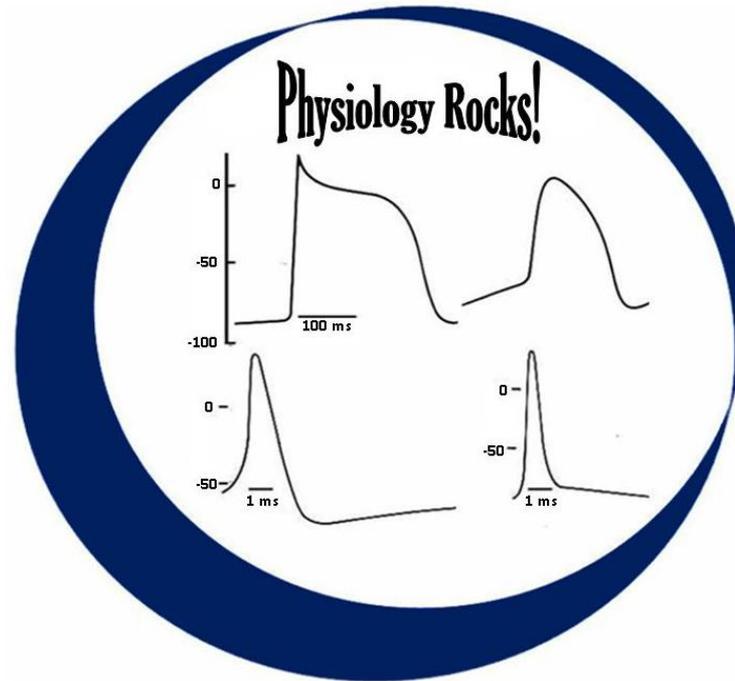


# Lecture 3

## Introduction to Electrocardiography



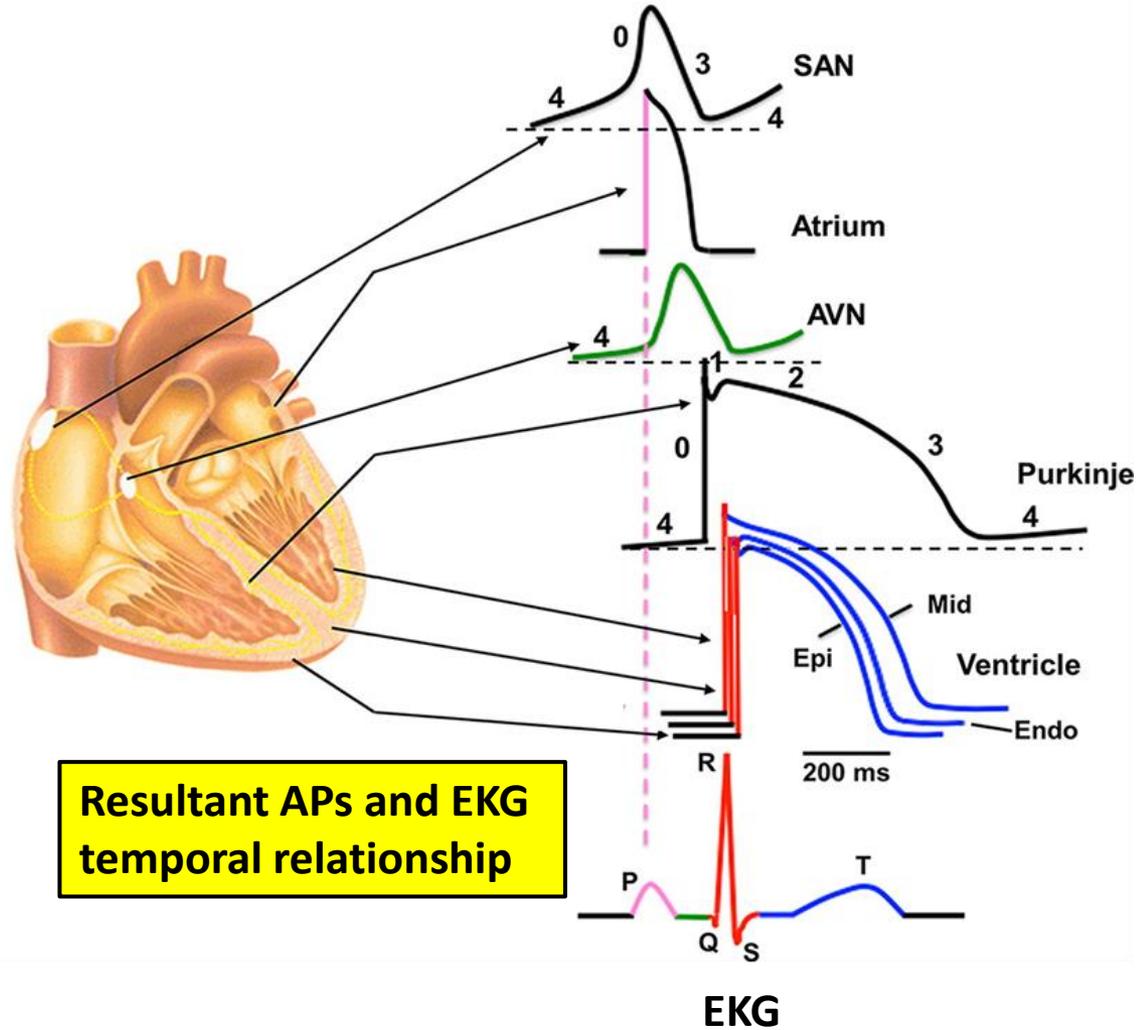
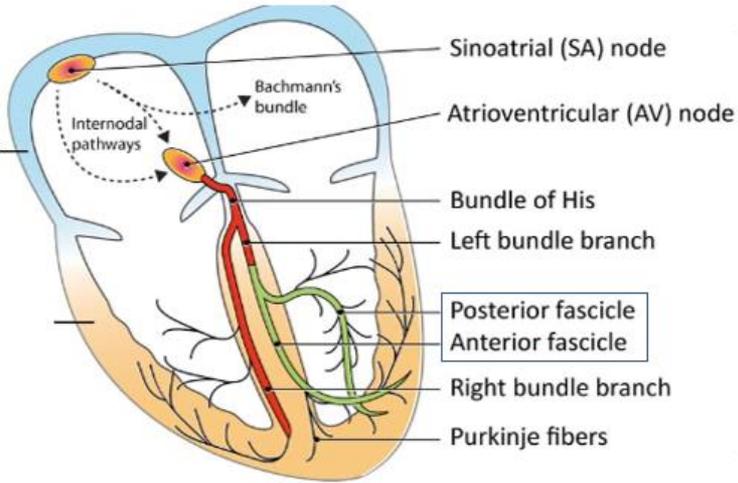
HN Mayrovitz PhD  
mayrovit@nova.edu  
mayrovitz.com

