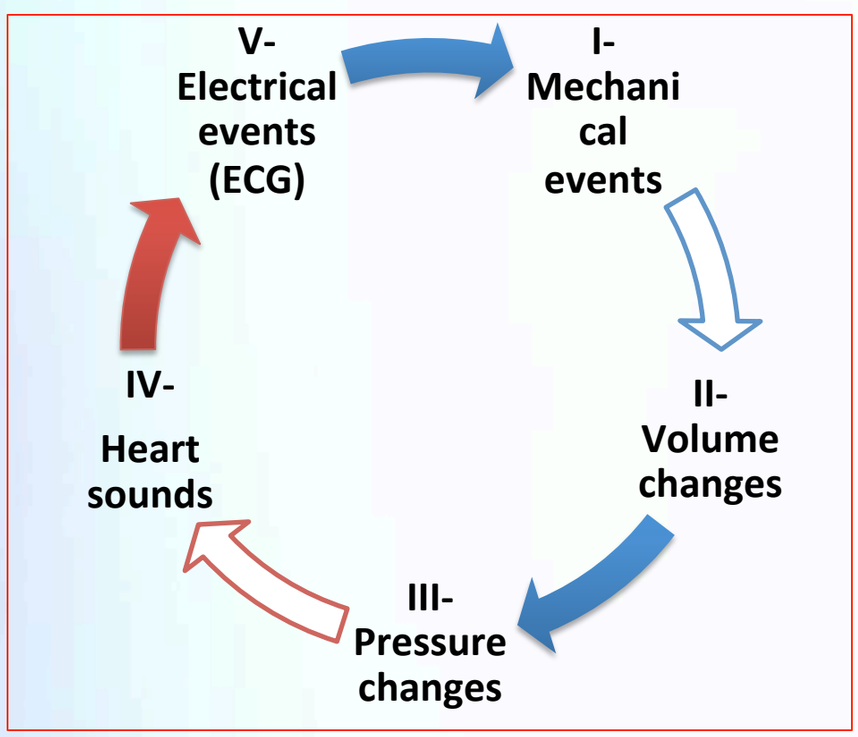
CARDIAC CYCLE



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

Consisted of (events in the cardiac cycle) :



Duration

When HR 72 bpm = 0.8 sec

When HR ↑ → duration become shorter

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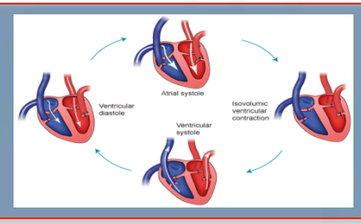
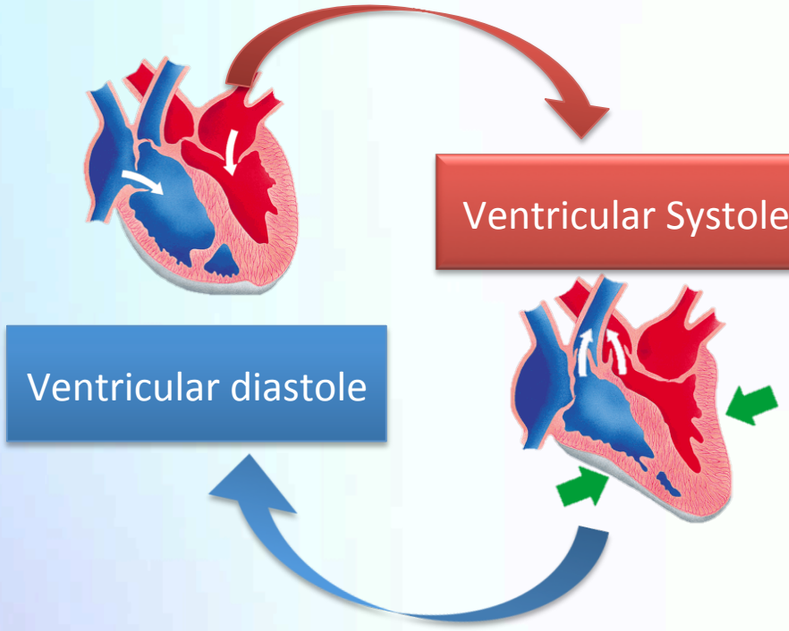
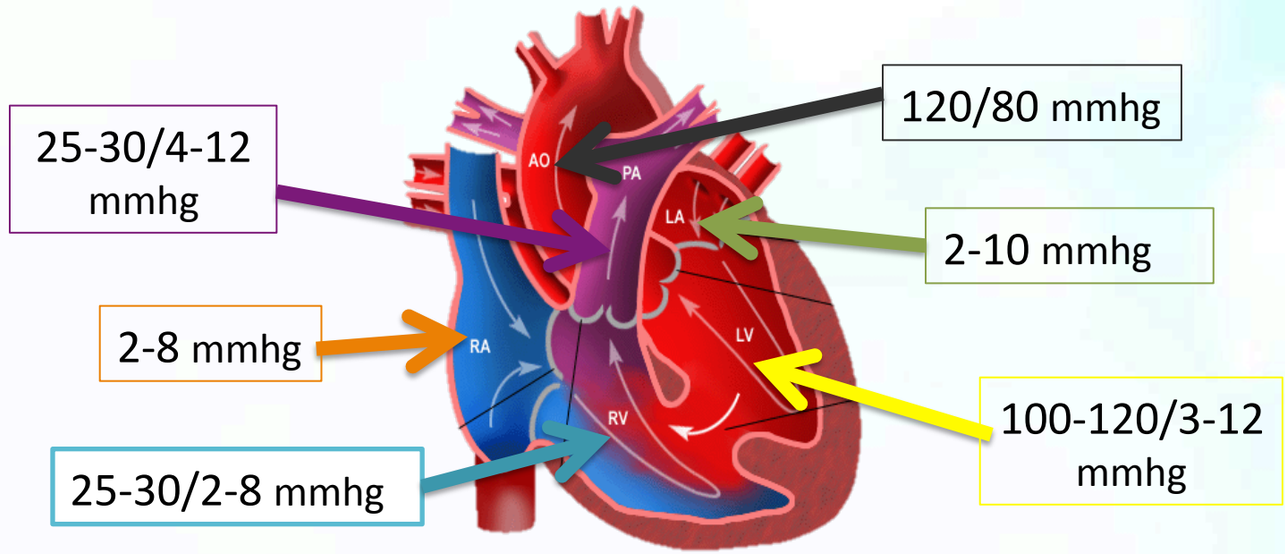
FIRST: MECHANICAL EVENTS



Each heartbeat consists of 2 major periods

- Systole (Contraction)
- Diastole (Relaxation)





Normally **diastole** is **longer** than **systole**

Importance of long ventricular diastole?

1. Coronary blood flow.
2. Ventricular filling.

	Ventricular	Atrial
Diastole	0.5 sec	0.7 sec
Systole	0.3 sec	0.1 sec

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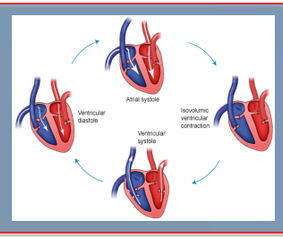
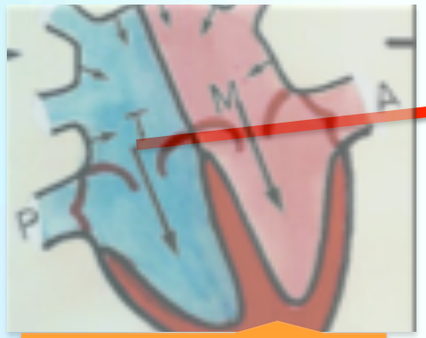
FIRST: MECHANICAL EVENTS



Note

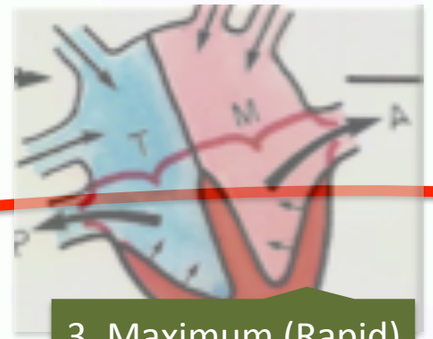
- Early ventricular diastole.
- Mid ventricular diastole.
- Late ventricular diastole.
- Ventricular systole.

* Considered '8' phases if including 1st phase of diastole

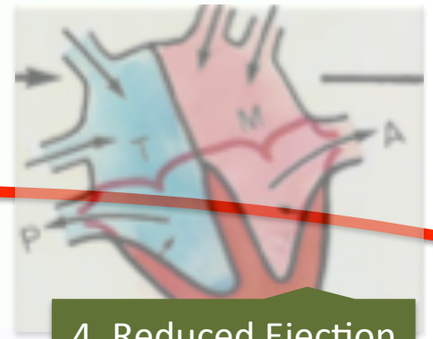


1. Atrial Systole

2. Isovolumetric Contraction Phase:



3. Maximum (Rapid) Ejection Phase:

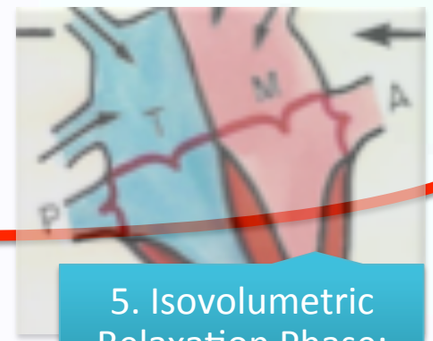


4. Reduced Ejection Phase:

* Protodiastolic Phase.

