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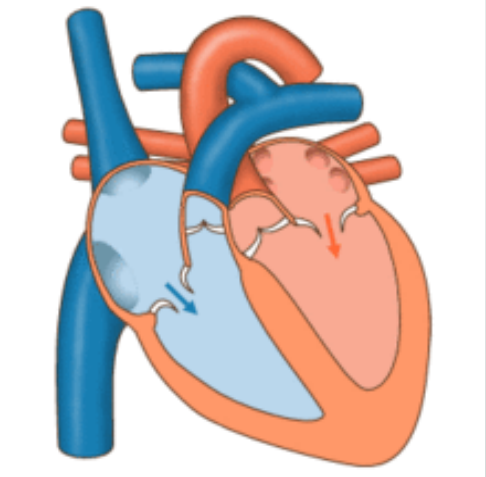
Cardiovascular Physiology

Cardiac Cycle- 2



Dr. Abeer A. Al-Masri, PhD

A. Professor,

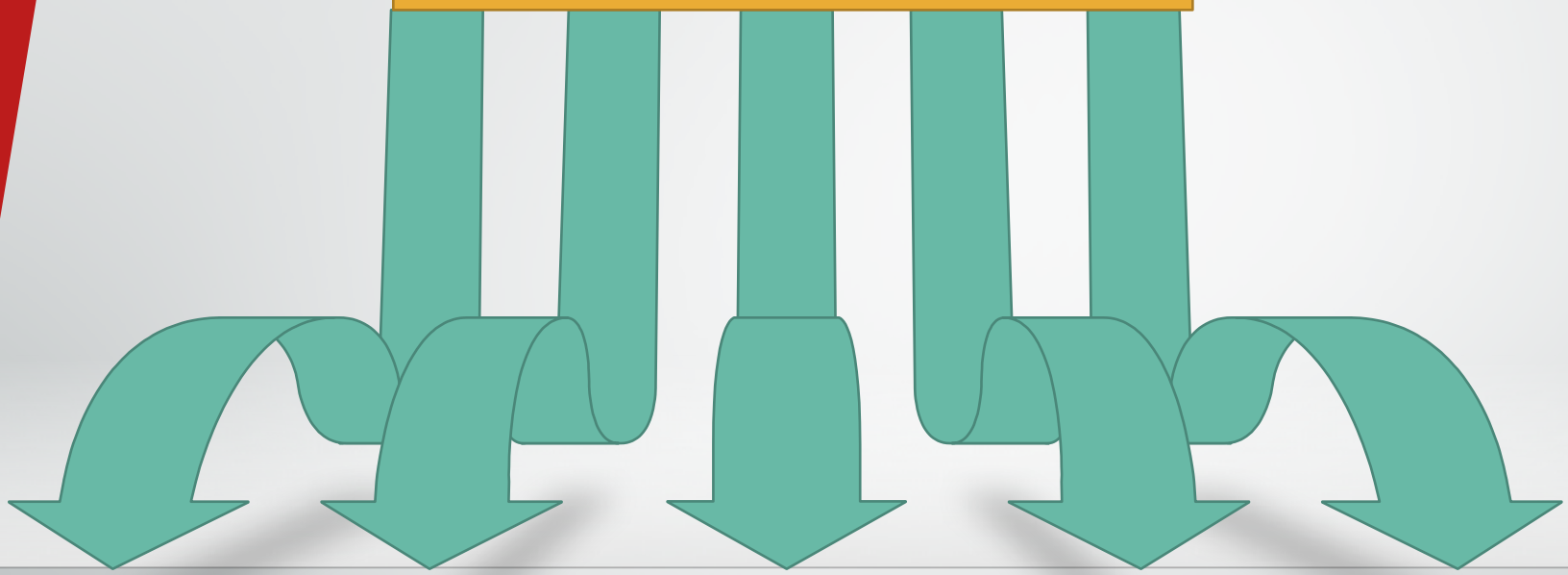
Consultant Cardiovascular Physiologist,

Faculty of Medicine, KSU.

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

- Electrical changes that occur in the cardiac cycle.
- Volume-Pressure relationship in the left ventricle.
- P-V Curve & P-V Loop.
- The systolic & diastolic periods.

Events in the Cardiac Cycle



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

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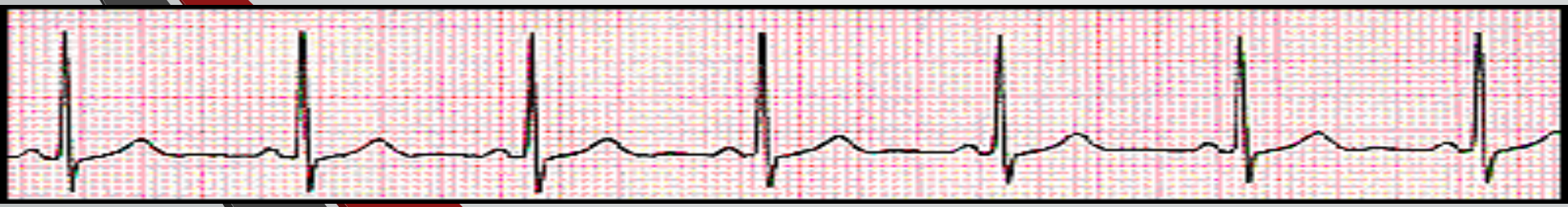
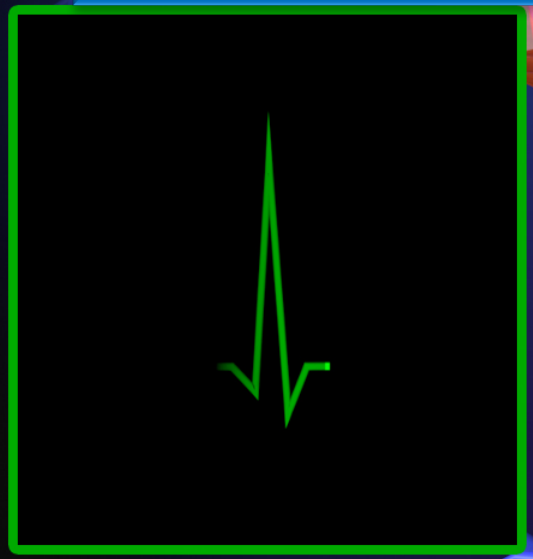
Electrical Changes (ECG) During the Cardiac Cycle