# Topics

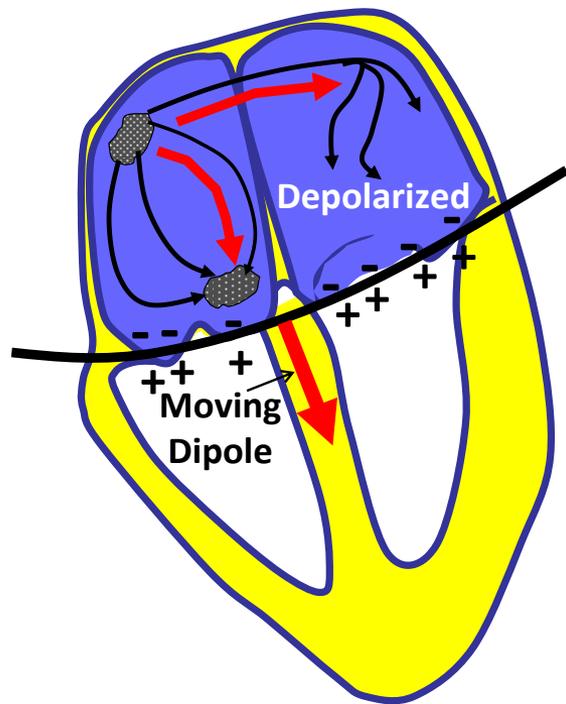
- Action potential – EKG relationship overview
- Moving electrical dipoles as a source of EKG signals
- EKG waves and intervals in relation to action potentials
- Measuring the EKG – leads and axes introduction
- EKG waves in relation to myocardial territories
- Conduction blocks
- Mean electrical axis (MEA) and axis deviations
- Vector projections to determine MEA
- EKG basic patterns
  - Normal
  - Ectopic impulses – Atrial and Ventricular
  - Tachycardias
  - Flutter wave
  - Atrial fibrillation
  - Ventricular fibrillation

# Action potential conduction as EKG source

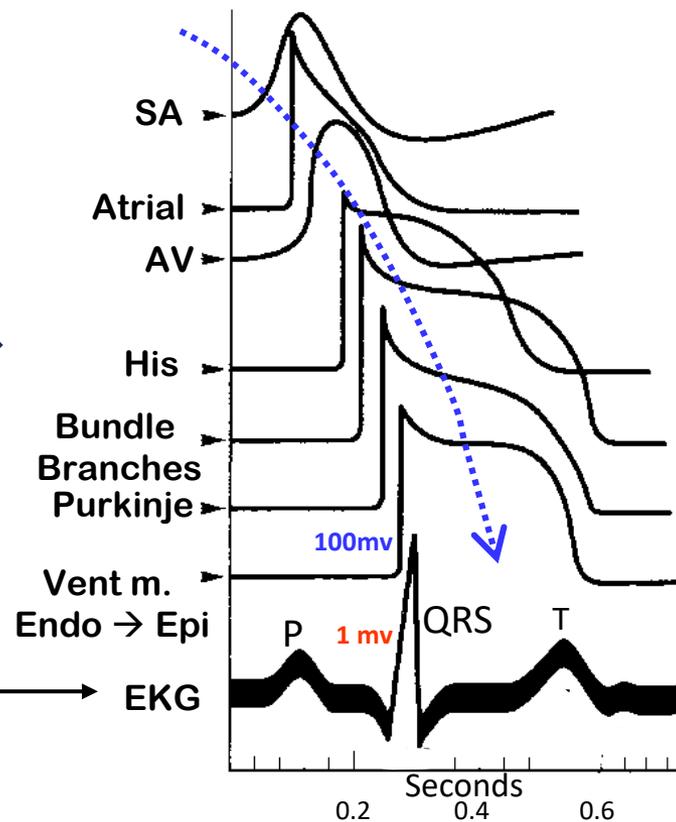
## Electrical Conduction Quick Review



# Moving waves of Changing Electrical Activity

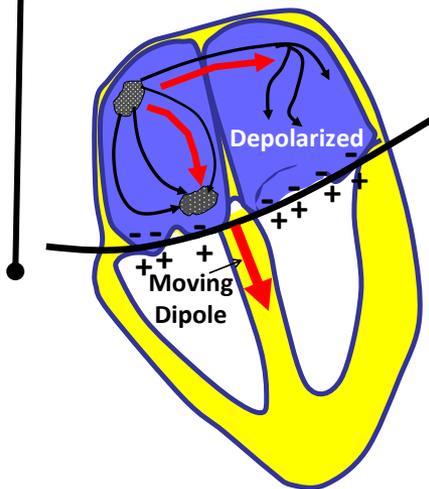
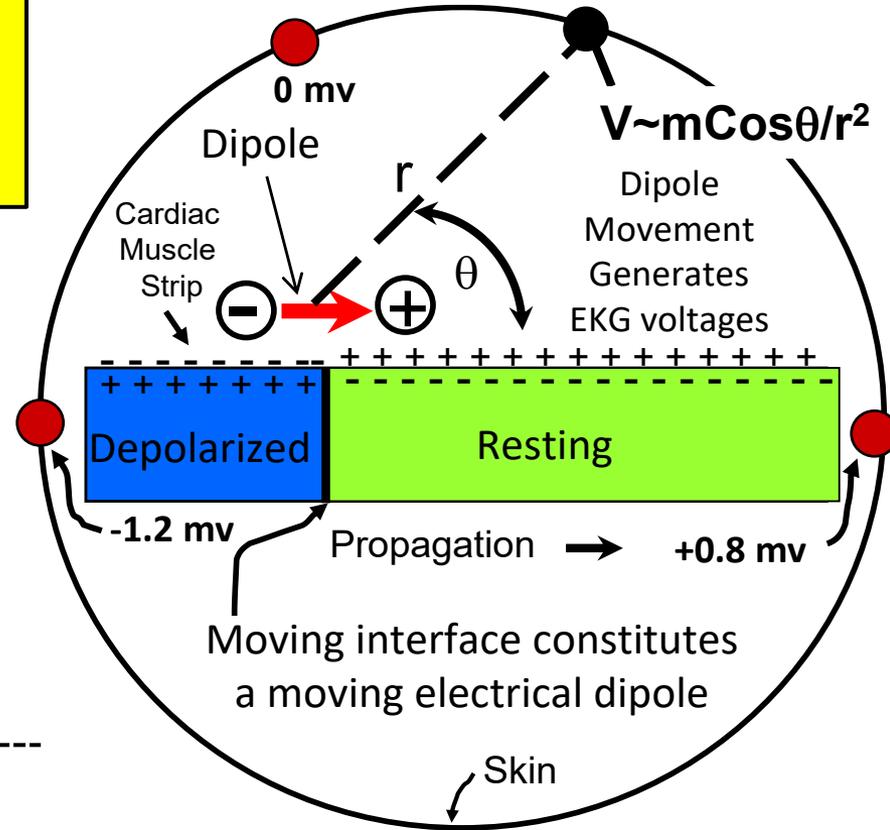
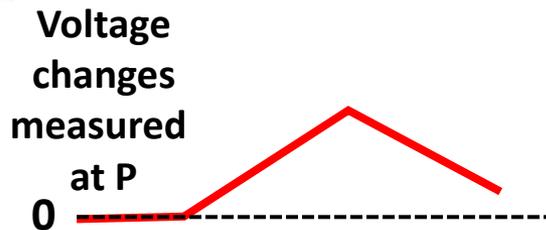
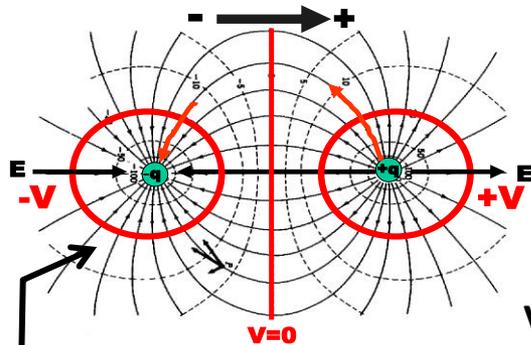