7. Reduced Filling Phase (Diastasis):

6. Rapid Filling Phase:



5. Isovolumetric Relaxation Phase:

Keep in mind these definitions

End-diastolic volume (EDV):

- Volume of blood in ventricles at the end of diastole.
- ≈ 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
- ≈ 40-60 ml

Ejection fraction (EF):

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

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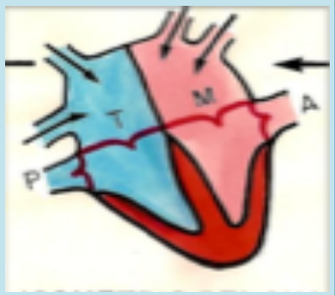
Phase	Interval	Preceded by:	Valves	Volume change	Pressure	Sound
1. Atrial Systole 	• End of ventricular diastole • (lasts 0.1 sec)	Arterial depolarization	• AV- vs open • semilunar- vs closed	Last27-30%of ventricular filling ≈ 40 ml → **ventricular volume ↑**	Atrial pressure ↑ →making "a" wave	**4th heart sound is heard** (Blood arriving the heart can't enter atria, it flows back up jugular vein) **NOTE:** this sound is clear in pathological cases
2. Isovolumetric Contraction Phase: 	• beginning of systole • (0.04 sec) •Quiescent period between closure of AV- vs & opening of Semilunar- vs. •Ventricle is a closed chamber	ventricular depolarization	Starts with closure of AV- vs	Volume in ventricle = EDV **CONSTANT**	• **Ventricular** pressure is greater that atrial → keeps increasing until reaching 80 mmHg. • **atrial pressure** →produce 'c'wave	**1st Heart sound** heard (due to closure of AV valves) **LUB**
3. Maximum (Rapid) Ejection : 	------	------	• Semilunar- vs open (when Ventricular pressure more than aortic) • AV-Vs are closed	Volume of ejected blood = 75% of SV → **Ventricular volume ↓ RAPIDLY**	• when Left **Ventricle** pressure = 80 mmHg • **Atrial** diastole (continue 'c' wave)	NO SOUNDS

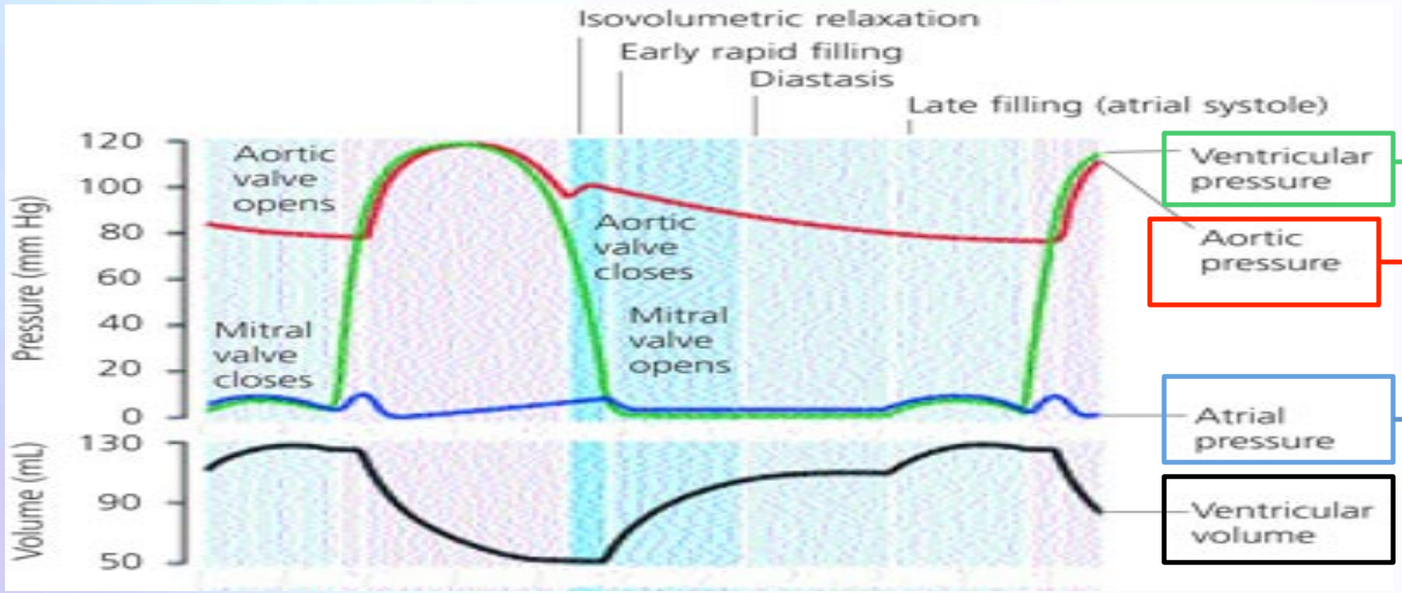
Phase	Interval	Preceded by:	Valves	Volume change	Pressure	Sound
4. Reduced Ejection Phase: 	• End of ventricular systole	-------	Beginning: aortic valve is open → decrease LV pressure → End : aortic valve closes	• Volume of ejected blood = 25% of SV • → **Ventricular volume ↓ SLOWLY**	• ↓ Ventricular pressure till 110 mmHg(→ Aortic- v closes) • Atrial diastole	-------
*Protodiastolic Phase ...	Between end of ventricular systole & aortic valve closure (very short)	-------	-------	**CONSTANT**	• Atrial diastole: • continuous ventricle	-------
5.Isovolumetric Relaxation Phase: 	• Beginning of diastole. • (0.04 sec)	ventricular repolarization	• Lv is a closed chamber. • Between closure of semilunar- vs & opening of AV-vs.	Blood in ventricle = ESV **CONSTANT**	Lv is a closed chamber→ decreases it's Pressure	**2nd Heart sound heard** (due to closure of semilunar valves) **DUB**

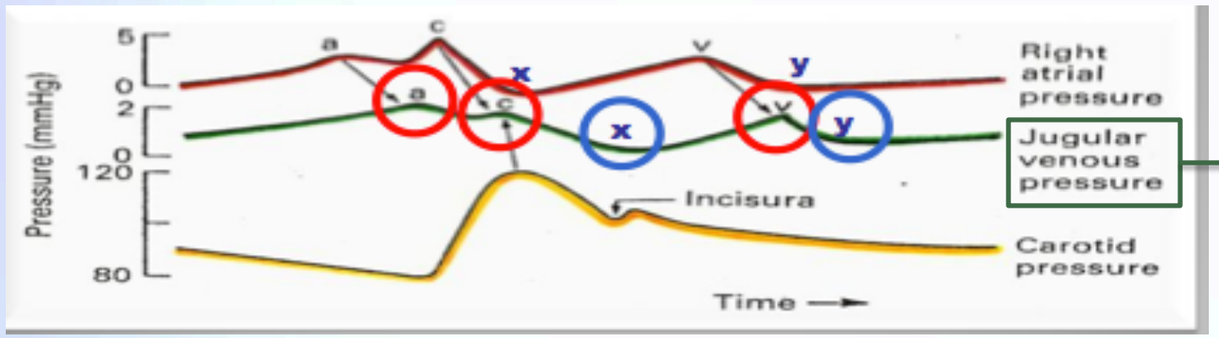
Phase	Interval	Preceded by:	Valves	Volume change	Pressure	Sound
6. Rapid Filling Phase:(passive) 	----	----	AV- vs open	≈ 60-70% of blood passes passively to the ventricles along pressure gradieAnt→ **L. ventricular volume↑ RAPIDLY**	Atrial pressure > ventricular pressure →produce 'V' wave	3rd Heart sound is produced NOTE; we can hear it clearly when exercising
7. Reduced Filling Phase (Diastasis): 	----	----	AV- vs open	**L. ventricular volume↑ SLOWLY**	LV pressure gradually ↑	No sound

SECOND ; VENTRICULAR VOLUME CHANGES

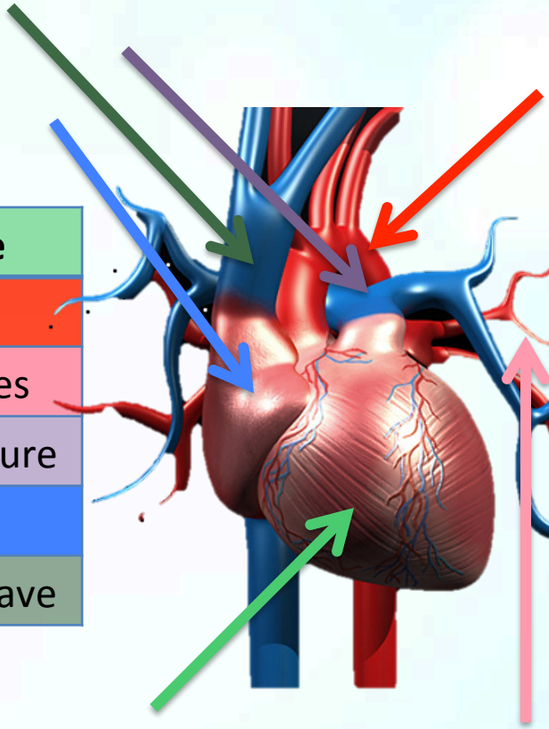
Changes in volume is mentioned in the tables of the mechanical events+ in the picture below: it's the black curve

THIRD ; PRESSURE CHANGES DURING THE CARDIAC CYCLE

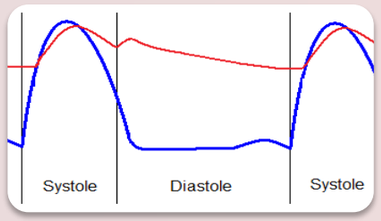


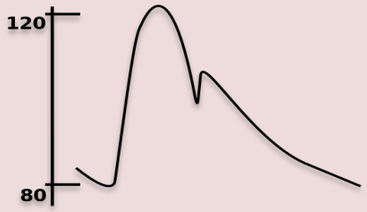


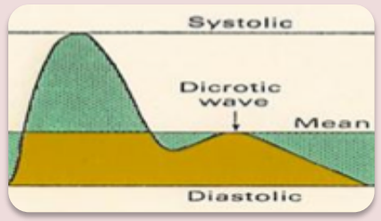
- **Ventricular pressure**
- Aortic pressure
- Arterial pressure waves
- Pulmonary artery pressure
- Atrial pressure
- Jugular venous pulse wave

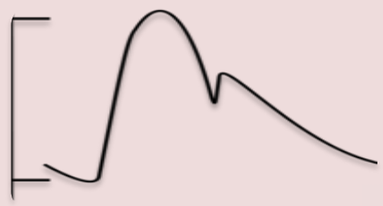


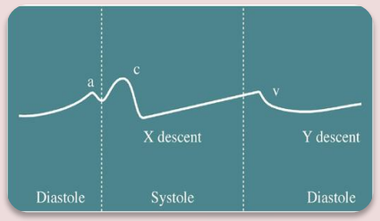
THIRD ; PRESSURE CHANGES DURING THE CARDIAC CYCLE

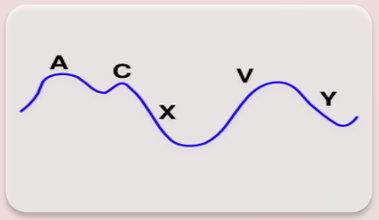












Ventricular Pressure Changes 120/3-12

Aortic pressure change 120/80

Arterial pressure changes 110-130/70-85

Pulmonary Artery Pressure Changes 25-30/4-12

Atrial pressure

Jugular venous pulse changes:

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

Similar to aortic pressure changes but with difference in magnitude

Similar recordings of transmitted delayed atrial waves:

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

Explained in the next page

Explained in the next pages

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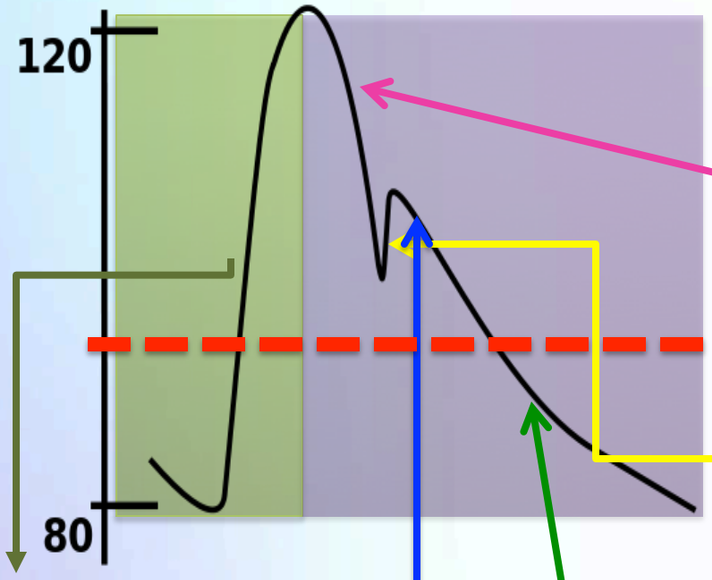
CON. THIRD ; PRESSURE CHANGES DURING THE CARDIAC CYCLE

AORTIC PRESSURE CHANGE
120/80



A. Ascending or anacrotic limb:

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

B. Descending or catacrotic limb: (4 STAGES)

1. ↓ Aortic press:
- With 'reduced ejection phase'
- Amount of blood enters aorta is LESS

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

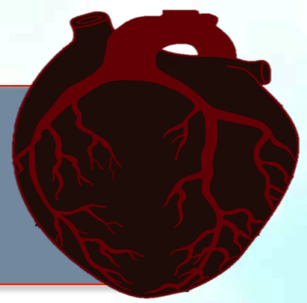
4. Slow ↓ aortic press:
Due to continued flow of blood from aorta → systemic circulation

significant
- Aortic Stenosis
- Shock or dehydration
- Aortic Regurgitation
- Hypertension
- Pregnancy

THIS LINE IS TO FIND THE MEAN PRESSURE OF AORTIC PRESSURE CHANGE

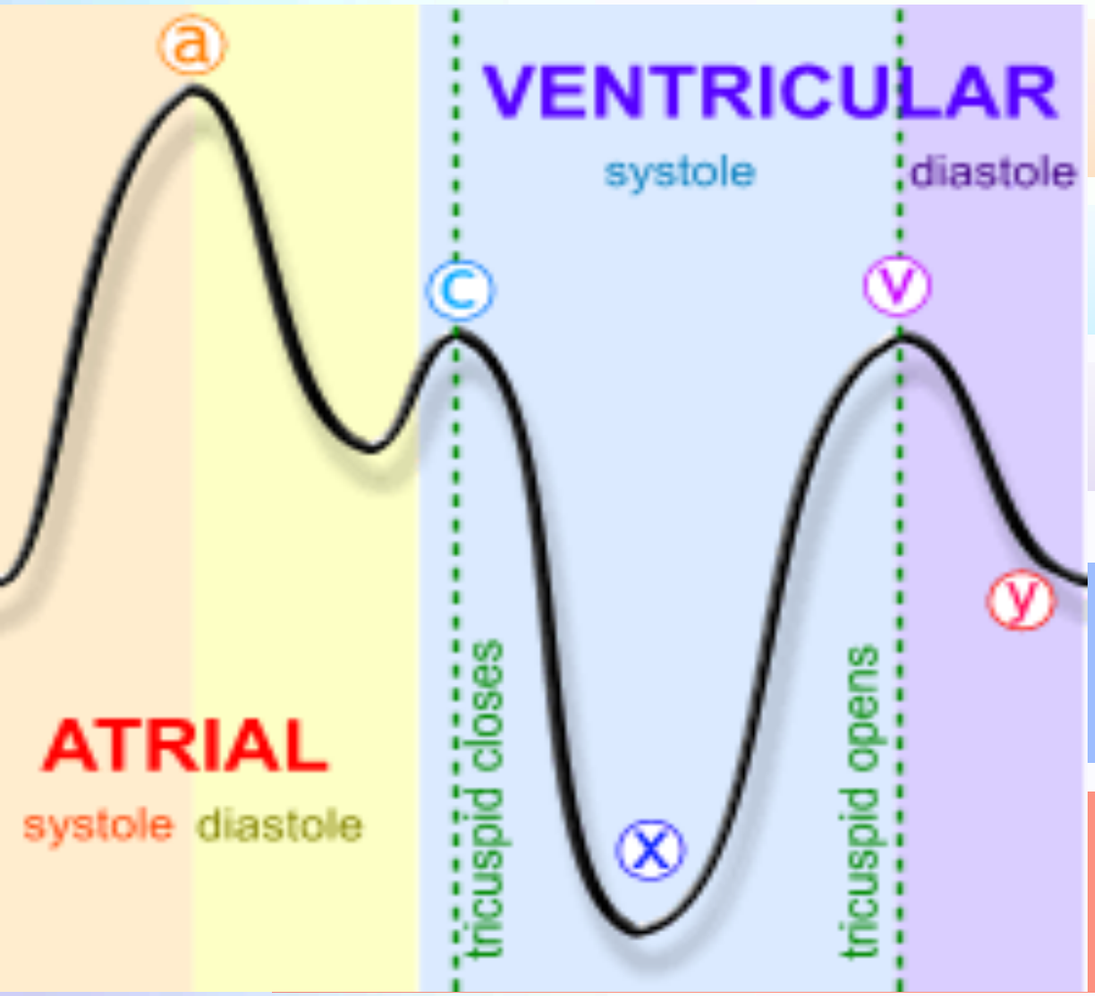
- **Mean Pressure =** diastolic P + 1/3 (systolic P - diastolic P)
- **Pulse pressure =** Systolic P – Diastolic P

CON. THIRD ; PRESSURE CHANGES DURING THE CARDIAC CYCLE



ATRIAL PRESSURE

~ **3 upward deflection** → a, c, & v
2 components in each wave: +ve (↑ press), -ve (↓ press)
~ **2 downward deflection** → x & y



'a' wave: Atraial systole:
↑ atrial pressure during atrial contraction

- +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

'c' wave: Ventricularsystole

- +ve→↑Atrialpressuredueto↑venousreturn(VR)during atrial diastole
- -ve → ↓ ↓ atrial pressure during 'rapid filling phase'

'x' descent:
Downward displacement of AV- vs during 'reduced ejection phase'

'y' descent:
↓ ↓ atrial pressure during 'reduced filling phase'

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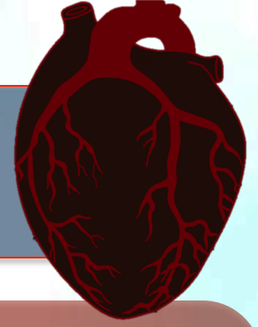
SUMMERY



Main function of the heart

Heart works as a pump

-It has 4 valves found at entry & exit of each ventricle

- Allow blood to flow in ONLY ONE direction

- Opening & closure of vs occur as a result of pressure gradient across the vs

Function of the atria, ventricles and valves

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 musculr projections called Papillary muscles

General principles in the cardiac cycle

- Contraction of the heart generates pressure changes, resulting in orderly blood movement

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

- Heart is a double pump (right & left sides) that work together

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

Different events that occur during the cardiac cycle

I: Mechanical events

II: Volume changes

III: Pressure changes

IV: Heart sounds

V: Electrical events (ECG)

For better understanding of the cardiac cycle, you can go through these videos, hopefully it will help you ☺

- **DR. Najeeb :** http://youtu.be/XbivIaFPoQI
- **Heart Physiology Ventricular filling :** http://youtu.be/h_eYvrfN_Ng

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MCQS

Q1. The _____ is a description of all the mechanical events that occur during one beat of the heart.

a. ventricular filing phase
b. cardiac cycle
c. mitral valve
d. aoritic pressure

Q2: The point in diastole where the mitral valve opens, _____ pressure is high because the ventricle has just finished ejecting blood into the aorta.

a. Atrium
b. Aorta
c. coronary sinus
d. pericardium

Q3: At the beginning of phase 1, the heart is _____

a. Contracting
b. silent
c. Staled
d. Relaxing

Q4: The closing of the bicuspid (mitral) valve will produce the S1 heart sound. This is the start of _____.

a. Diastole
b. neurotransmitters released
c. action potential
d. Systole

Q5: During phase 4 both _____and _____ are closed. So, the volume in _____ cannot change. This is the period of isovolumetric contraction.

a. mitral valve; aortic valve; ventricle
b. pulmonary valve; aortic valve; lungs
c. pulmonary valve; mitral valve; atrium
d. mitral valve; pulmonary valve; ventricle

Q6: The heart spends 2/3 of its time relaxing and 1/3 contracting.

a. True
b. False

Q7: Phase 3 is known as rapid ejections. When pressure in the ventricle exceeds the pressure in the aorta, the aortic valve opens; increasing aortic pressure.

a. True
b. False

Q8:During phase 5, _____ has occurred.

a. Depolarization
b. relative refraction
c. Repolarization
d. hyperpolarization

Answers : Q1: b – Q2:b – Q3:d -Q4:d -Q5a : - Q6: a-Q7:a -Q8: c

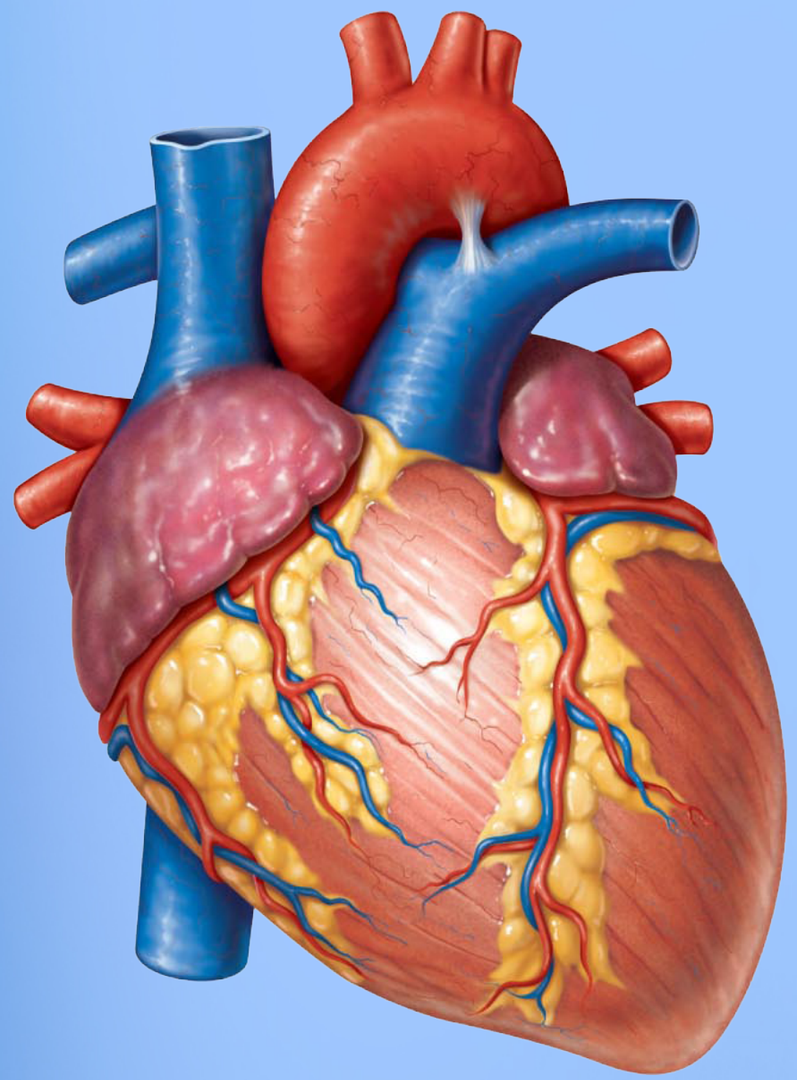
Quiz your self ☺: http://www.proprofs.com/quiz-school/story.php?title=cardiac-cycle-block-3