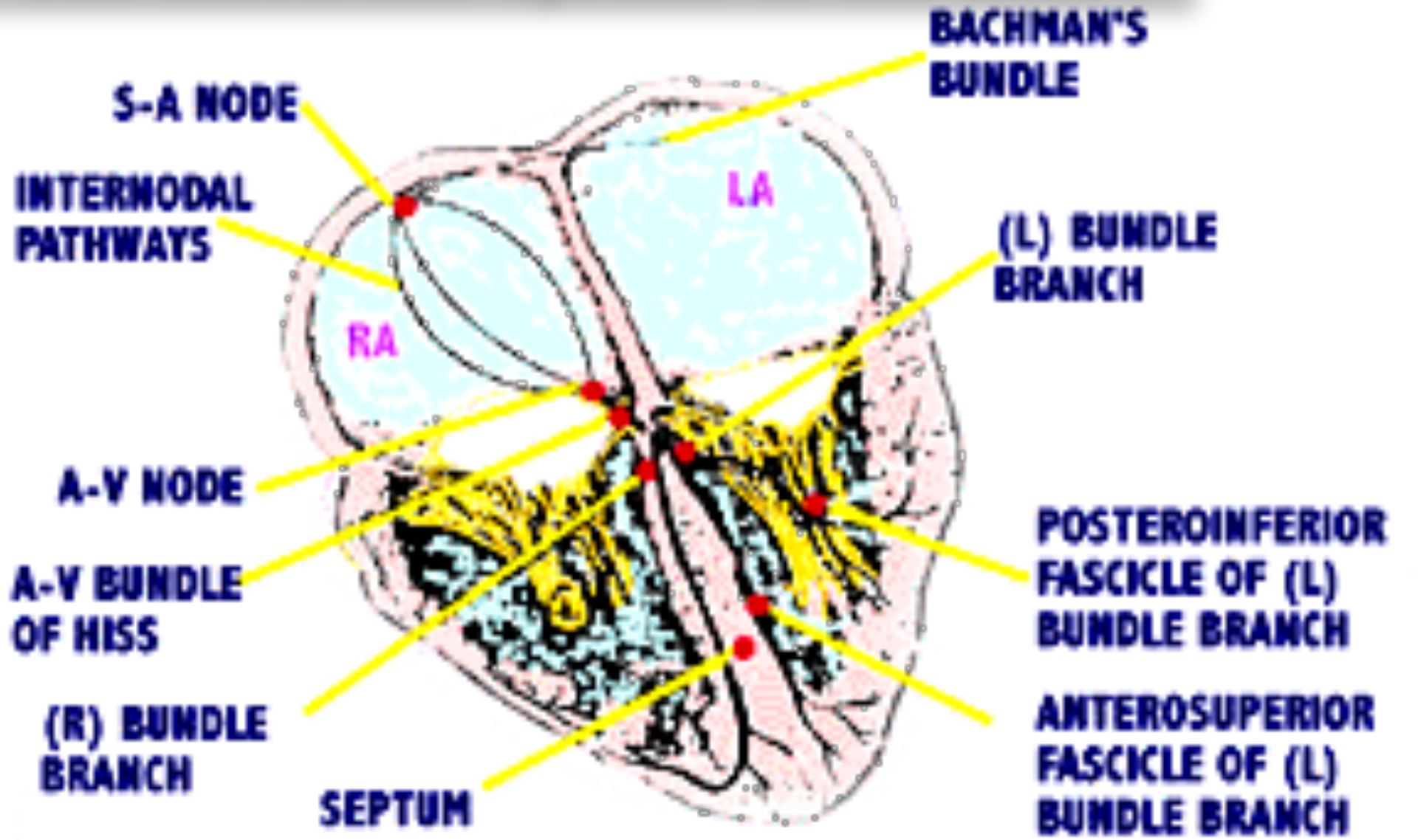


ECG?

A diagnostic tool that records of the electrical activity (action potentials) generated by the heart from chest surface, per unit time



The Electrical System of the Heart



Electrical activity of heart

- **To produce normal sinus rhythm, (3) criteria must be met:**
  1. Action potential must originate in SA- node.
  2. SA nodal impulse must occur regularly at a rate of 60 – 100 impulses per minute.
  3. Activation of myocardium must occur in correct sequence & correct timing & delays.

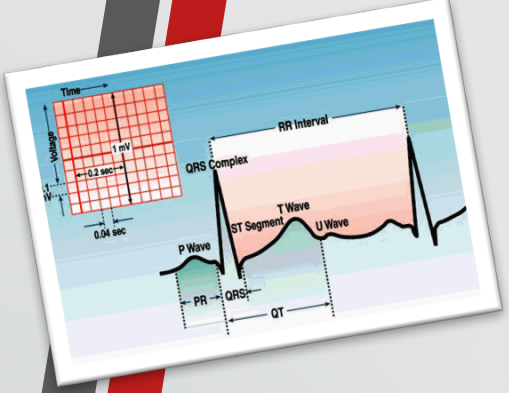
- SA node rate: 60-100 b/min.
- Under vagal influence 70-80 b/min.

Electrical activity of heart...

- Action potential (AP) originates in SA- node at time zero.
- It then takes a total of (0.1 sec.) to spread through the atria.
- Atrial depolarization is followed by atrial contraction for (0.1 sec.)
- The impulse then reaches AV- node, His Bundle & the Purkinje system to the farthest point in ventricles in (0.08 - 0.1 sec.)
- Ventricles contract for a total time period of (0.3 sec.)
- Total time period for one cardiac cycle = 0.8 - 0.83 sec. when heart rate = 72 bpm.

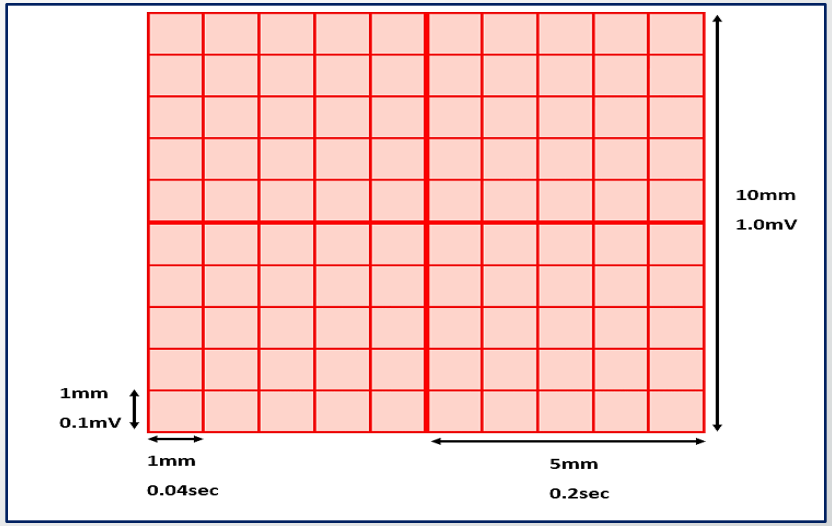
Ectopic & Latent Pacemakers

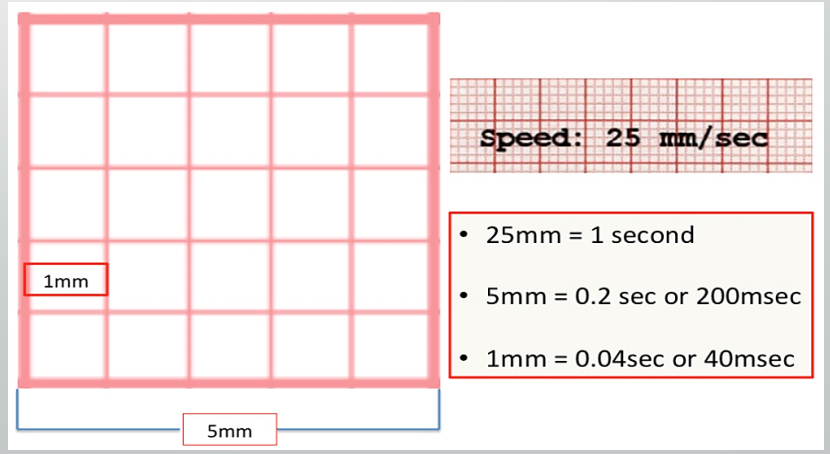
- In addition to the SA- node, AV- node, His bundle & Purkinje fibers have intrinsic automaticity & ability to set a pace. They are called **latent Pacemakers.**
- **Latent Pacemakers** are normally suppressed & function only if the SA- node is damaged, or its impulse is blocked, or if the rate of firing of the latent pacemakers increases.
- AV- node discharges at 40 –60 b/min.
- If both damaged then bundle of His or Purkinje fibers fires at 20- 40 beats/min.
- Sometimes atrial or ventricular fiber is excessively excitable & become pacemaker.
- A pacemaker elsewhere than the SA- node is called **Ectopic Pacemaker.**



ECG Paper Calibration: Time and Voltage

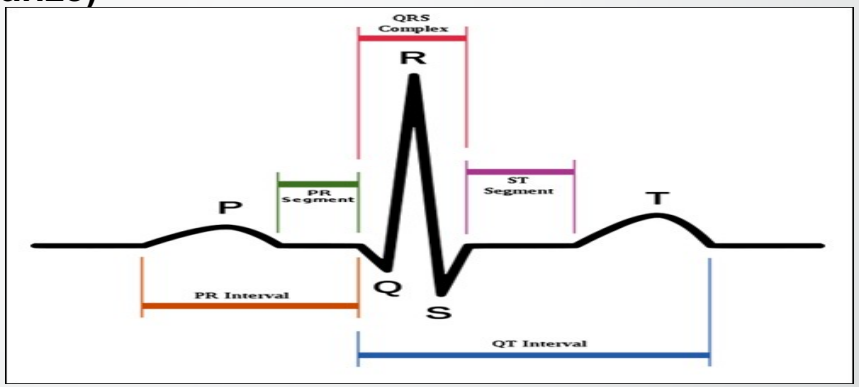
- ECG is displayed on a graph paper as waves.
- Speed: ECG machine runs at 25mm/sec.
  - X-axis is the time.
  - 1mm square corresponds to 0.04 sec.
- Voltage is measured on vertical Y-axis.
  - 0.1mV/mm (1mV=10mm.)