**Moving waves of changing electrical activity constitute a moving dipole resulting in the measured EKG**

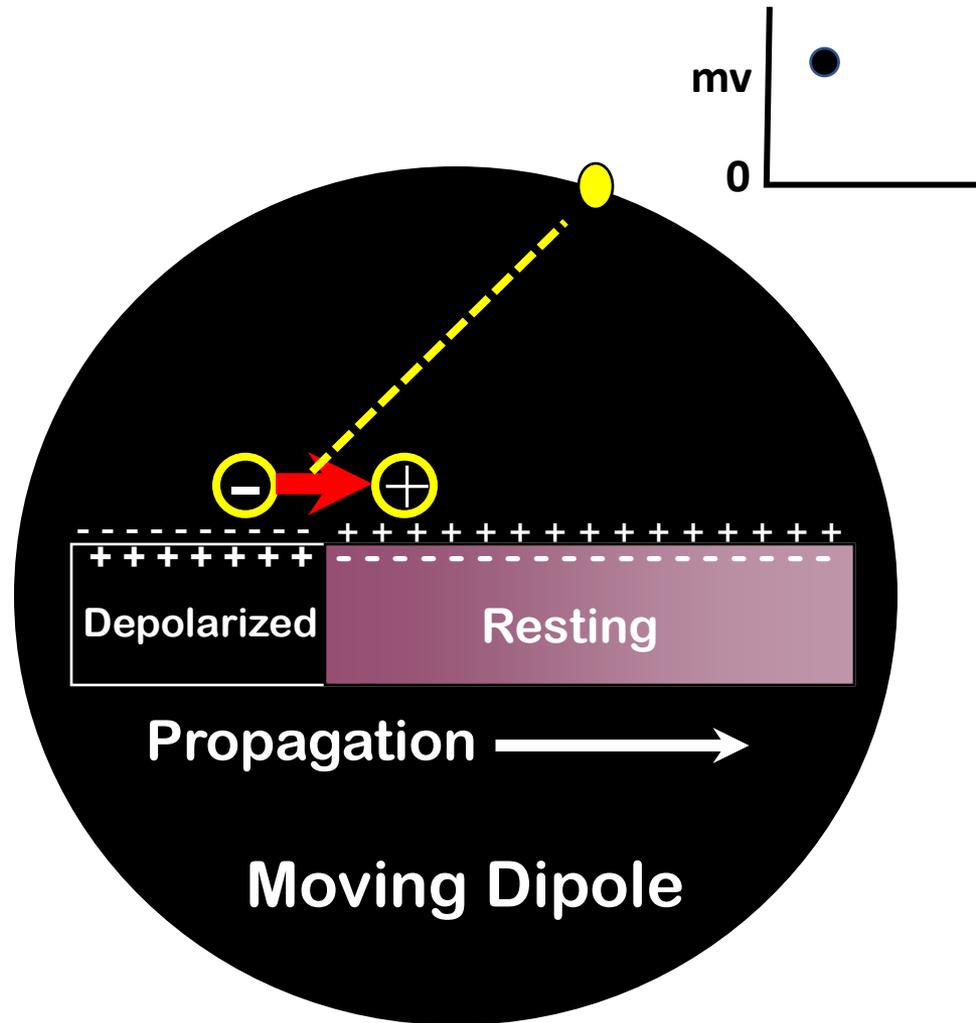


# Moving Dipole → Voltage Change at a Distance

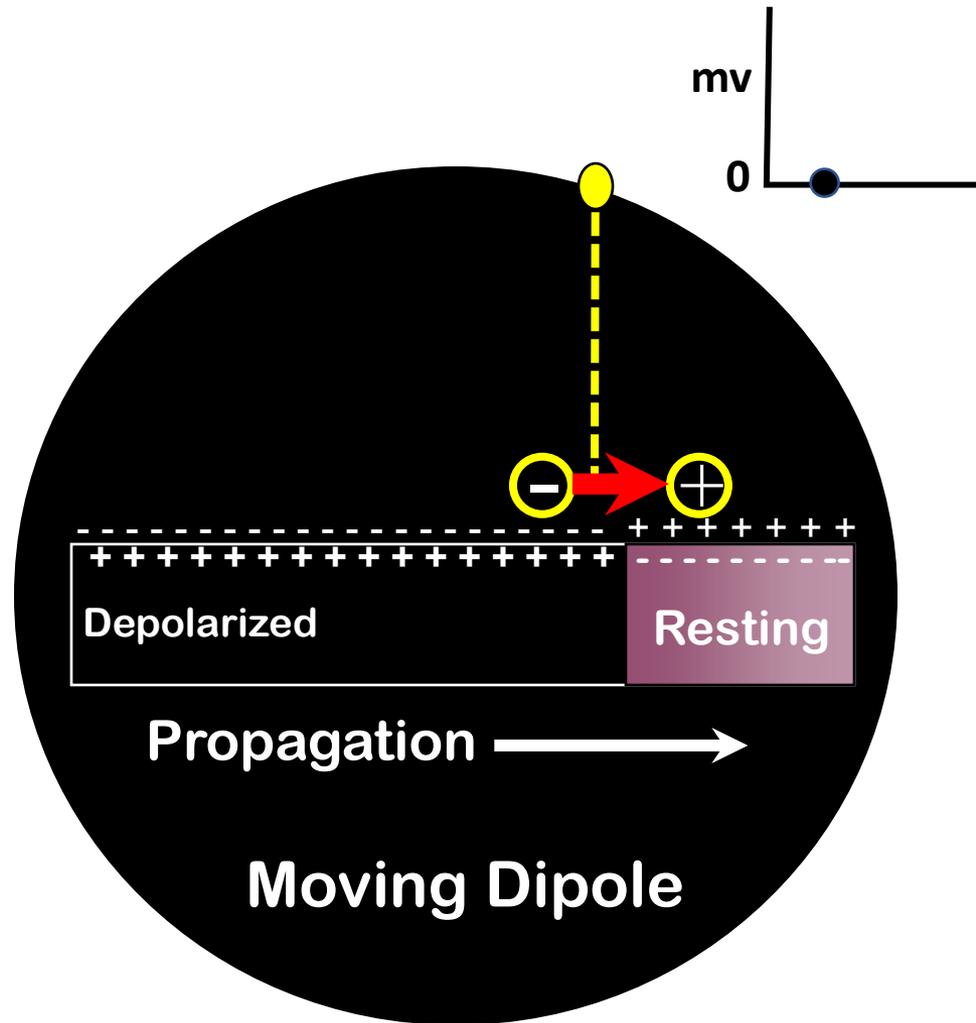
- Dipole: Equal but opposite separated charge
- Moving wave of cardiac depolarization viewed as a moving dipole
- As long as its moving it generates a voltage
- Sensed (measured) voltage is the EKG (ECG)