Done by : Sara Alkharashi

Revised by: Mojahed Otayef

5

CARDIAC CYCLE- 2



Cardiovascular Block

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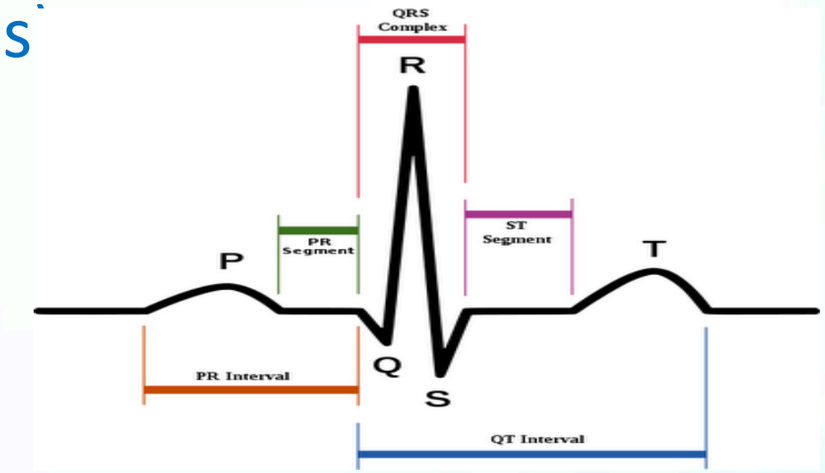
At end of this lecture you should be able to know:

- ✓ Electrical changes that occur during the
- ✓cardiac cycle
- ✓ The Pressure - Volume Curve
- ✓ The Volume - Pressure Loop

Electrical Changes (ECG) During the Cardiac Cycle

Record of the electrical activity (action potentials) generated by the heart, per unit time



ECG waveforms:

- (3) waves:
  - QRS complex
  - P waves
  - T waves
- (2) intervals between waves
  - PR & QT
  - PR & QT
- (1) segment
  - ST segment

- ❖ 3 positive waves … (P, R & T)
- ❖ 2 negative waves … (Q & S)

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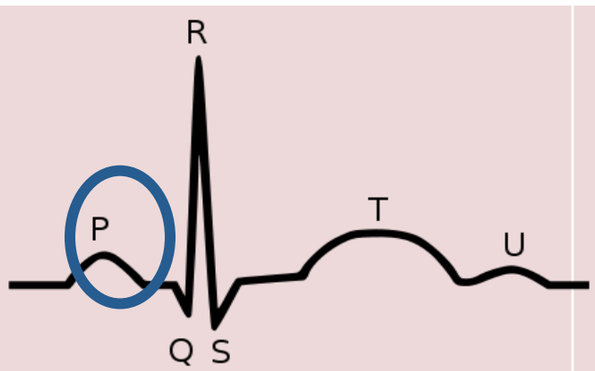
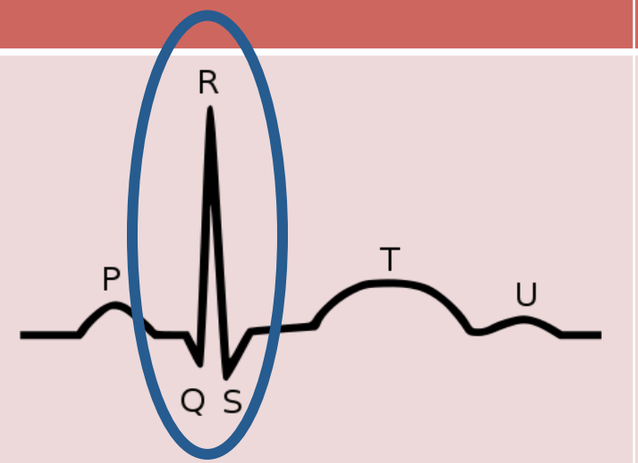
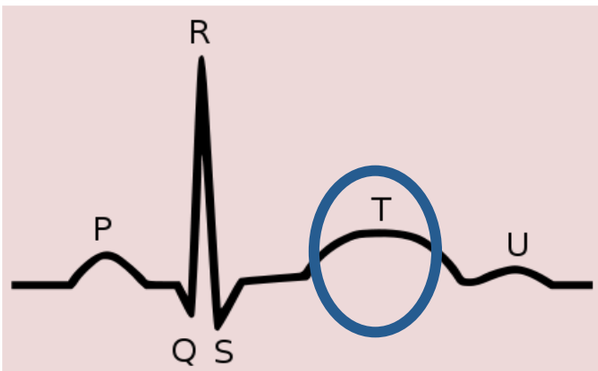
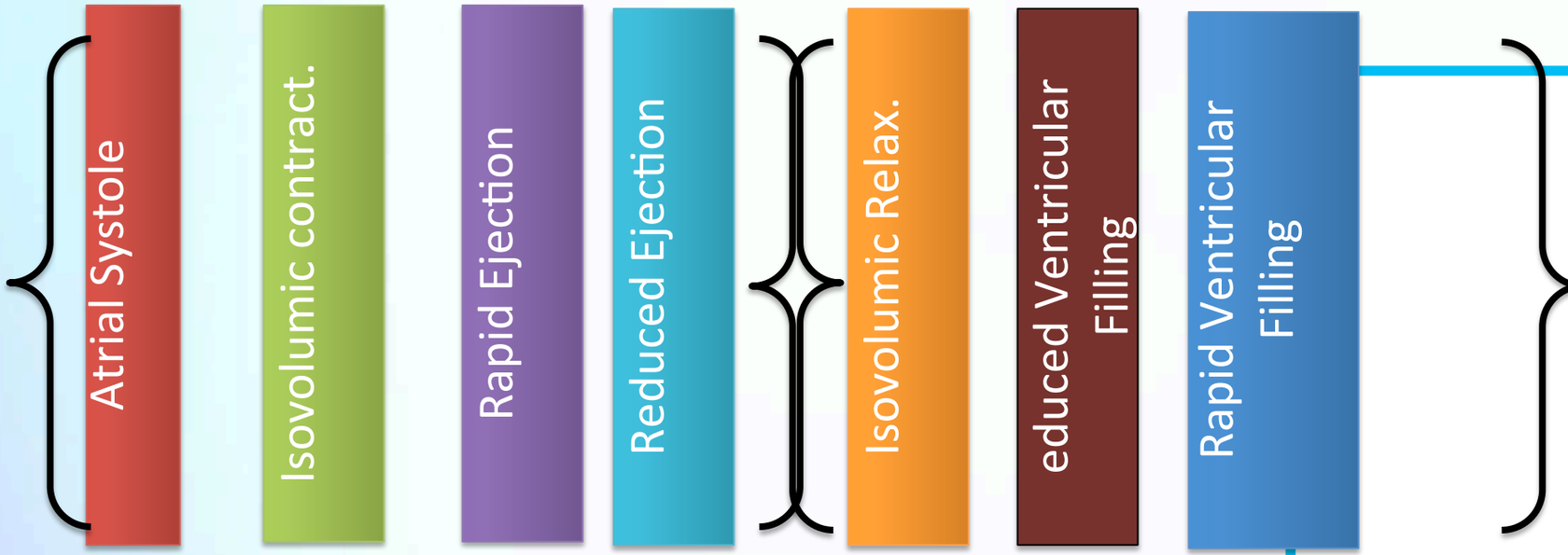
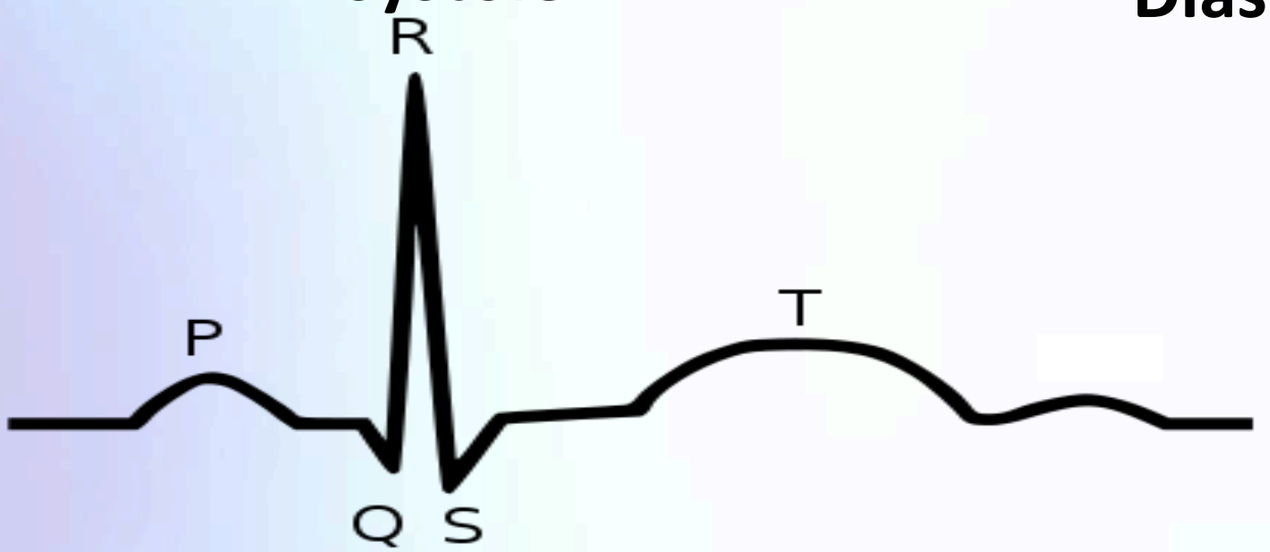
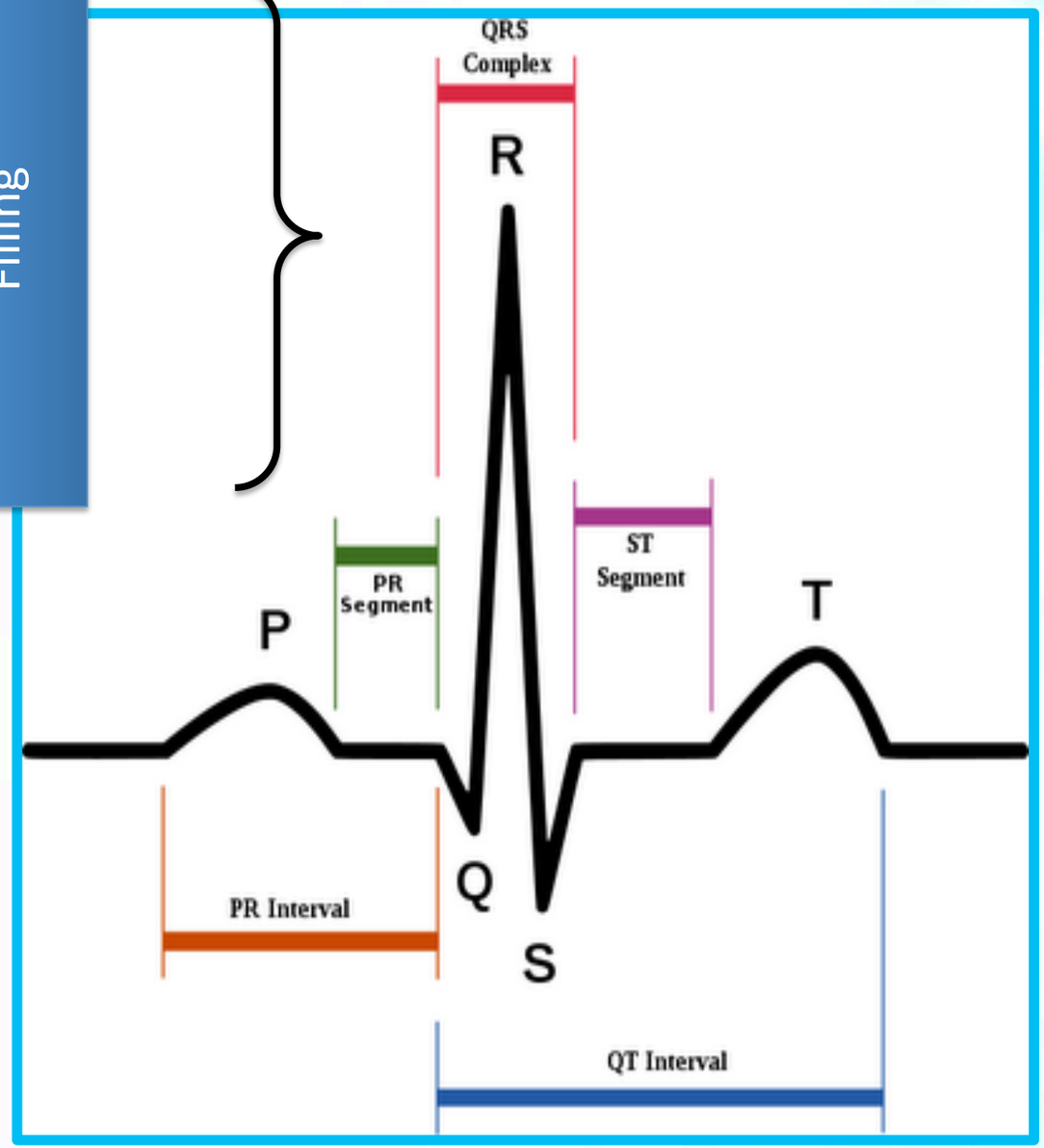
ECG waveforms:

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

ECG waveforms:







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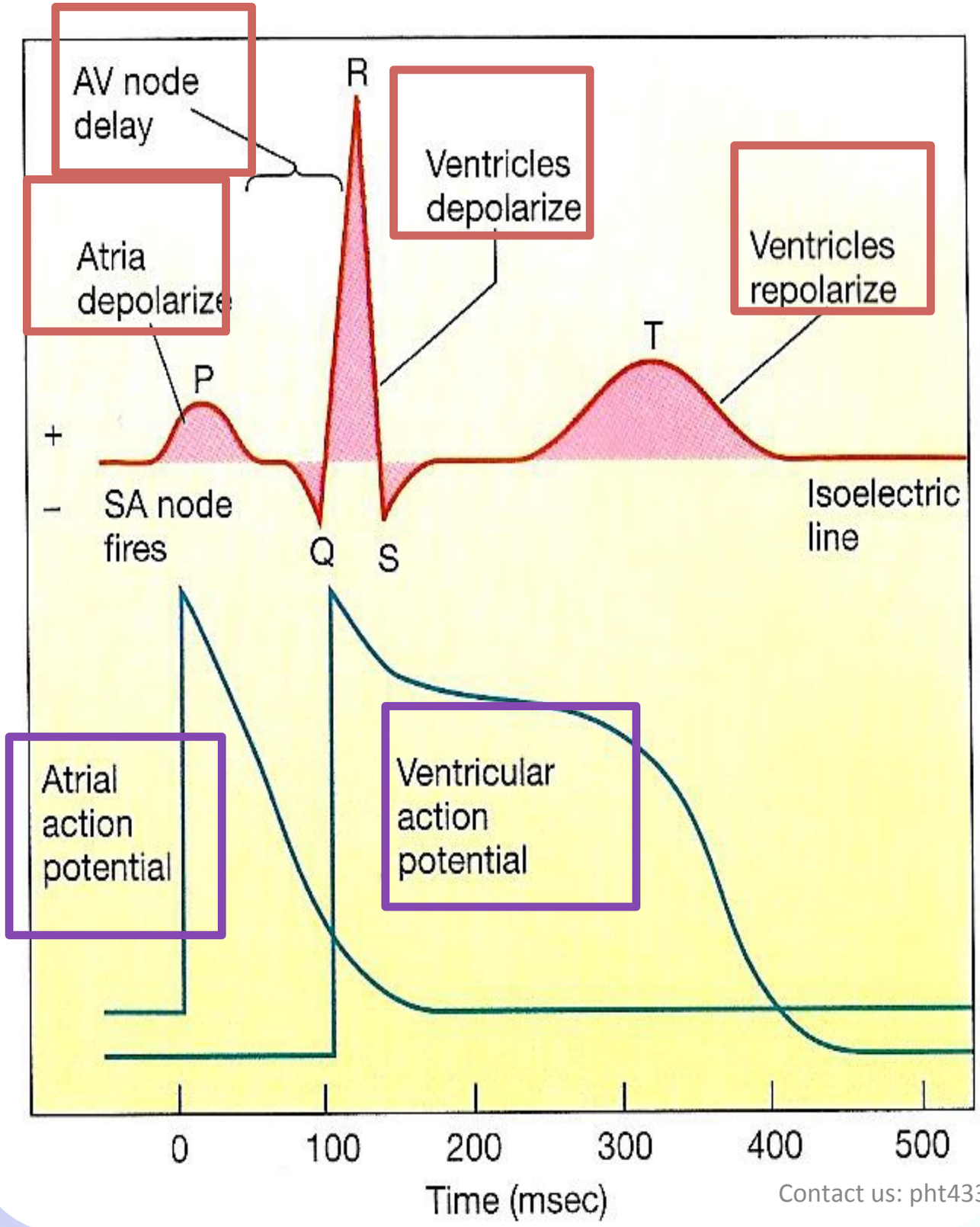
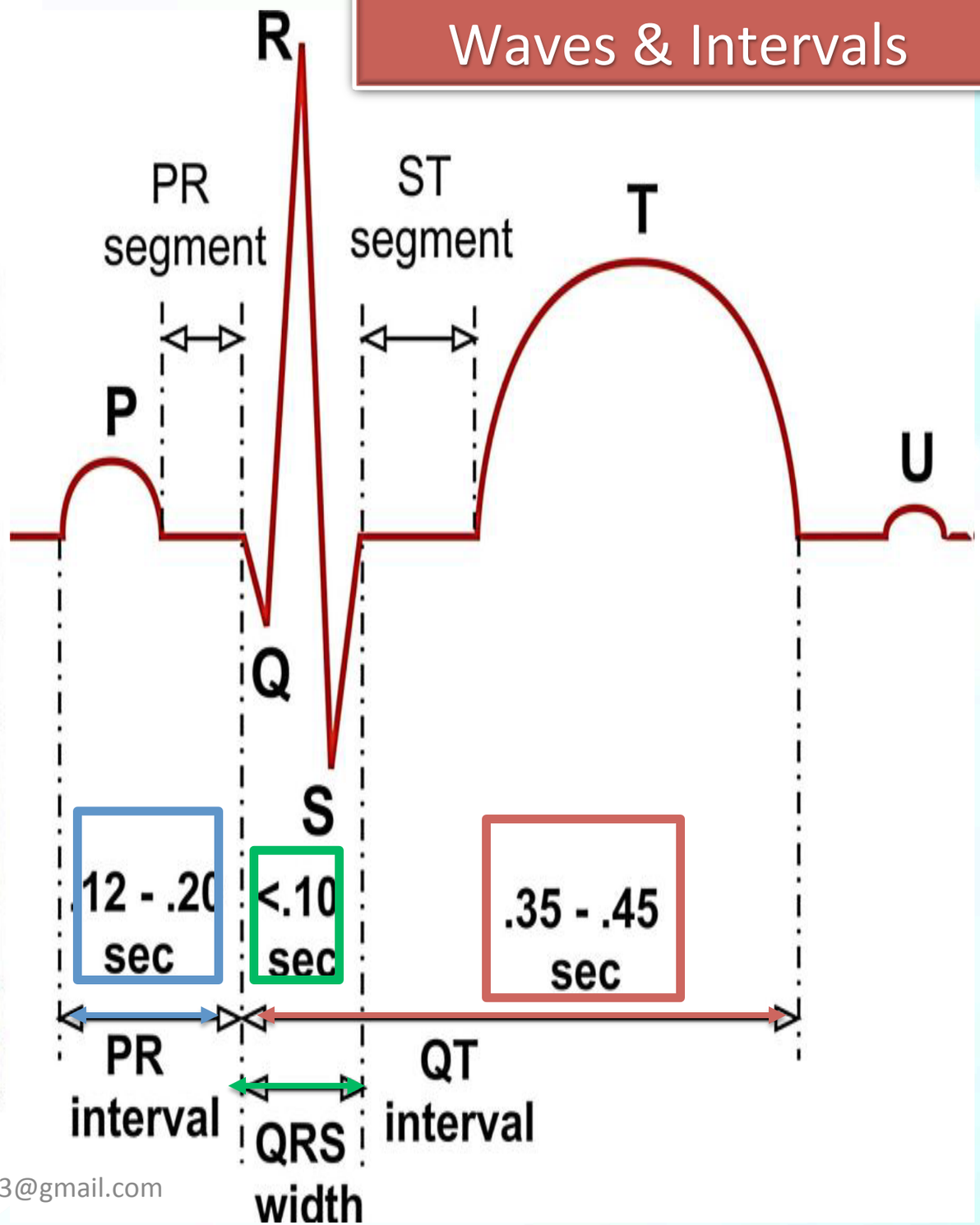