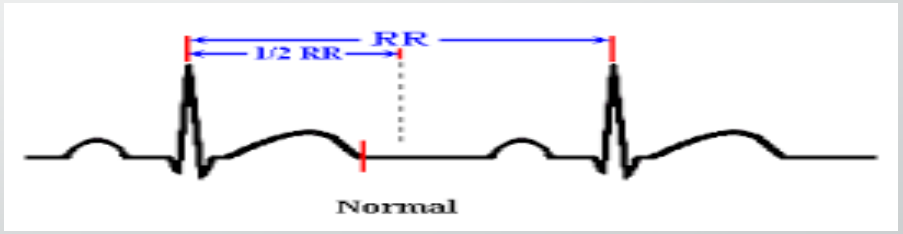


ECG waveforms, Intervals & Segments

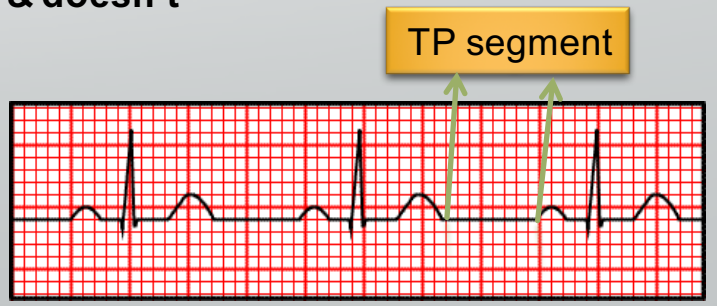
- **One heartbeat is normally recorded as:**
  - **3 waves:** (depolarize & repolarize)
    - P- wave
    - QRS complex
    - T- wave
    - 3 positive waves (P, R & T- waves)
    - 2 negative waves (Q & S- waves)



  - **3 time intervals:** (include waves)
    - P-R interval
    - Q-T interval
    - R-R interval

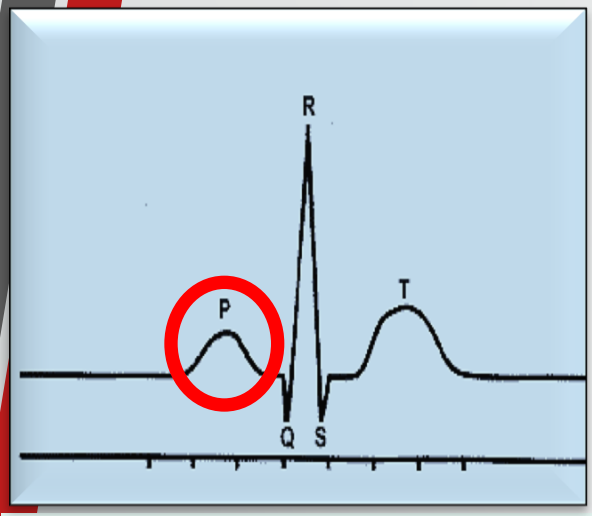


  - **3 segments:** (isoelectric, & doesn't include waves)
    - PR segment
    - ST segment
    - TP segment



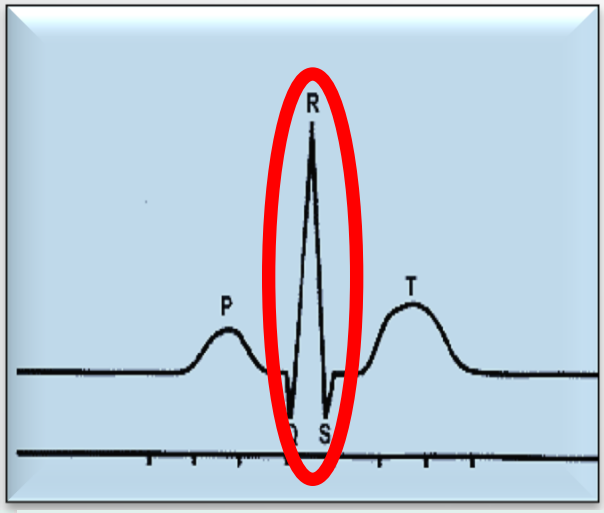
Causes of ECG Waves

P- Wave



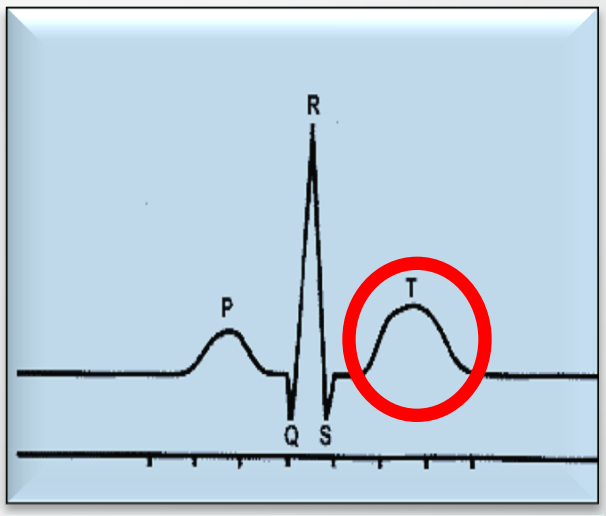
- Due to atrial depolarization.
- P- wave is recorded before the onset of atrial systole.

QRS Complex



- Due to ventricular depolarization
- QRS complex is recorded before the onset of ventricular systole (isometric contraction phase.)

T- Wave



- Due to ventricular repolarization
- T- wave is recorded before the onset of ventricular diastole (isometric relaxation phase.)

Causes of ECG waves

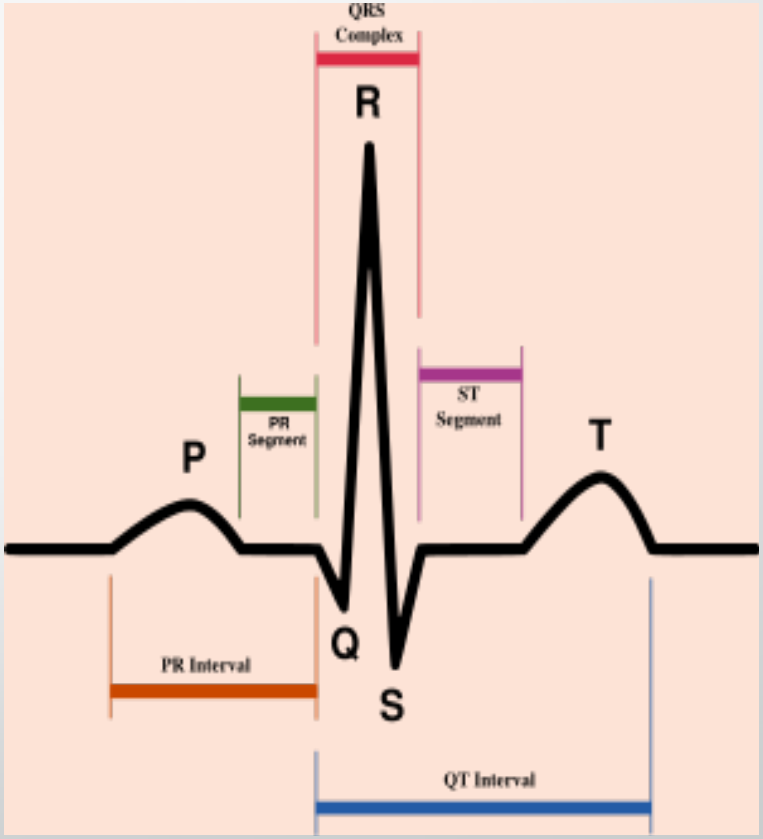
ECG Wave	Cause	Represent
P- wave	**Atrial depolarization**	• Time of electrical impulse from SA node to spread through atrial muscle. • Duration = 0.08 – 0.1 sec • Precedes atrial contraction by ≈ 0.01 - 0.02 sec
QRS complex	**Ventricular depolarization**	• Measured from beginning of Q wave till end of S wave. • Consists of 3 waves: **Q wave: (-ve):** Produced by depolarization of interventricular septum. **R wave: (+ve):** Produced by depolarization of ventricular wall. **S wave: (-ve):** Produced by depolarization of the base of the heart. • Duration ≤ 0.1 sec. • Precedes ventricular contraction by ≈ 0.02 sec. • Occurs after P-wave by ≈ 0.12-0.2 sec = PR interval
T- wave	**Ventricular repolarization**	• Occurs during latter part of systole, before the onset of diastole. • Ventricular repolarization progresses from apex to the base of the heart. • Duration = 0.27 sec.

N.B.