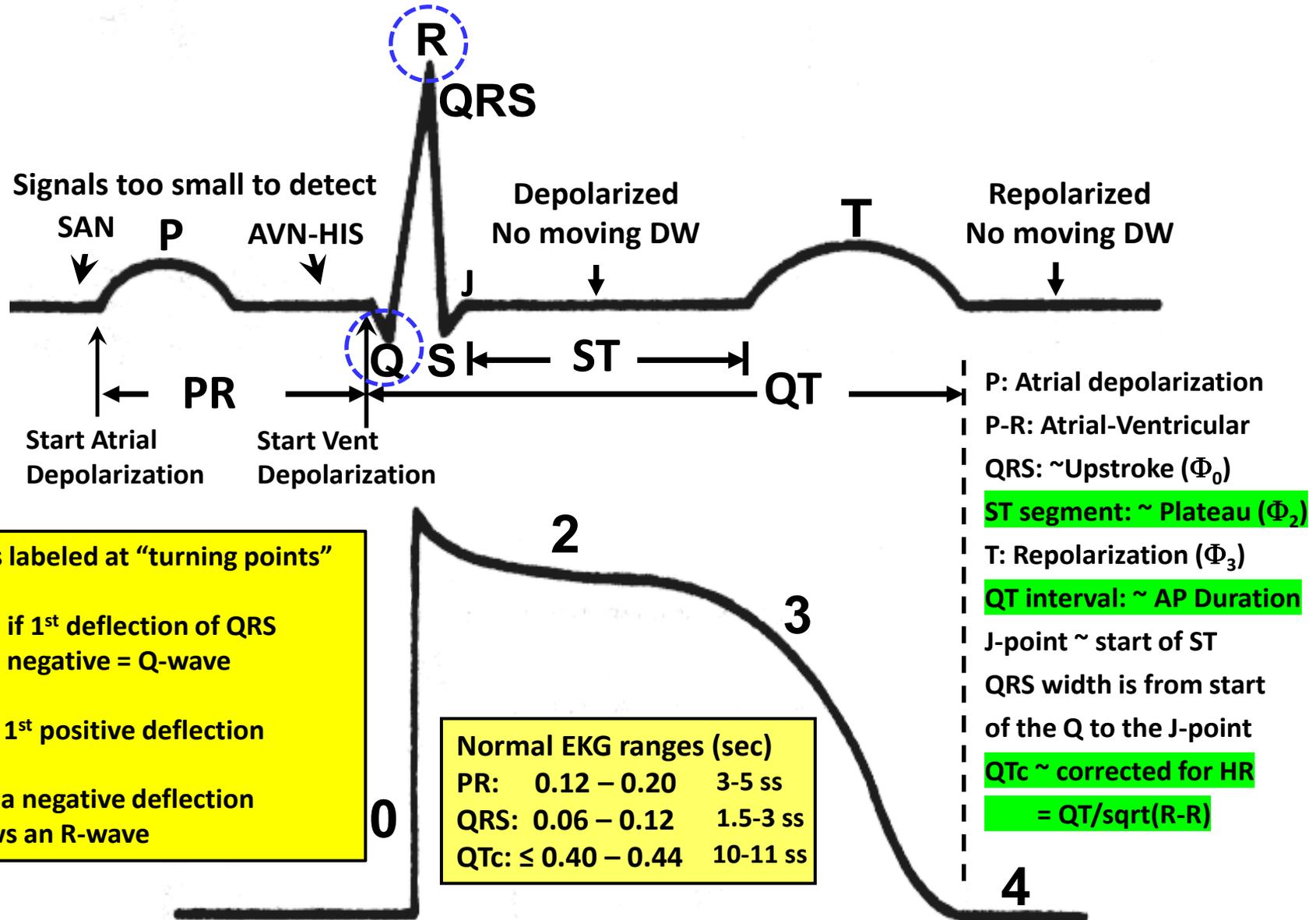
# Moving Dipole → Voltage Change at a Distance