Normal duration of ECG Waves & Intervals



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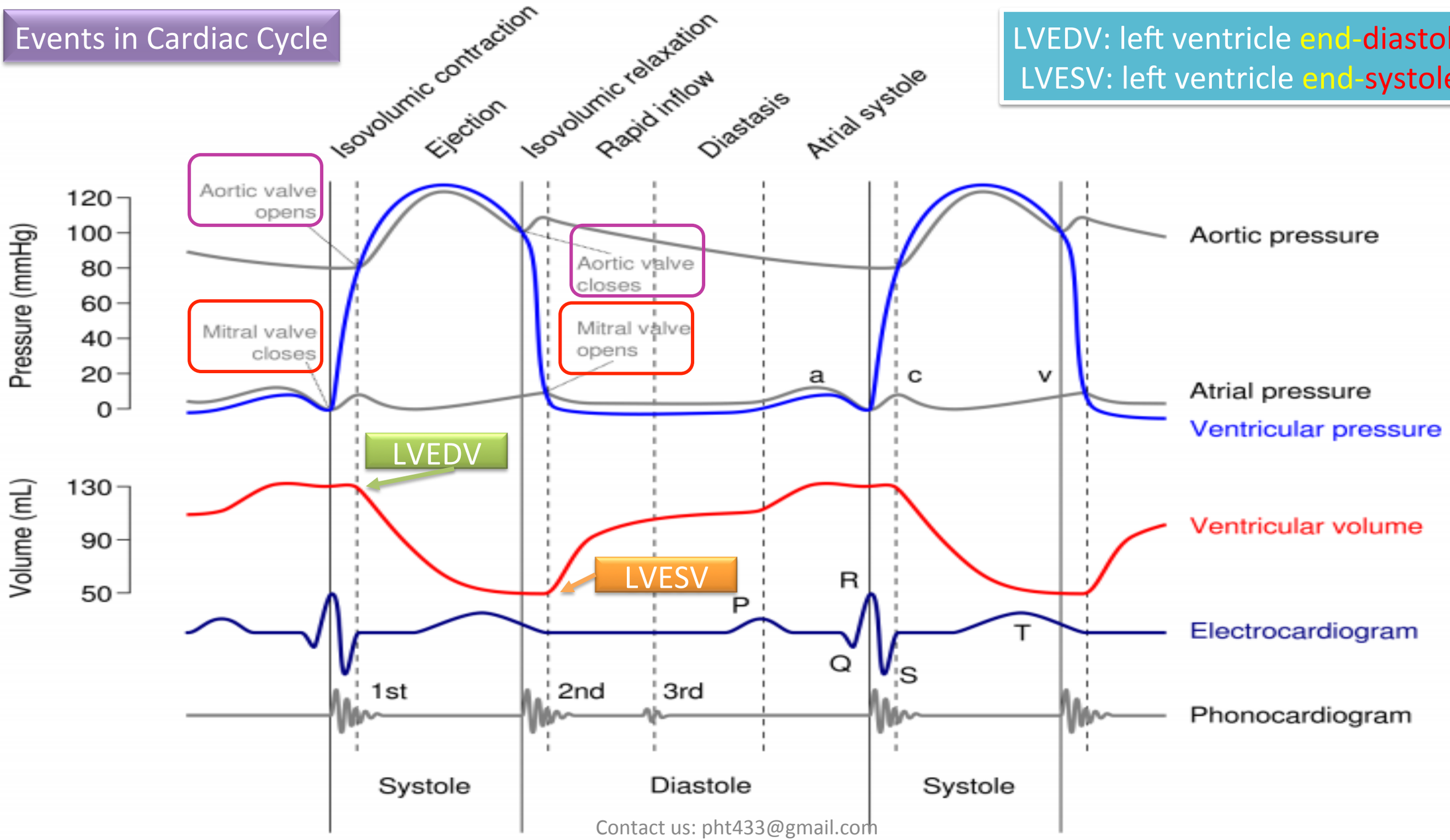
Pressure – Volume Curve "The Complete Picture"

Events in Cardiac Cycle

LVEDV: left ventricle end-diastole
LVESV: left ventricle end-systole



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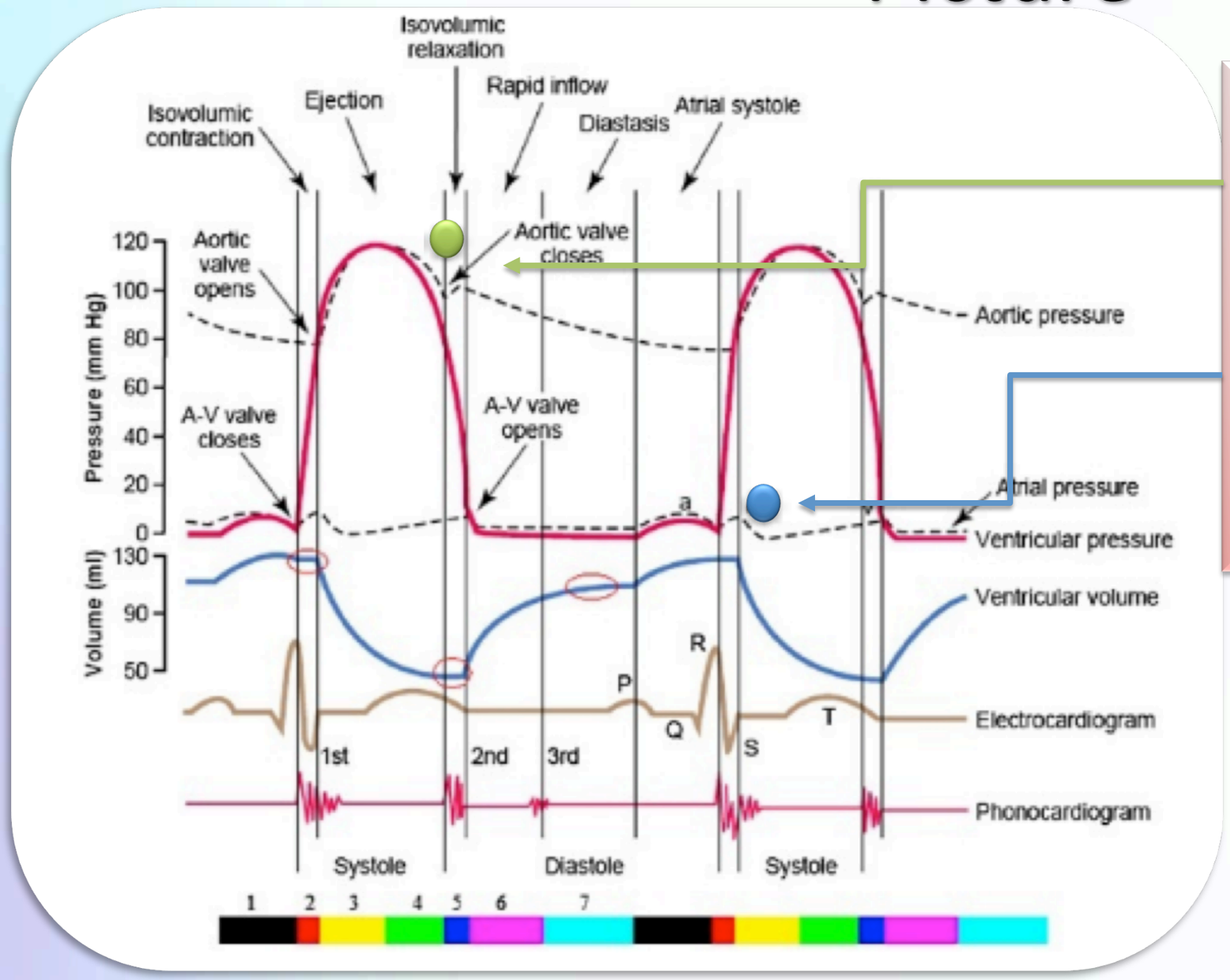
Pressure – Volume Curve "The Complete Picture"



1-when aortic valve close, the blood come back to the aortic artery and that cause increase slightly in the P.

2-when the ventricle contract the AV valve raise up and that lead to increase the atrial pressure

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Pressure - Volume Loop

- Left Ventricular Pressure – Volume Loop

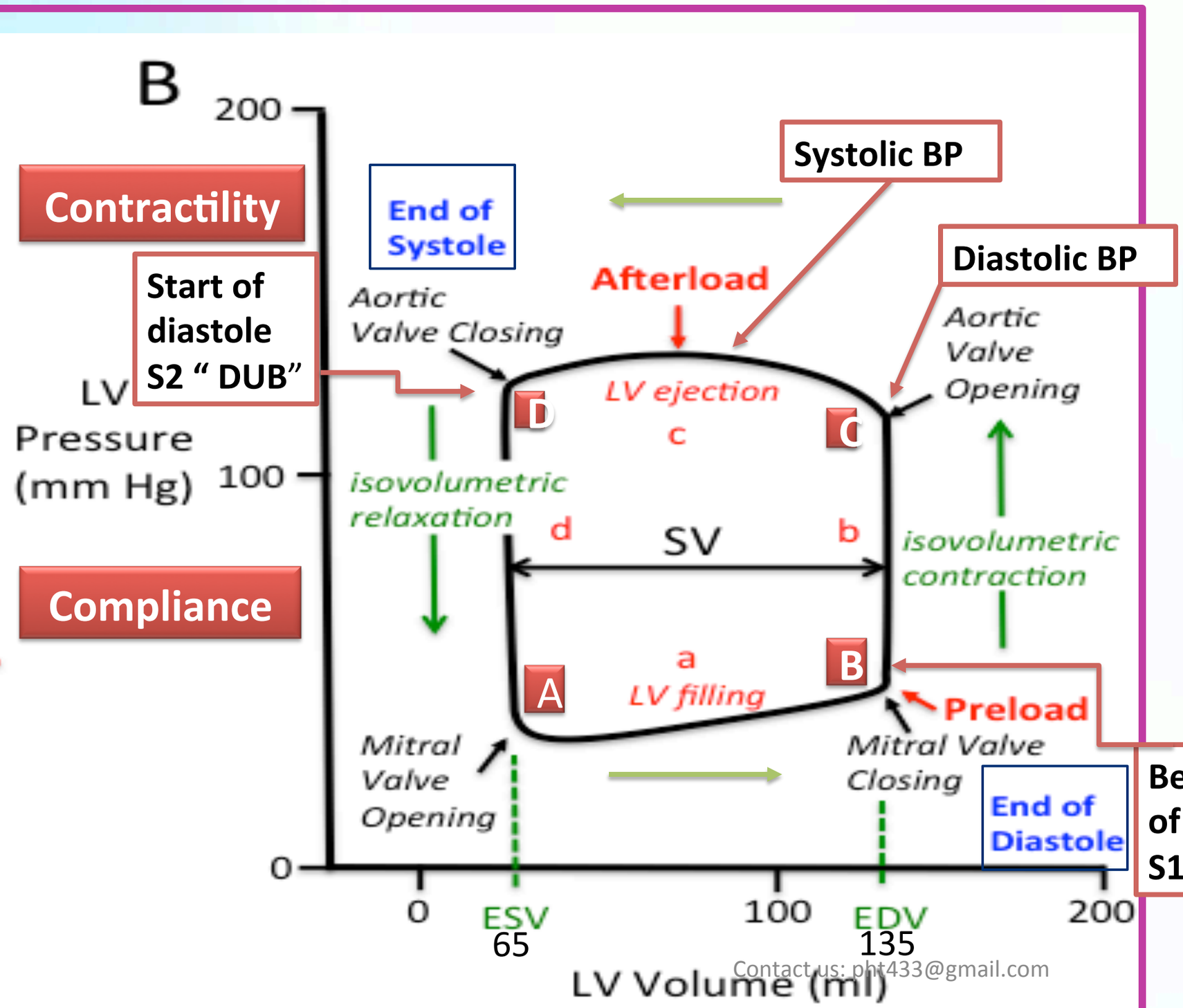
Correlation of intra-ventricular changes in volume & pressure that occur during one cardiac cycle.