Atrial repolarization occurs at the same time with ventricular depolarization. But, since ventricular depolarization wave is giant, it masks the atrial repolarization wave

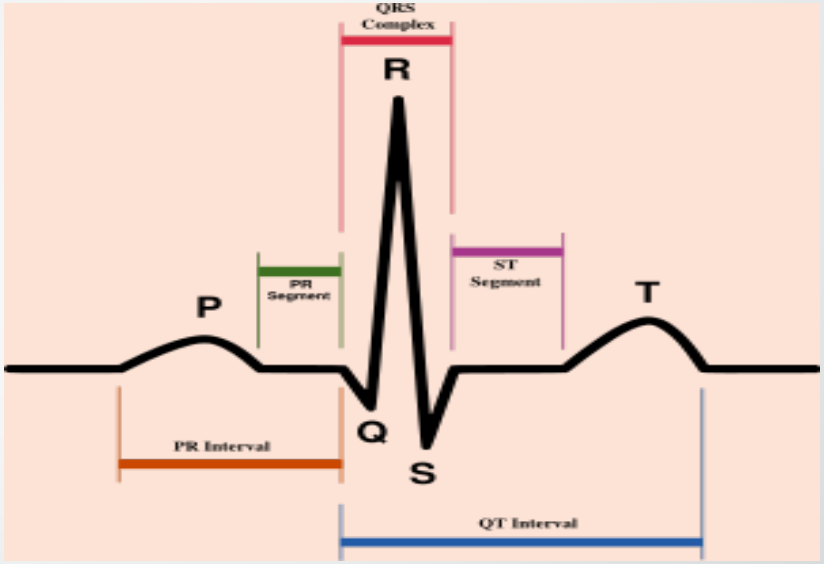
P-R interval

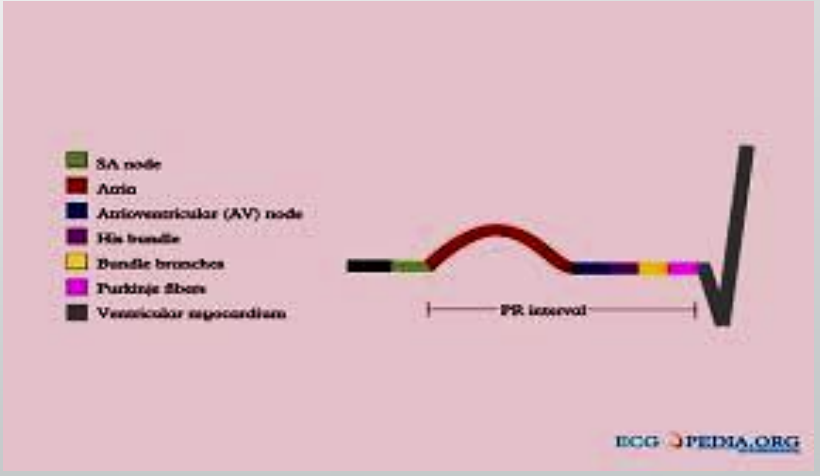
- P-R interval is the time from the initial depolarization of atria to the initial depolarization of ventricles.
- Time period measured from start of P-wave to start of QRS complex; Thus P-R interval includes P- wave & PR segment
- P-R interval range = 0.12-0.2 sec.
- An increase in conduction velocity through AV node will decrease P-R interval (sympathetic stimulation) & vice versa.



PR segment

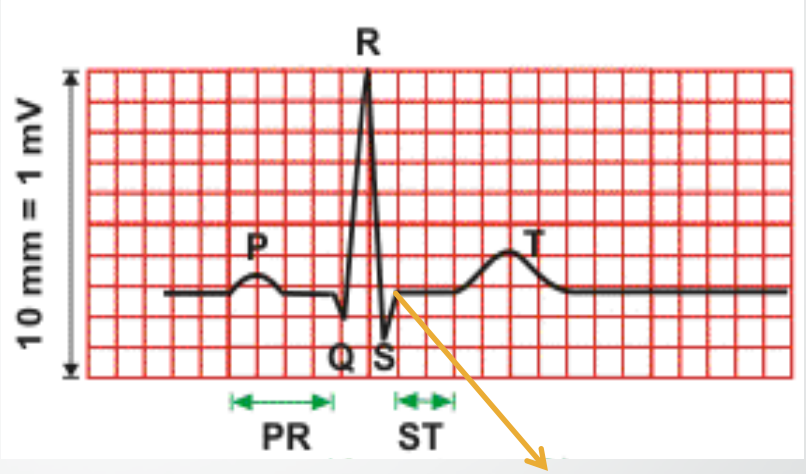
- P- wave is followed by brief isoelectric (zero voltage) flat portion of ECG that corresponds to AV-node conduction → PR segment.
- This segment correlates with conduction time through the AV-node & AV bundle or AV nodal delay = 0.13 sec.

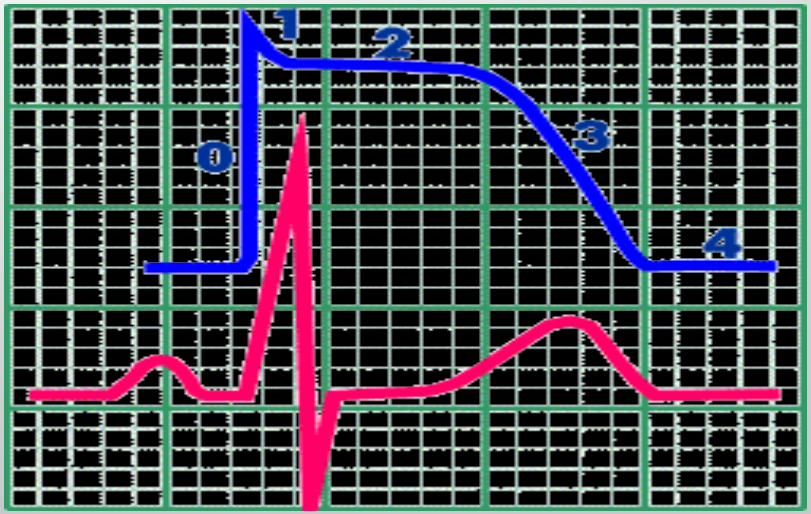




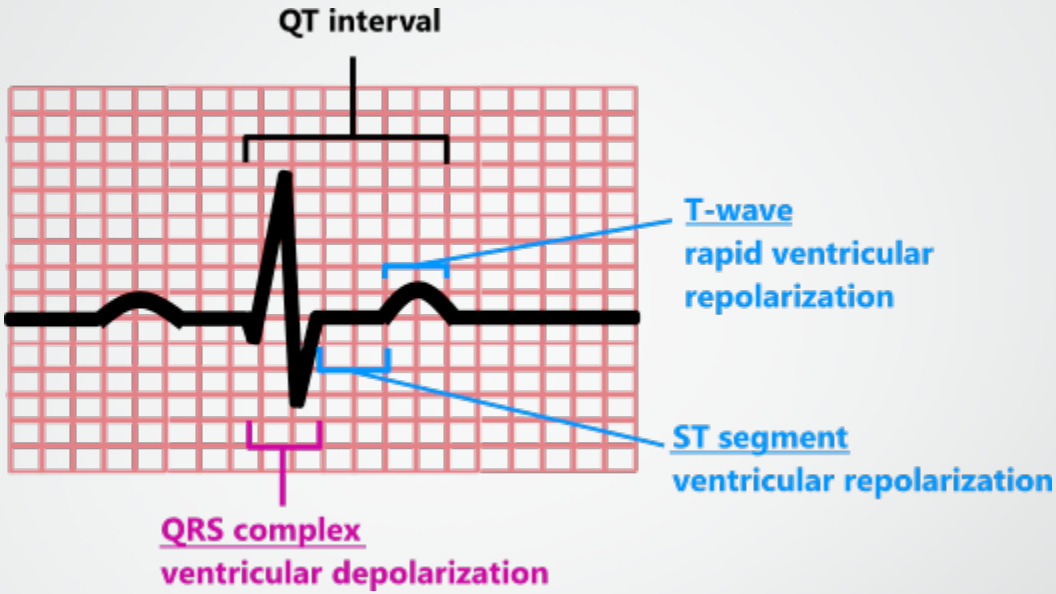
ST segment

- Isoelectric segment follows the QRS complex, showing that there is no potential difference between areas of myocardium at this stage.
- At this time, both ventricles depolarized & roughly corresponds to the plateau phase of the ventricular action potential.
- **J point:** at end of QRS, zero reference potential for analyzing current of injury.