# Moving Dipole → Voltage Change at a Distance

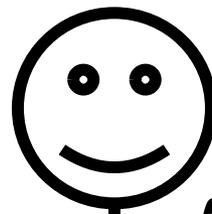


# EKG Components and Relationship to AP

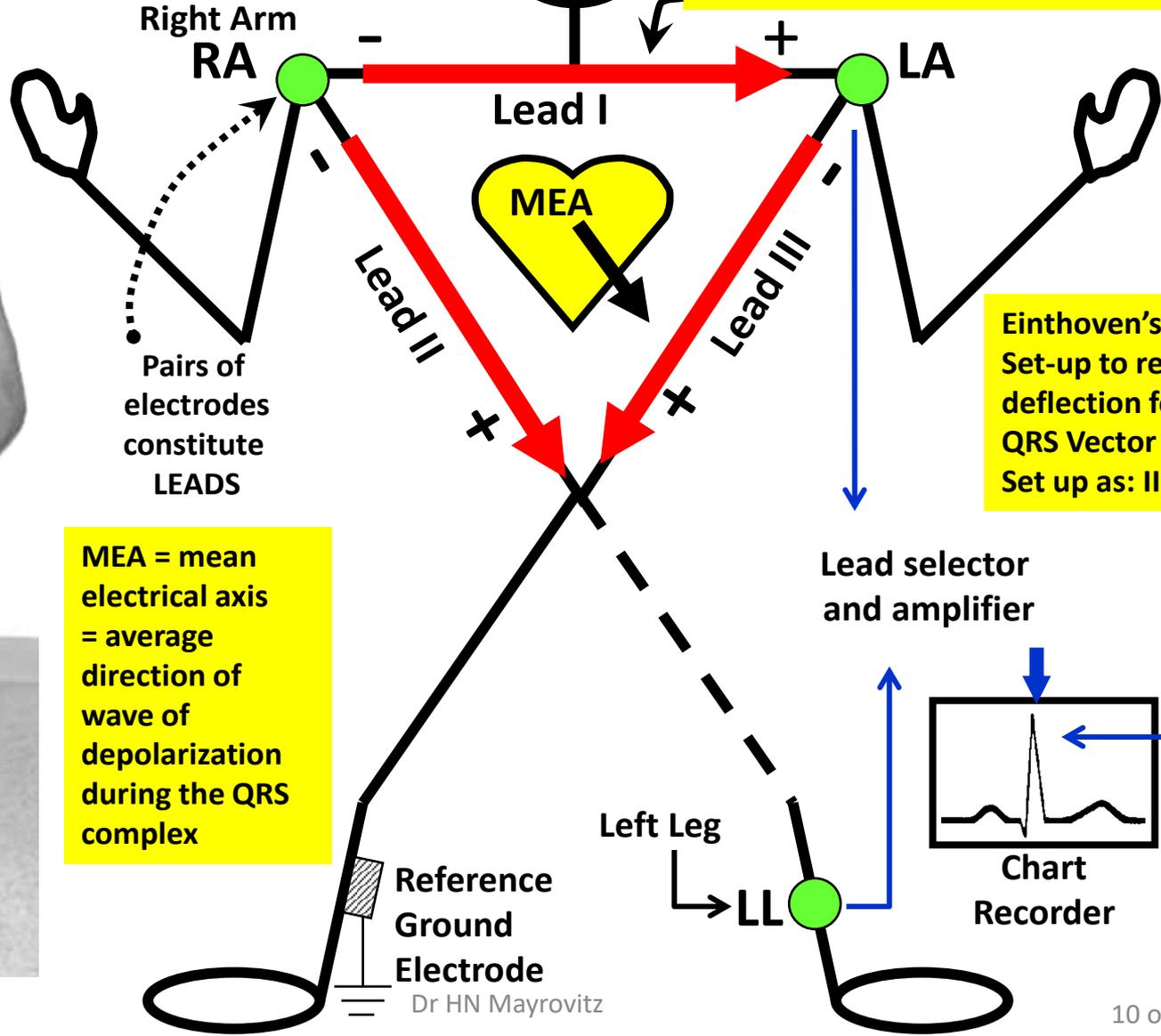


# Measuring the EKG

# Leads, Axes & Einthoven Frontal Plane



Lead axes ("sense") standardized + direction = (-) to (+); tail-to-tip Dipole projection in this sense causes upward EKG deflection



Pairs of electrodes constitute LEADS

Einthoven's Triangle Set-up to record (+) deflection for normal QRS Vector (MEA) Set up as:  $II = I + III$

MEA = mean electrical axis = average direction of wave of depolarization during the QRS complex

Lead selector and amplifier

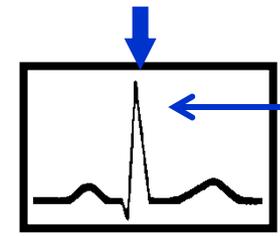
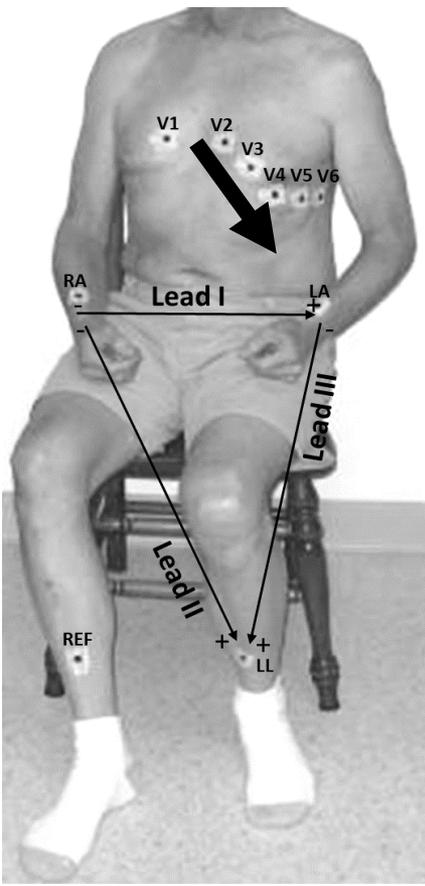


Chart Recorder

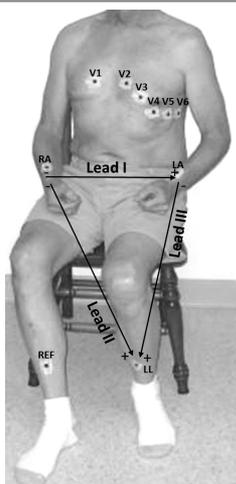
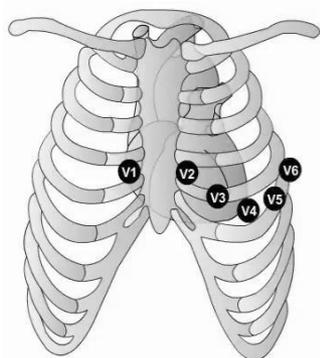
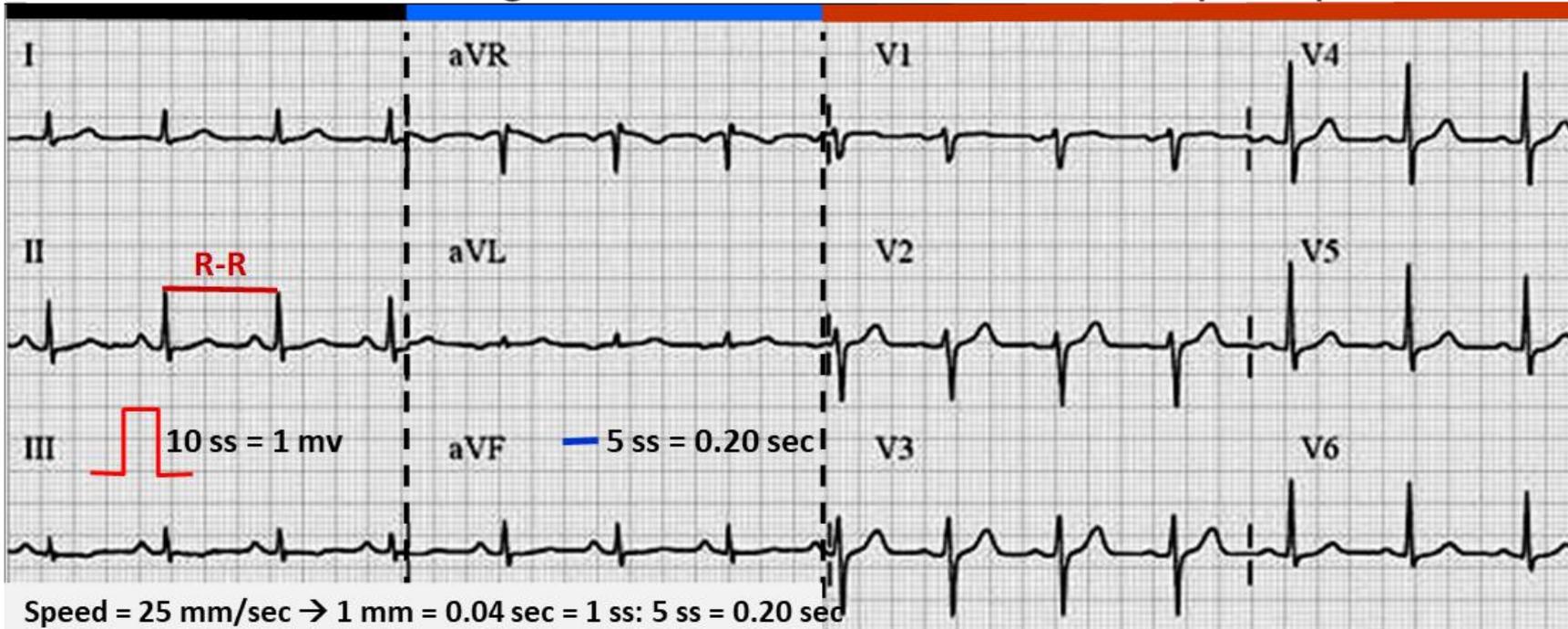