Basic Myocardial Muscle Mechanics:

➢ Both ventricular systole & diastole can be divided into early & late phases

	Systole:	Diastole:
Early	Isovolumetric Contraction	'Isovolumetric Relaxation'
Late	Isotonic Contraction' = 'Ejection Phase	'Isotonic Relaxation' = 'Filling Phase

Ventricular Pressure - Volume Loop



SV = EDV - ESV

SV = Stroke volume

LVEDV: left ventricle end-diastole
LVESV: left ventricle end-systole
LV: left ventricle

A→B: passive filling and atrial contraction
B →C: Isovolumetric Contraction
C →D: ejection of blood into aorta
D →A: Isovolumetric relaxation

1 loop = 1 heartbeat

Beginning of Systole S1 " LUB"

NOTES*

SV= EDV- ESV

SV=is the volume of blood pumped from one ventricle of the heart with each beat.

we can measure PP(PULS PRESSRE) from BLOOD PRESSURE

* for example: BLOOD PRESSURE = 120\80 mmgh so PULS PRESSRE = 120-80 >> just for your inform.

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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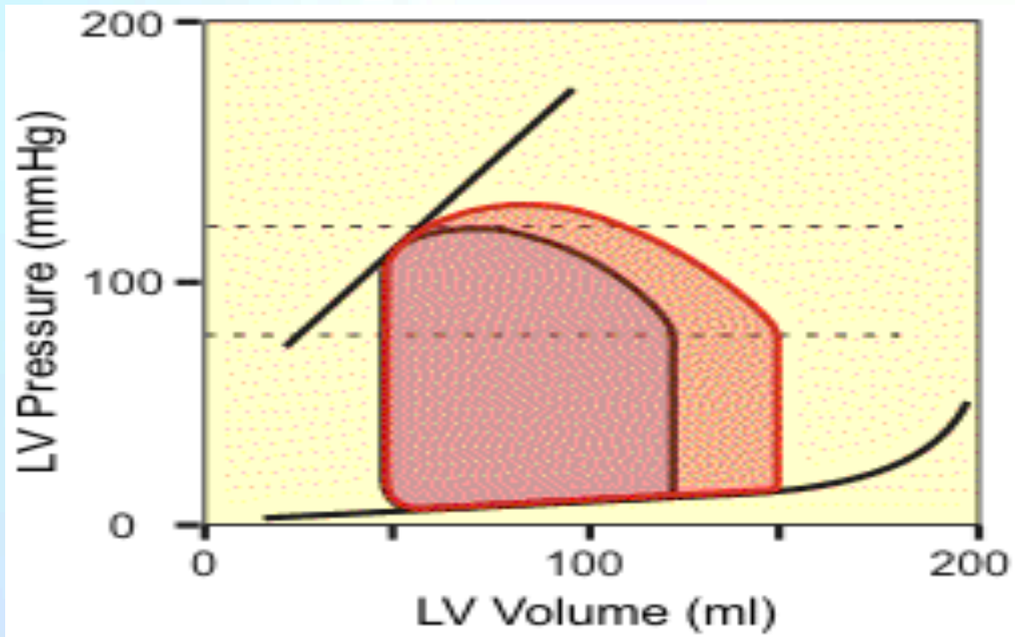
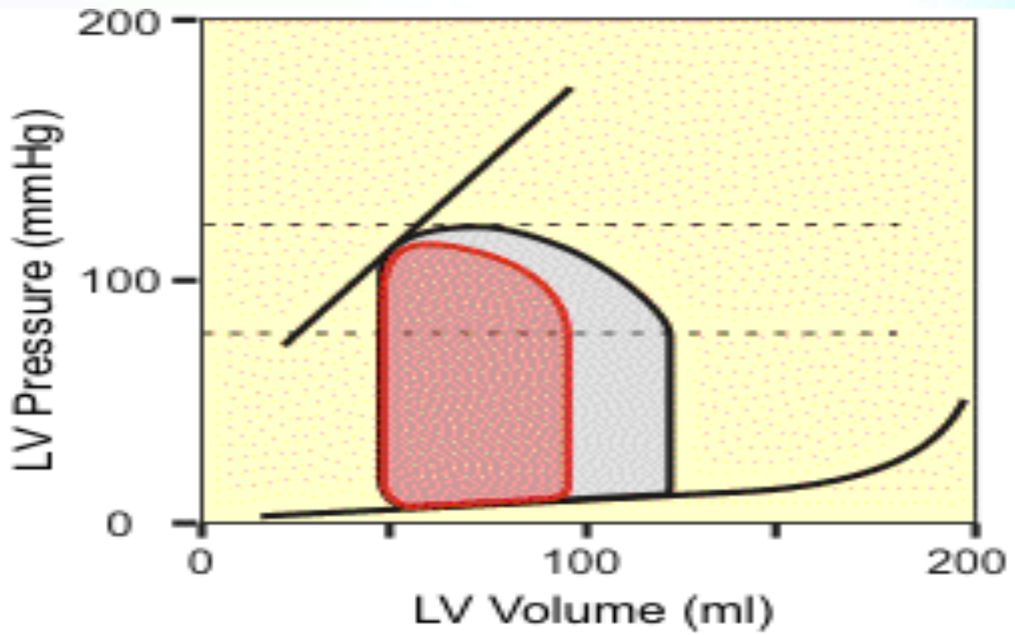
Pressure - Volume Loop

✓During Ventricular Systole: Muscle contracts & generates pressure which causes changes in volume	✓During Ventricular Diastole: Muscle is relaxing & venous blood returns to the heart resulting in changes in absolute volume & pressure
Measured by ‘Contractility’	✓Measured by ‘Compliance’: $C = \Delta V / \Delta P$
✓**Affected by**: Function of the muscle Initial volume (Preload) Initial pressure (Afterload)	✓**Affected by:** Connective tissue Venous pressure Venous resistance

Increasing Ventricular Preload Increases SV



Increased preload (increased EDV; red loop) at constant aortic diastolic pressure and inotropy. SV increases and ESV remains unchanged; EF increases slightly. Dashed lines represent normal aortic systolic and diastolic pressures.



Decreased preload (decreased EDV; red loop) at constant aortic diastolic pressure and inotropy. SV decreases and ESV remains unchanged; EF decreases slightly. Dashed lines represent normal aortic systolic and diastolic pressures.

Preload: nether pressure or volume LV wall stress at end diastole contraction begin

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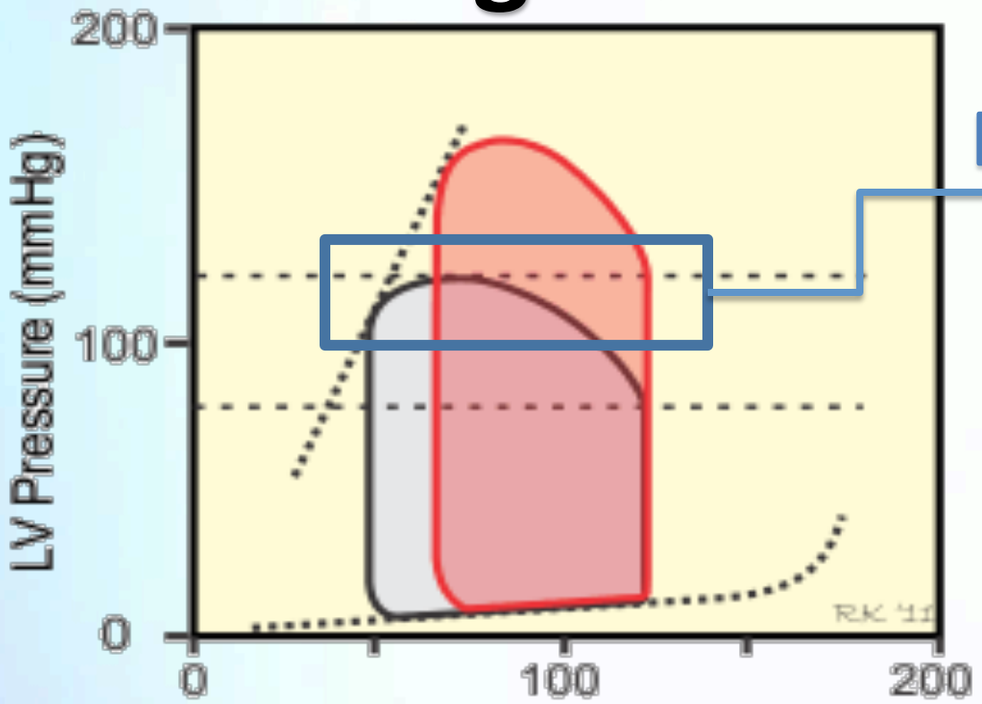
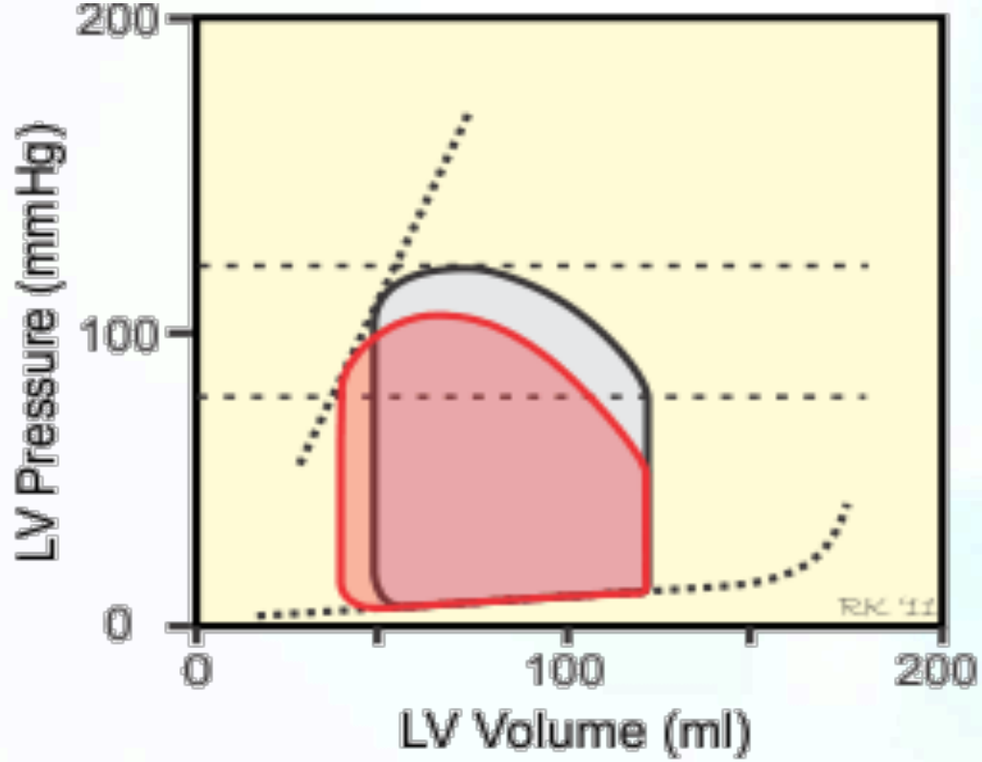
Increasing Ventricular Afterload Decreases SV