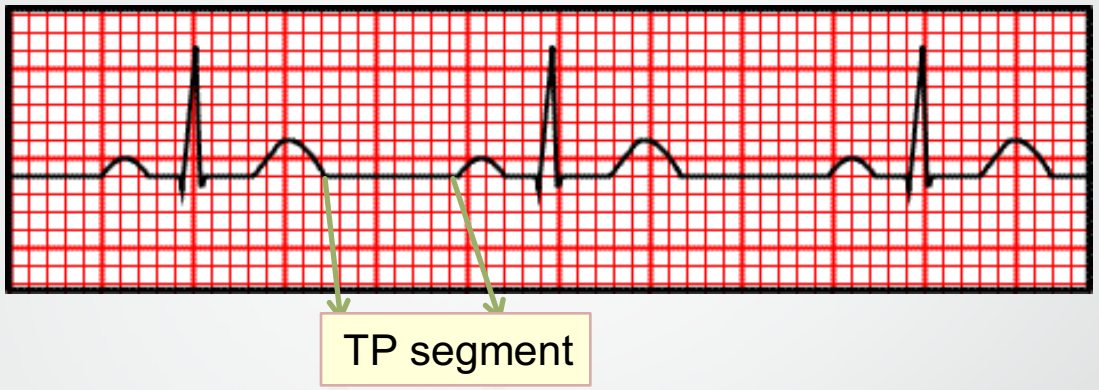


Q-T interval



- The Q-T interval includes the QRS complex, ST segment & T- wave.
- It represents total time taken by ventricle to depolarize & repolarize [contraction of ventricles]
- Q-T interval range = 0.35 – 0.45 sec.
- Approximate Refractory period of ventricle.

TP segment



- Time interval from ventricular repolarization till next atrial depolarization.
- Calculated from end of T- wave to beginning of P- wave.
- It represents ventricular filling.

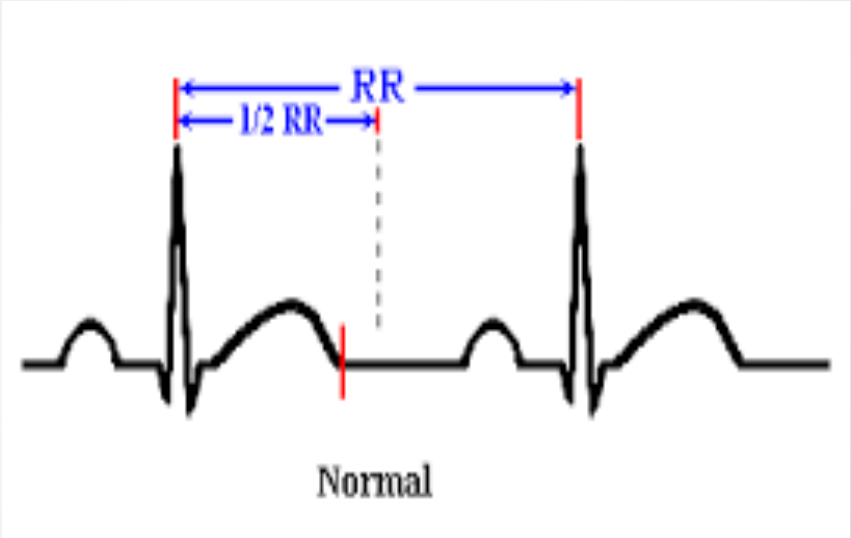
Note:

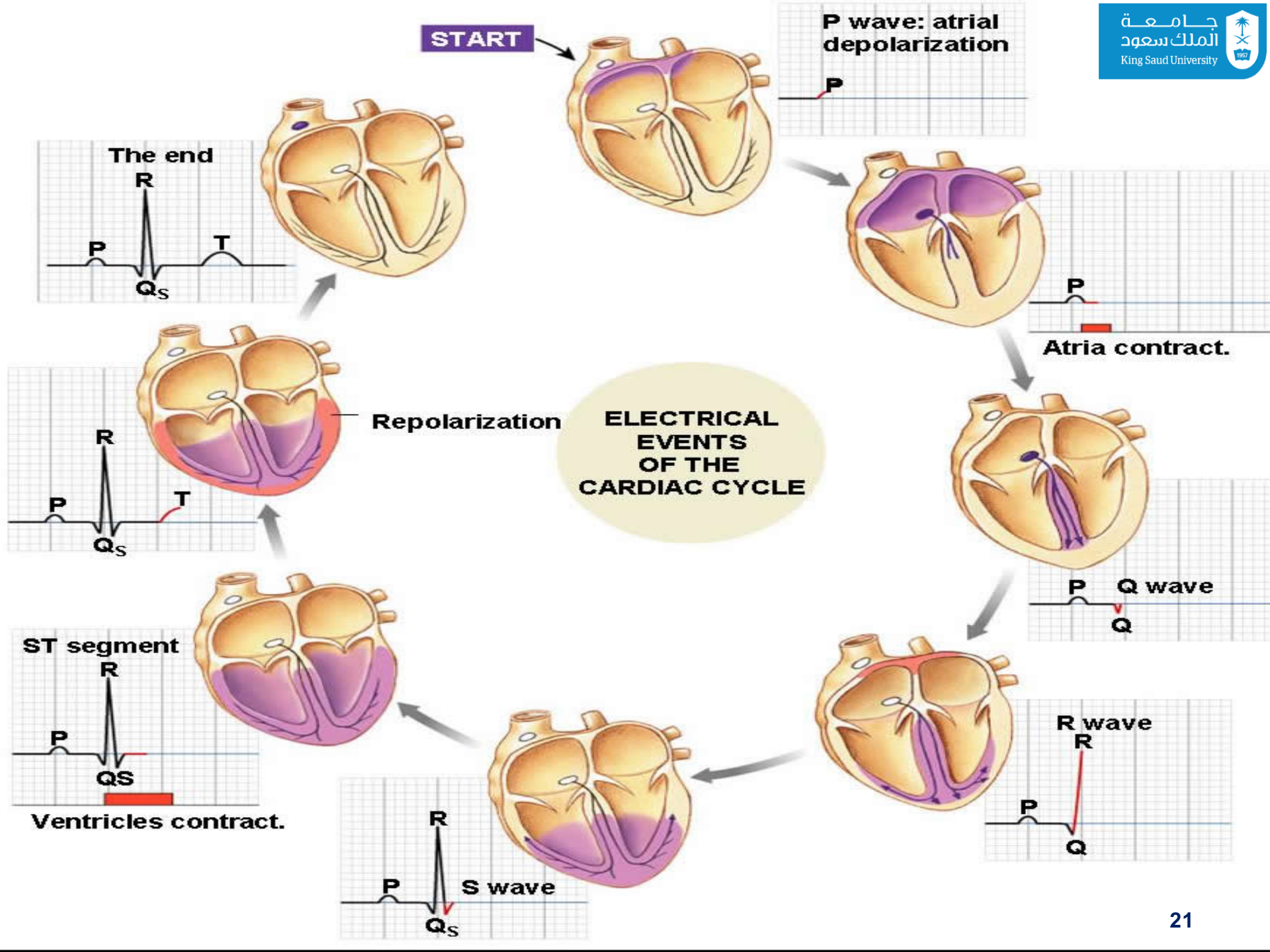
No current flow in the heart during segment's time.