# Normal 12-lead EKG

Standard Limb Leads

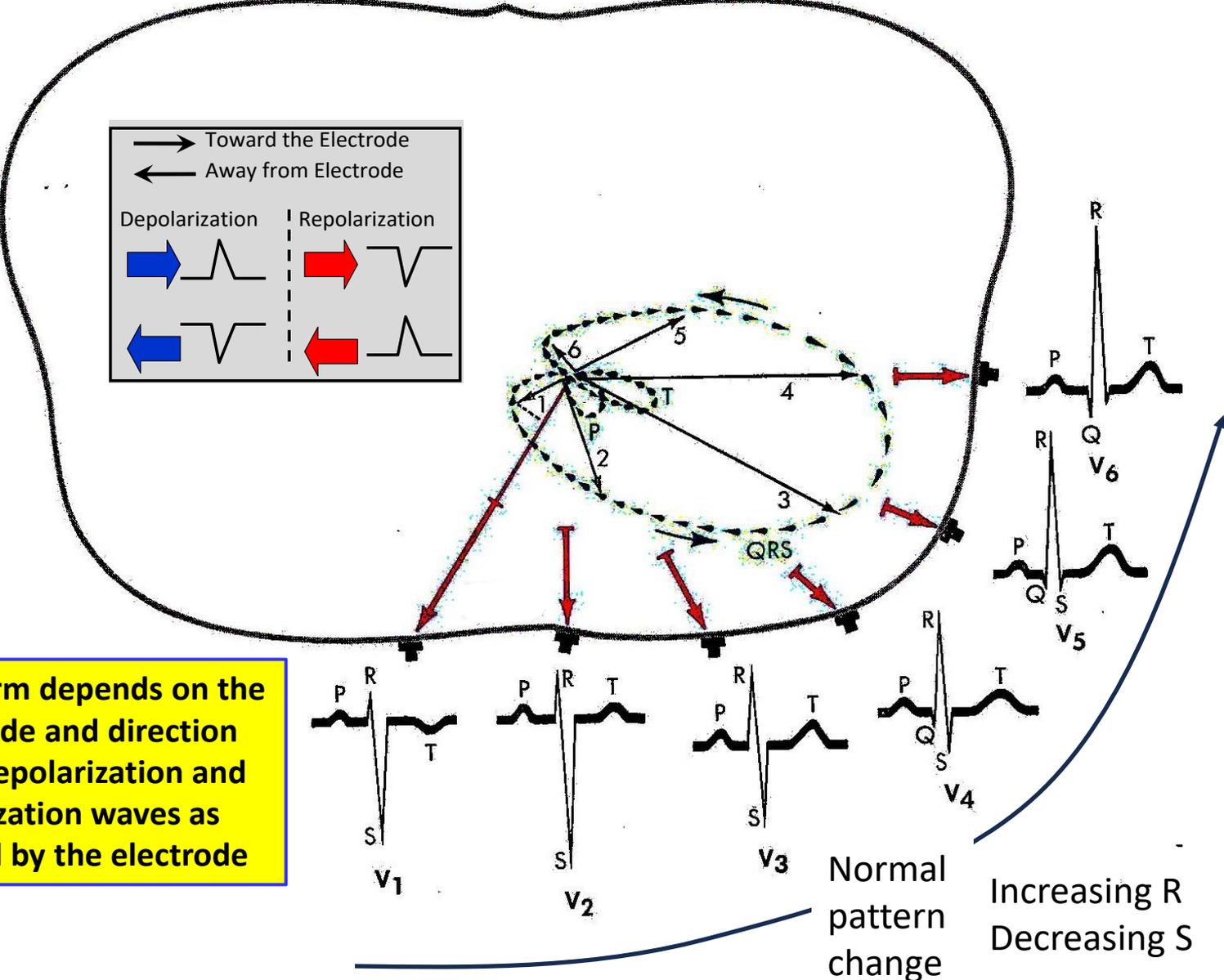
Augmented Leads

Precordial (Chest) Leads



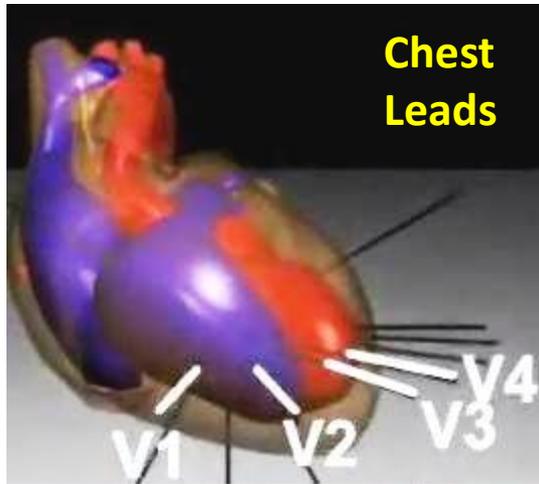
**Time Standard Calibration**  
 Speed = 25 mm/sec  
 1 mm = 0.04 sec = 1 small square (ss)  
 5 ss = one big box = 0.20 sec  
**Amplitude Calibration**  
 10 ss = 1 mv

# Chest (Precordial) Leads: EKG Deflections



**Waveform depends on the magnitude and direction of the depolarization and repolarization waves as received by the electrode**