Increased afterload (increased aortic pressure; red loop) at constant preload (EDV) & inotropy. SV decreases and ESV increases; EF decreases. Horizontal dashed lines represent normal aortic systolic and diastolic pressures.



Decreased afterload (decreased aortic pressure; red loop) at constant preload (EDV) & inotropy. SV increases and ESV decreases; EF increases. Horizontal dashed lines represent normal aortic systolic and diastolic pressures.

Aftereload: nether pressure or volume LV wall stress during ejection

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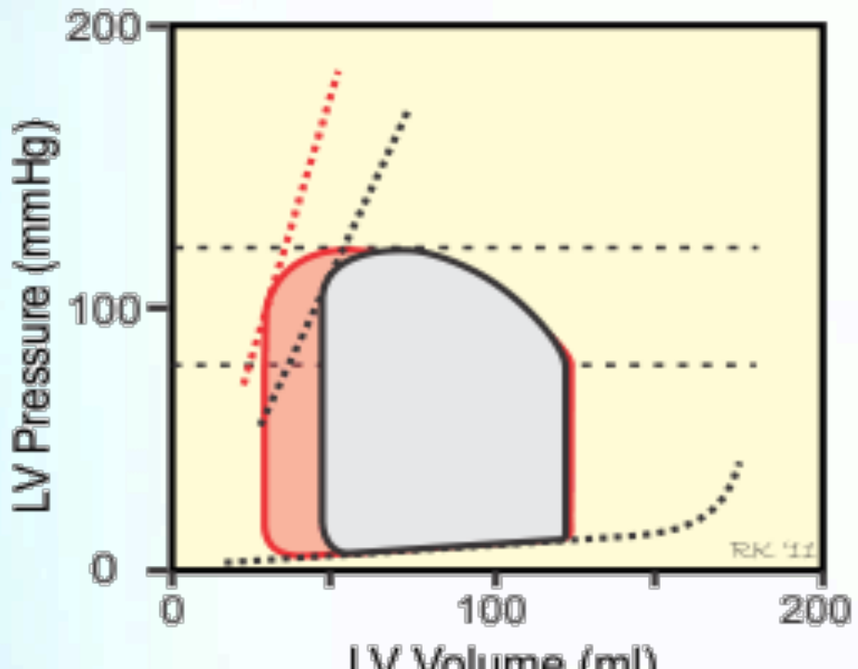
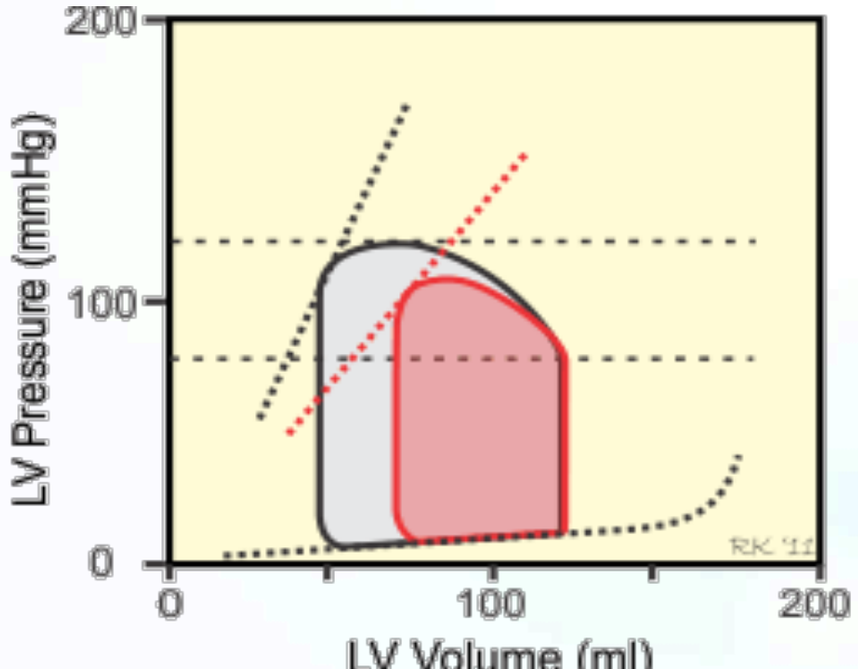
Increasing Ventricular Contractility Increases SV



Increased inotropy (red loop) at constant preload (EDV) & aortic systolic and diastolic pressures. SV increases and ESV decreases; EF increases. Horizontal dashed lines represent normal aortic systolic and diastolic pressures.



Decreased inotropy (red loop) at constant preload (EDV) & aortic systolic and diastolic pressure. SV decreases and ESV increases; EF decreases. Horizontal dashed lines represent normal aortic systolic and diastolic pressures.

Myocardial contractility represents the intrinsic ability of the heart/myocardium to contract and pump ..(Back to L 1 for more definition)

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SUMMARY

Electrical Changes (ECG) During the Cardiac Cycle

Record of the electrical activity (action potentials) generated by the heart, per unit time

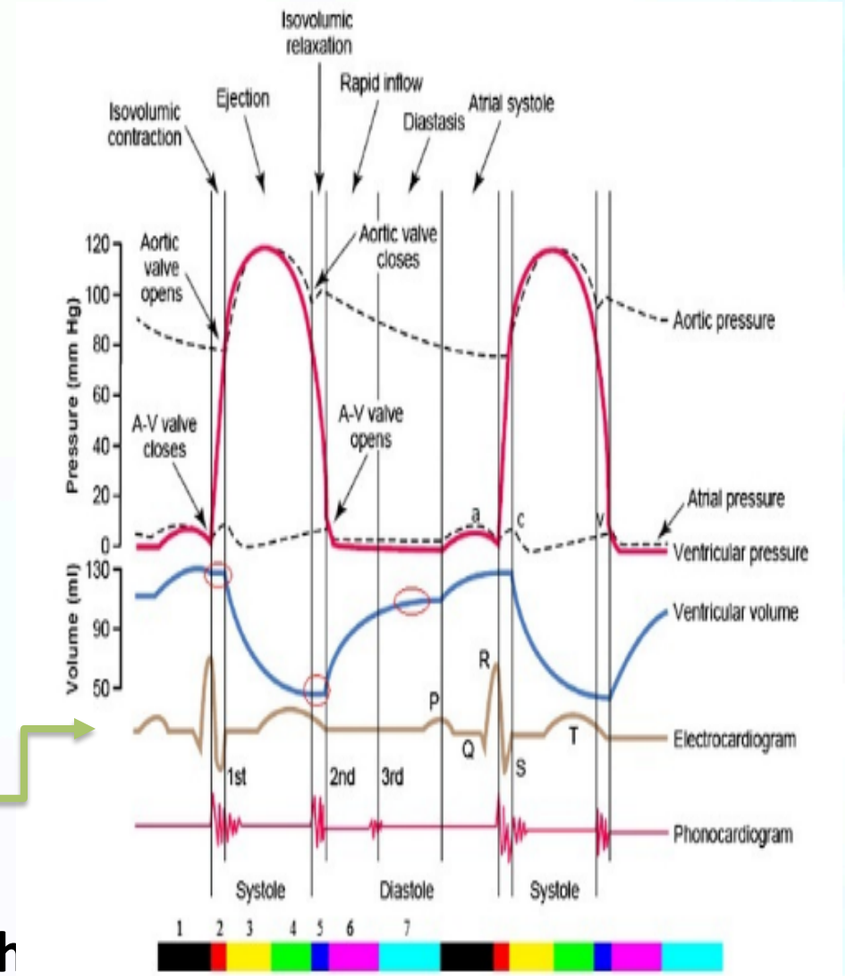
One heartbeat is normally recorded as:

- ✓ (3) **waves**: **P- wave,** Due to atrial depolarization

QRS- complex Due to ventricular depolarization

& T- wave Due to ventricular repolarization

- ✓ (2) **intervals between waves**: **PR & QT intervals**
- ✓ (1) **segment**: ST segment



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Muscle contracts & generates pressure which causes changes in volume

During Ventricular Diastole:

Muscle is relaxing & venous blood returns to the heart resulting in changes in absolute volume & pressure

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QUSTIONS

1-QRS-waves accurse during

A-atrial depolarization

B-ventricle depolarization

C-atrial repolarization

2-Early systole happen during

A-Isovolumetric Contraction

B - Isovolumetric relax

C-ejection phase

3-Which one of the following happen during ventricle systole

A- Isovolumetric relax

B-rapid filling phase

C-rapid ejection and

4- mitral valve open after

A- Isovolumetric contraction

B- Isovolumetric relax

C- filling phase

5- **Increasing Ventricular Afterload lead to**

A- decrease SV

B-increase aortic pressure

C- decrease ESV

6-End of diastole begin when

A-aortic valve close

B- mitral valve close

C- mitral valve open

7-Passive filling happen during

A- aortic valve open

B- mitral valve close

C- mitral valve open

8-During Ventricular Systole:

Measured by :

A- Contractility

B- Compliance

1(B),2(A),3(C),4(B),5(A),6(B),7(C),8(A)

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Revised by: Mojahed Otayef