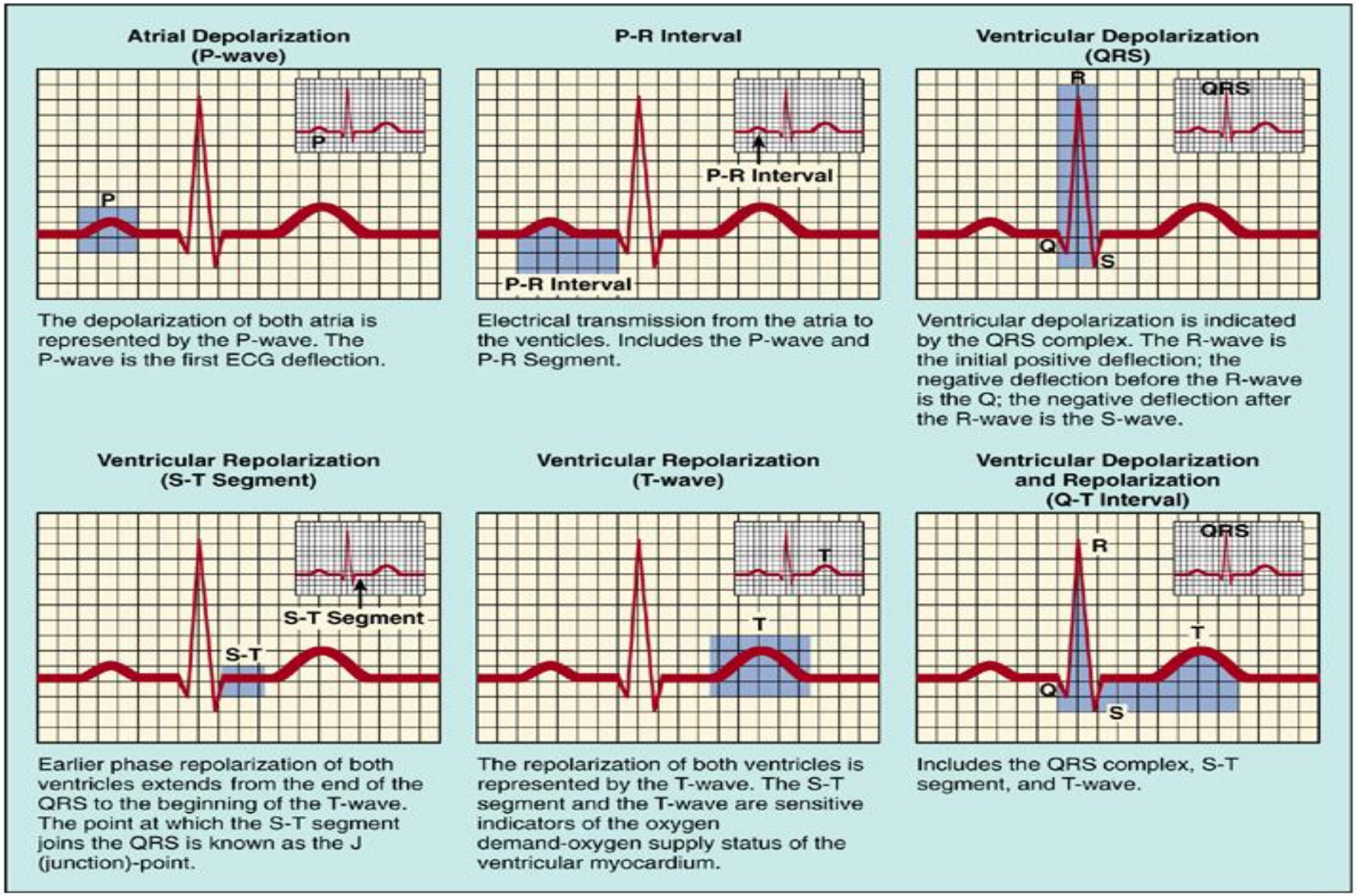
1. **PR segment:** AV- node delay.
2. **ST segment:** Cardiac muscle completely depolarized.
3. **TP segment:** Ventricular filling takes place.

R-R interval

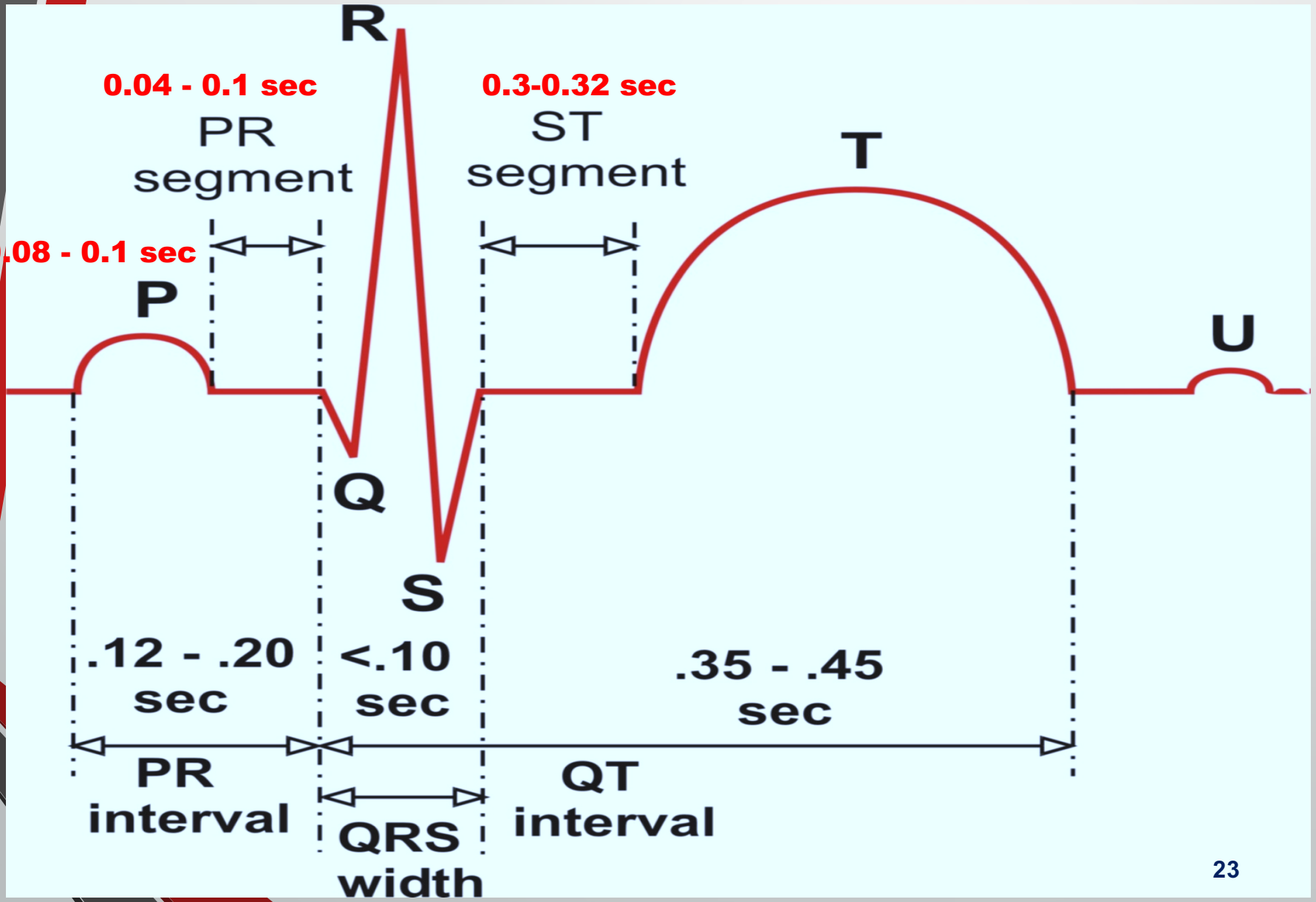
- The interval between two successive R- waves.
- It determines the heart rate & cardiac cycle length.
- Heart rate can be measured by counting the number of R-waves per minute.




START
P wave: atrial depolarization
P
Atria contract.
P Q wave
Q
R wave
R
P
Q
S wave
R
P
QS
Ventricles contract.
ST segment
R
P
QS
Repolarization
R
P
T
QS
The end
R
P
T
QS
ELECTRICAL EVENTS OF THE CARDIAC CYCLE