# Chest and Limb Leads: **Sensed Territories**



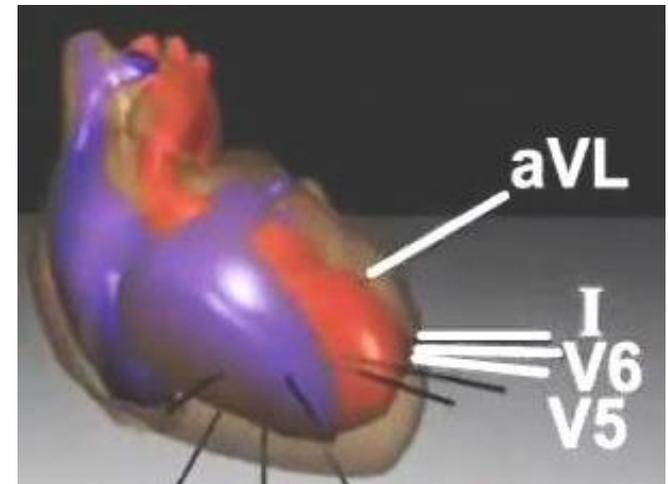
**Chest Leads**

**Anterior V1 → V4**

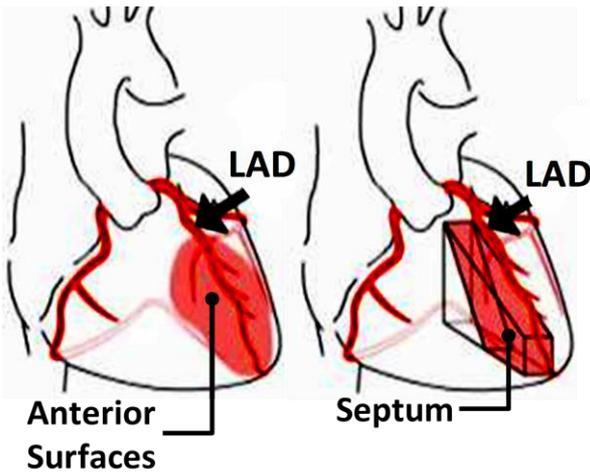


**Limb Leads**

**Inferior III aV<sub>F</sub> II**

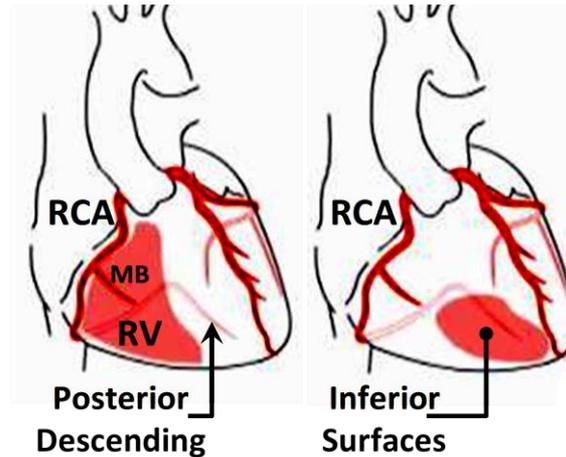


**Left Lateral aV<sub>L</sub> I V6 V5**



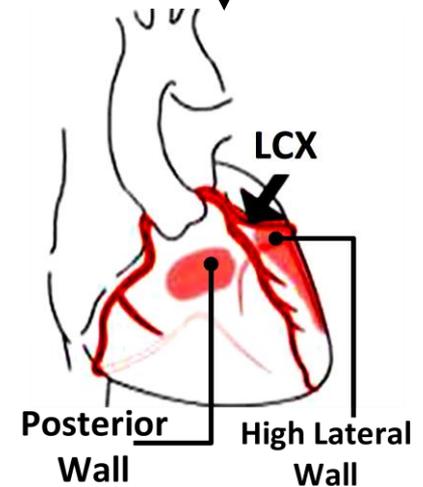
Anterior Surfaces

Septum



Posterior Descending

Inferior Surfaces



Posterior Wall

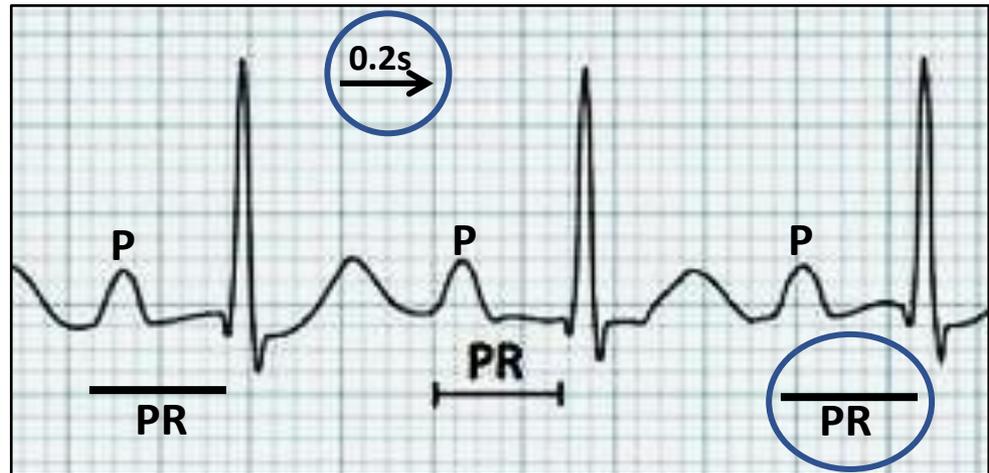
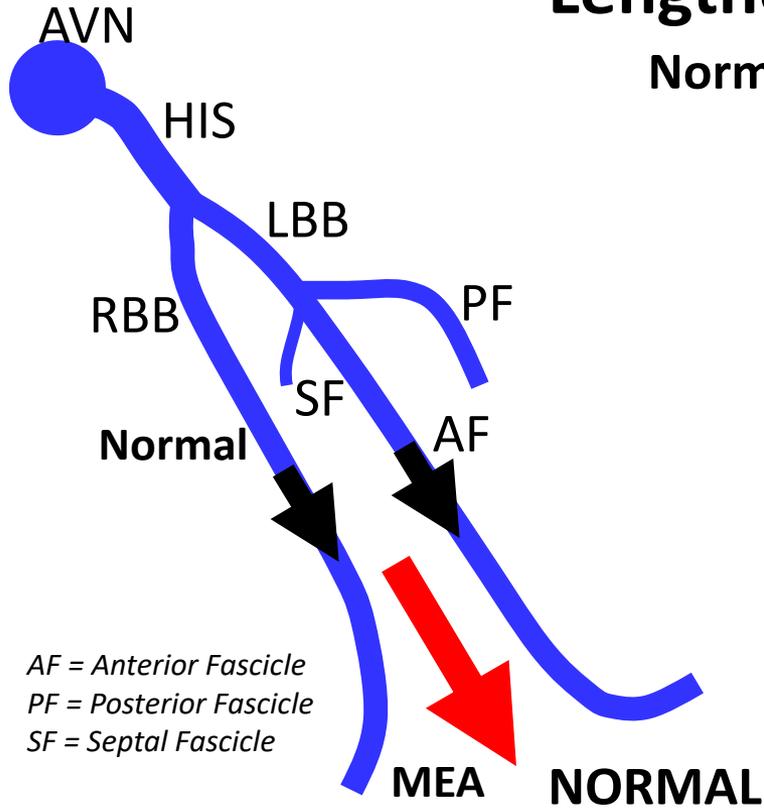
High Lateral Wall

RCA = right coronary artery  
 LAD = left anterior descending  
 LCX = left circumflex