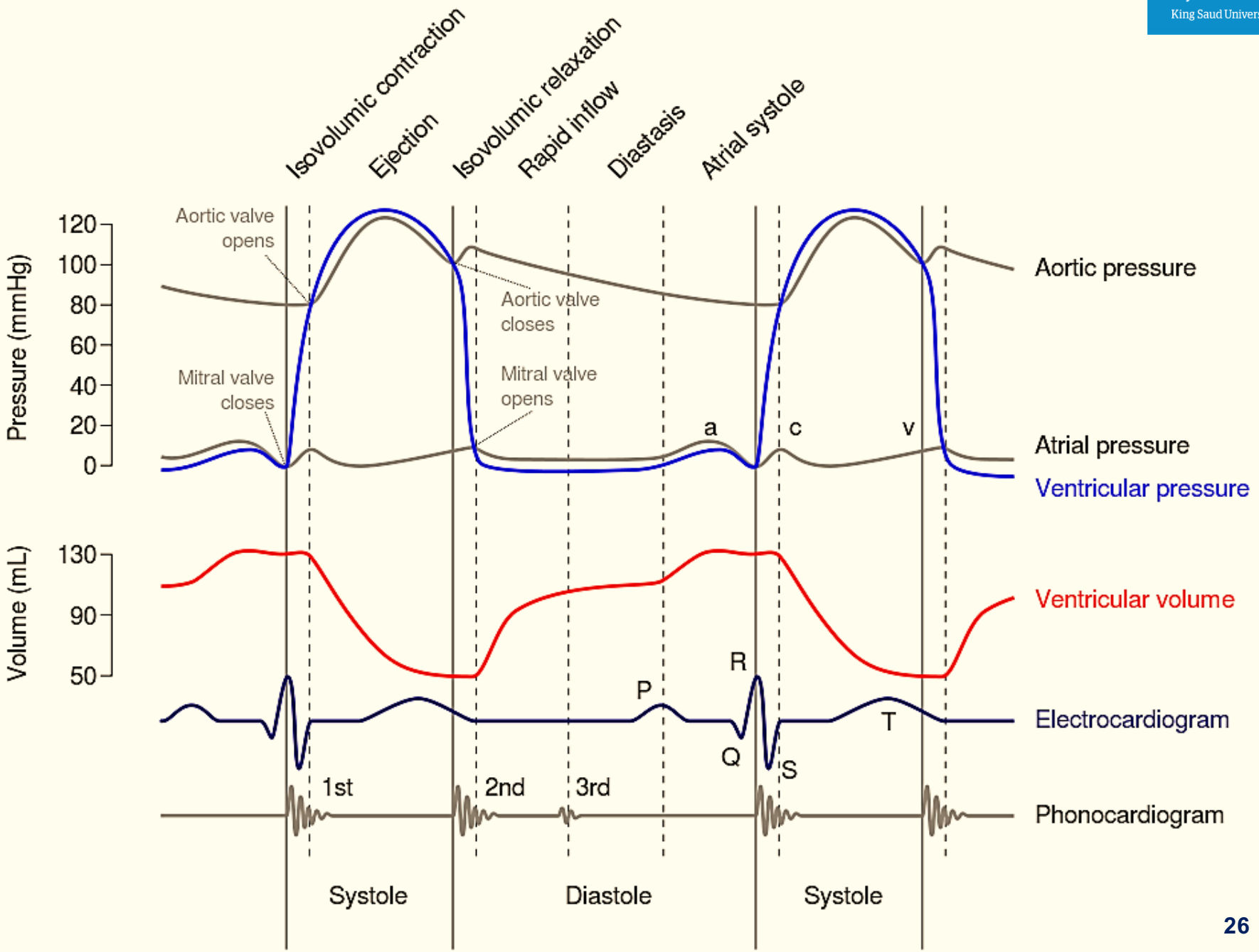


ECG Waves, Intervals & Segments



Left Ventricular Pressure versus Volume

Left Ventricular Pressure – Volume Curve "The Complete Picture"


Isovolumic contraction
Ejection
Isovolumic relaxation
Rapid inflow
Diastasis
Atrial systole
Pressure (mmHg)
120
100
80
60
40
20
0
Aortic valve opens
Aortic valve closes
Mitral valve closes
Mitral valve opens
a
c
v
Aortic pressure
Atrial pressure
Ventricular pressure
Volume (mL)
130
90
50
Ventricular volume
R
P
T
Q
S
Electrocardiogram
1st
2nd
3rd
Phonocardiogram
Systole
Diastole
Systole

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Left Ventricular Pressure - Volume Loop

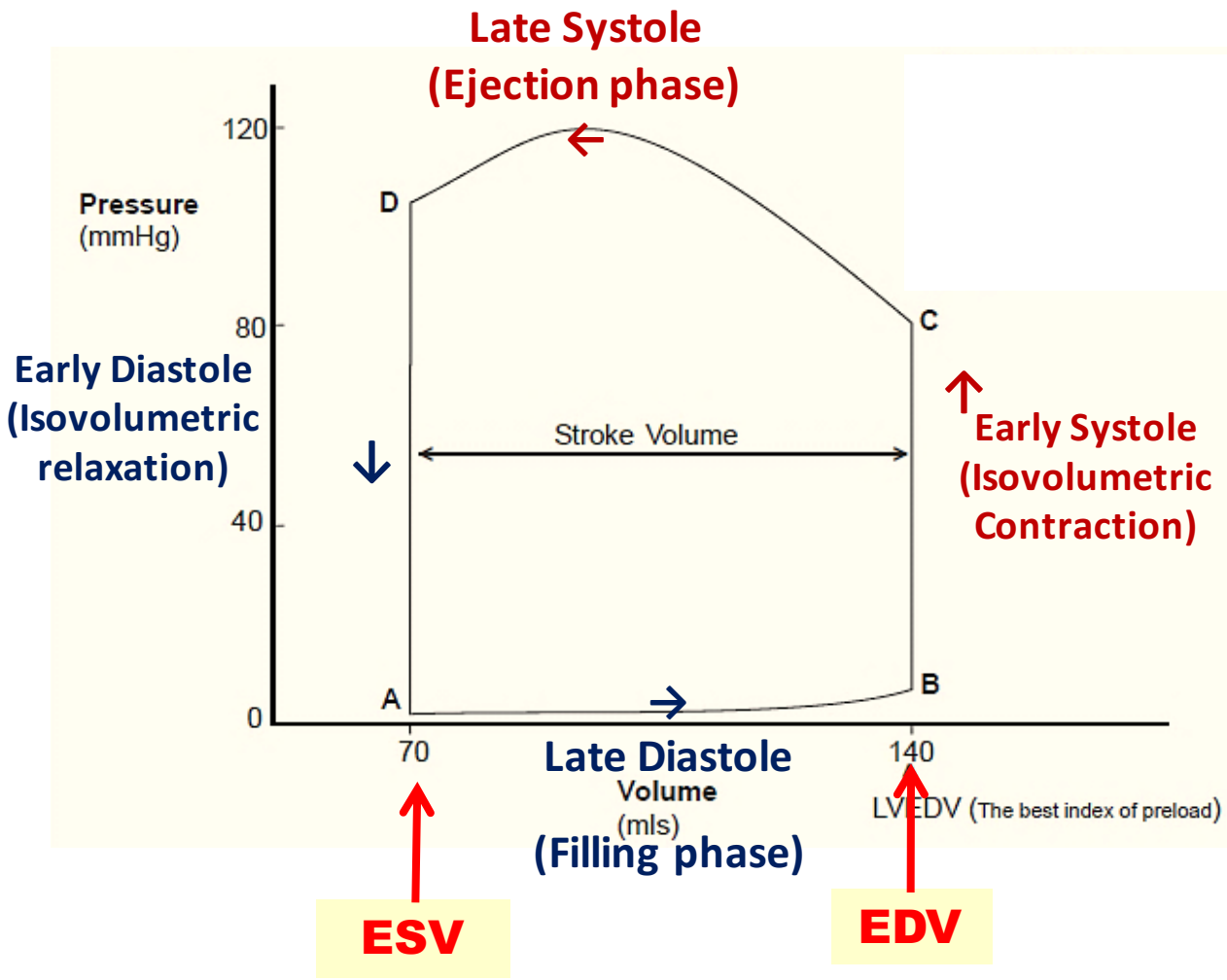
Left Ventricular Pressure – Volume Loop

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:**
  - Early systole = 'Isovolumetric Contraction.'
  - Late systole = Isotonic Contraction 'Ejection Phase.'
- **Diastole:**
  - Early diastole = 'Isovolumetric Relaxation.'
  - Late diastole = Isotonic Relaxation 'Filling Phase.'

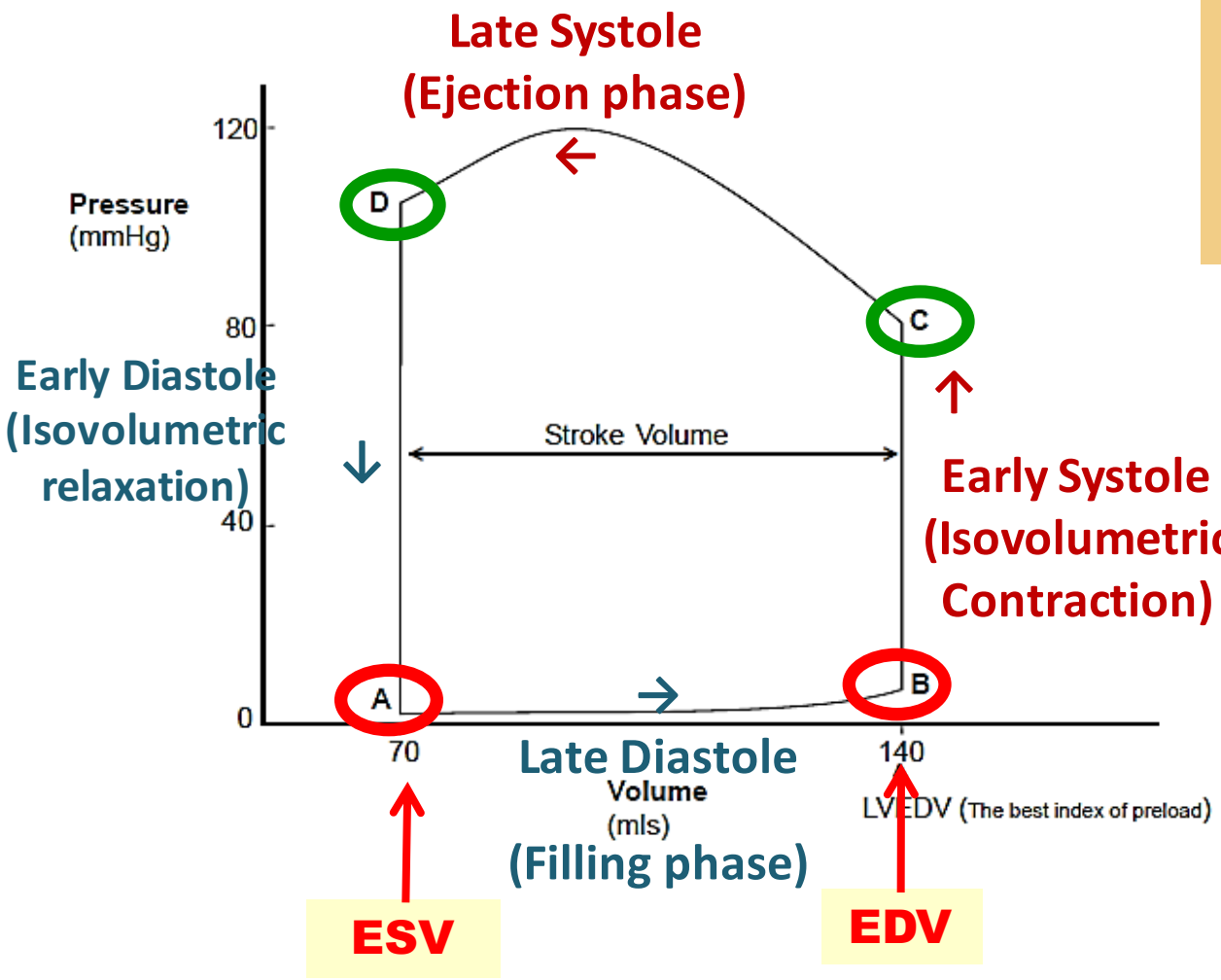
Ventricular Pressure - Volume Loop



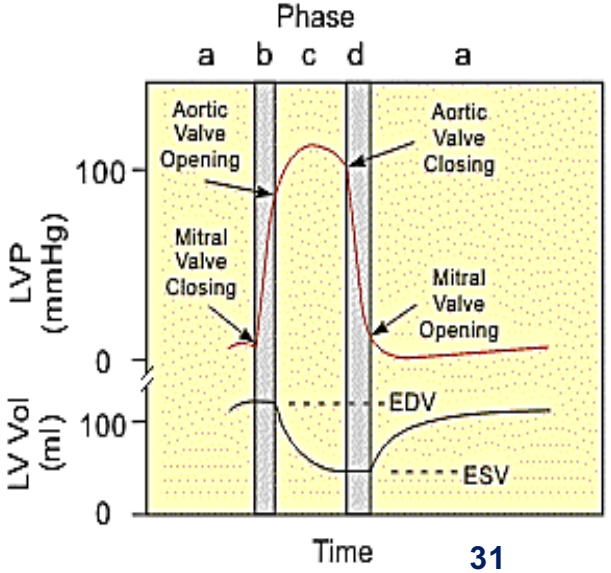
- Plots LV pressure against LV volume through one complete cardiac cycle

- **Systole:** divided into,
  - Early systole
  - Late systole
- **Diastole:** divided into,
  - Early diastole
  - Late diastole

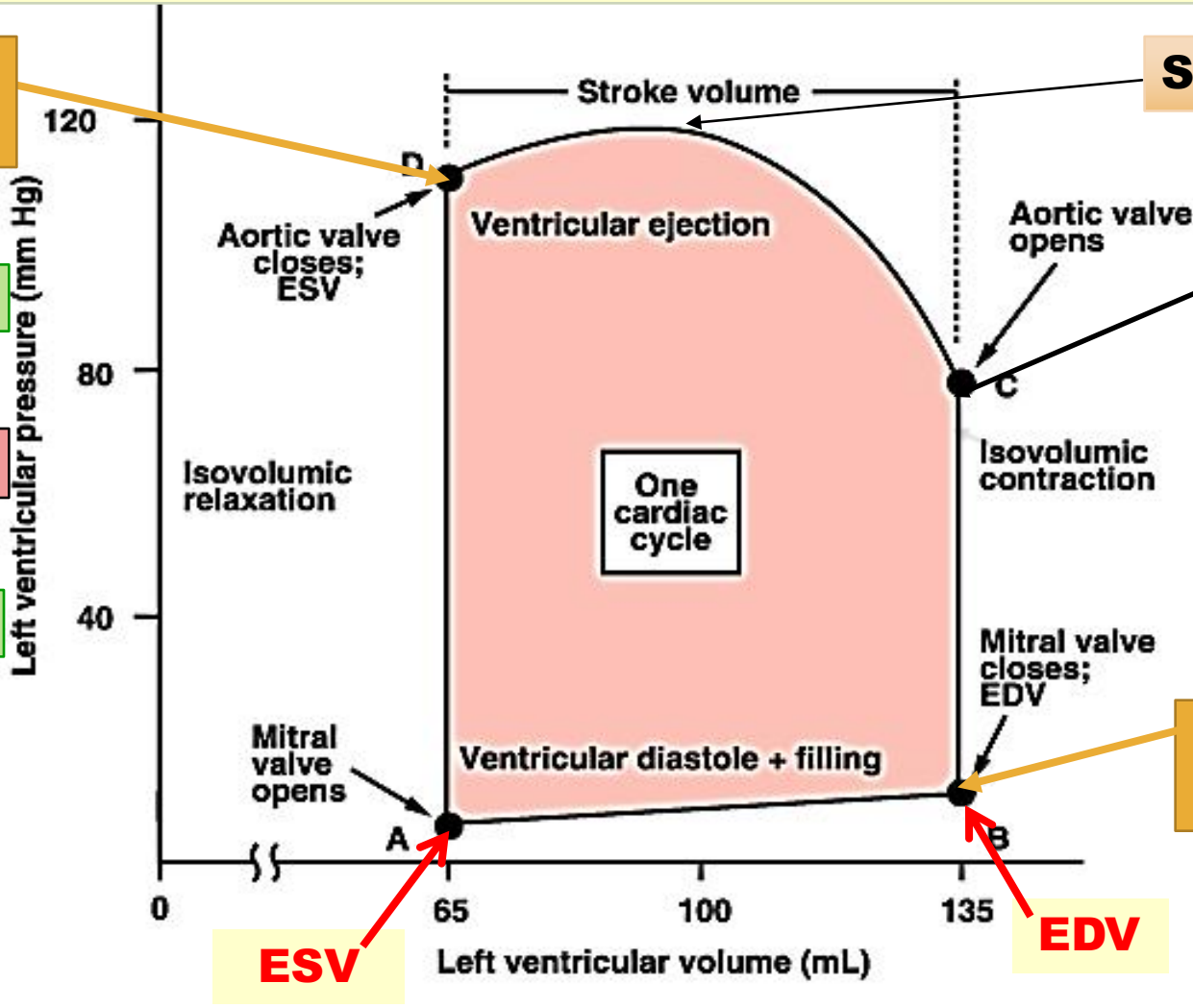
Ventricular Pressure - Volume Loop



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



Ventricular Pressure - Volume Loop



End of Systole

Systolic BP

Contractility

Diastolic BP

Area = Work

Compliance

Beginning of Systole

A → B: Passive filling and atrial contraction

B → C: Isovolumic contraction

C → D: Ejection of blood into aorta

D → A: Isovolumic relaxation

SV = EDV - ESV

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.


Thank You