# Conduction Blocks: 1°

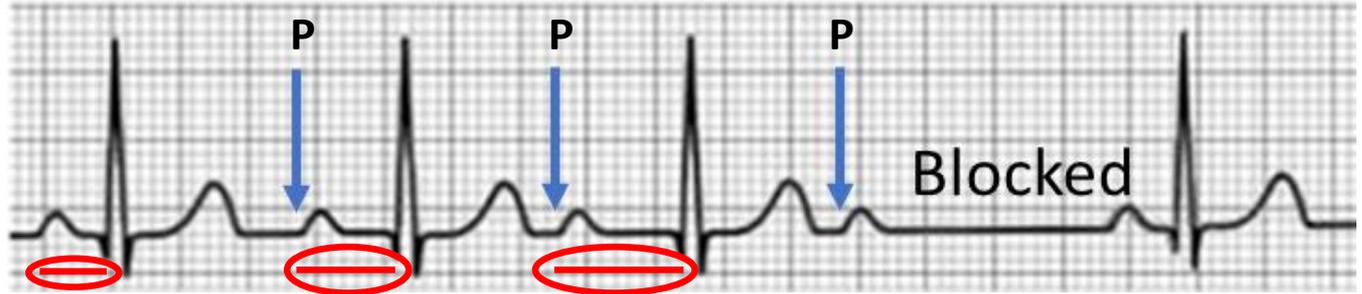
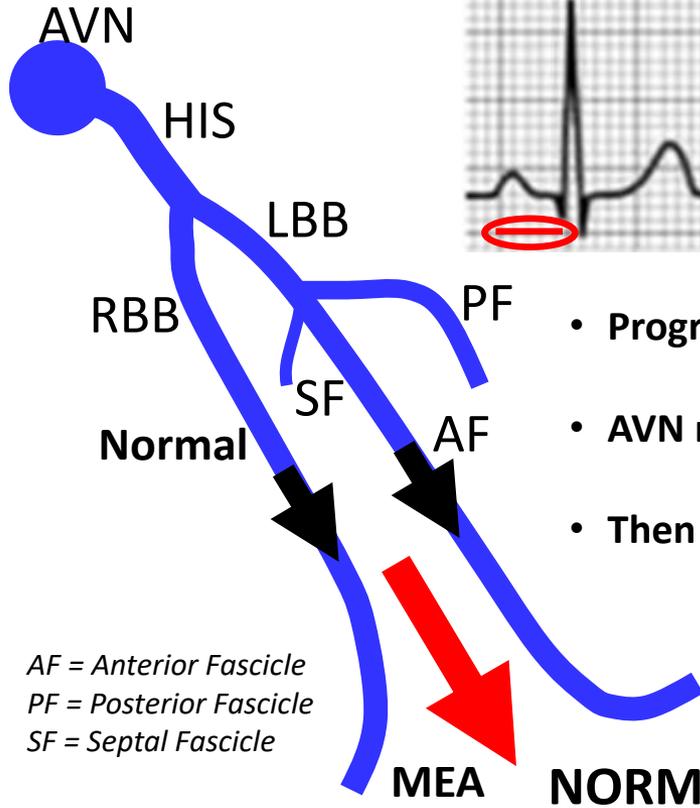
## Lengthened PR Interval

Normal PR: 0.12 – 0.2 s



**IF PR consistently > 0.2s = 5 ss then 1° block  
Often issue is with AVN**

# Conduction Blocks: 2°

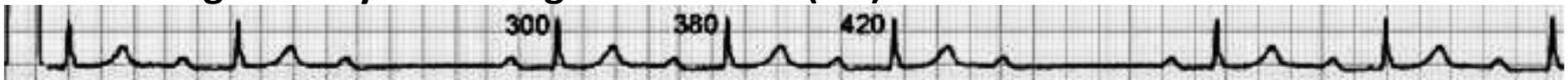


- Progressively increasing PR interval until a QRS does not occur
- AVN recovery time progressively increasing until refractory
- Then pattern repeats

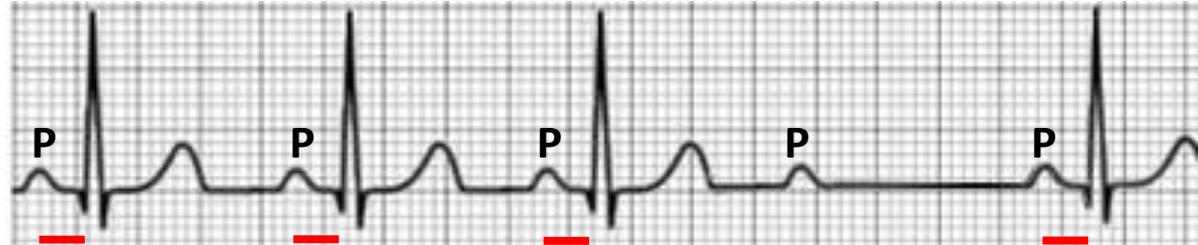
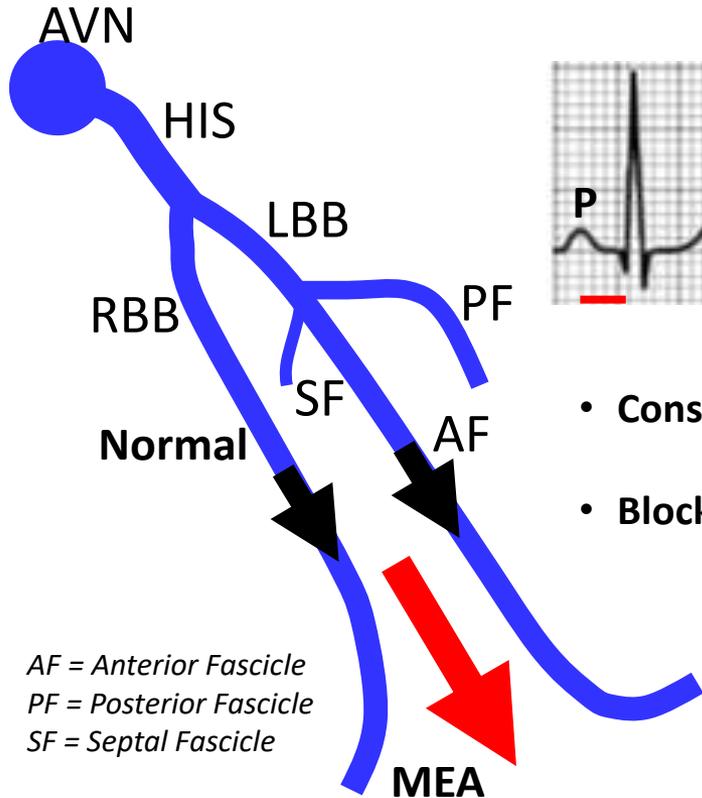
**Mobitz 1 / Wenckebach**

Progressively increasing P-R intervals (ms)

Blocked

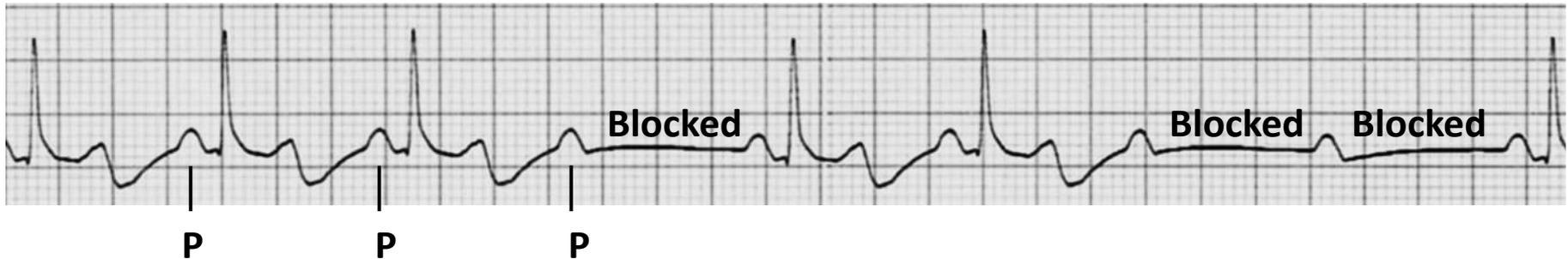


# Conduction Blocks: 2°



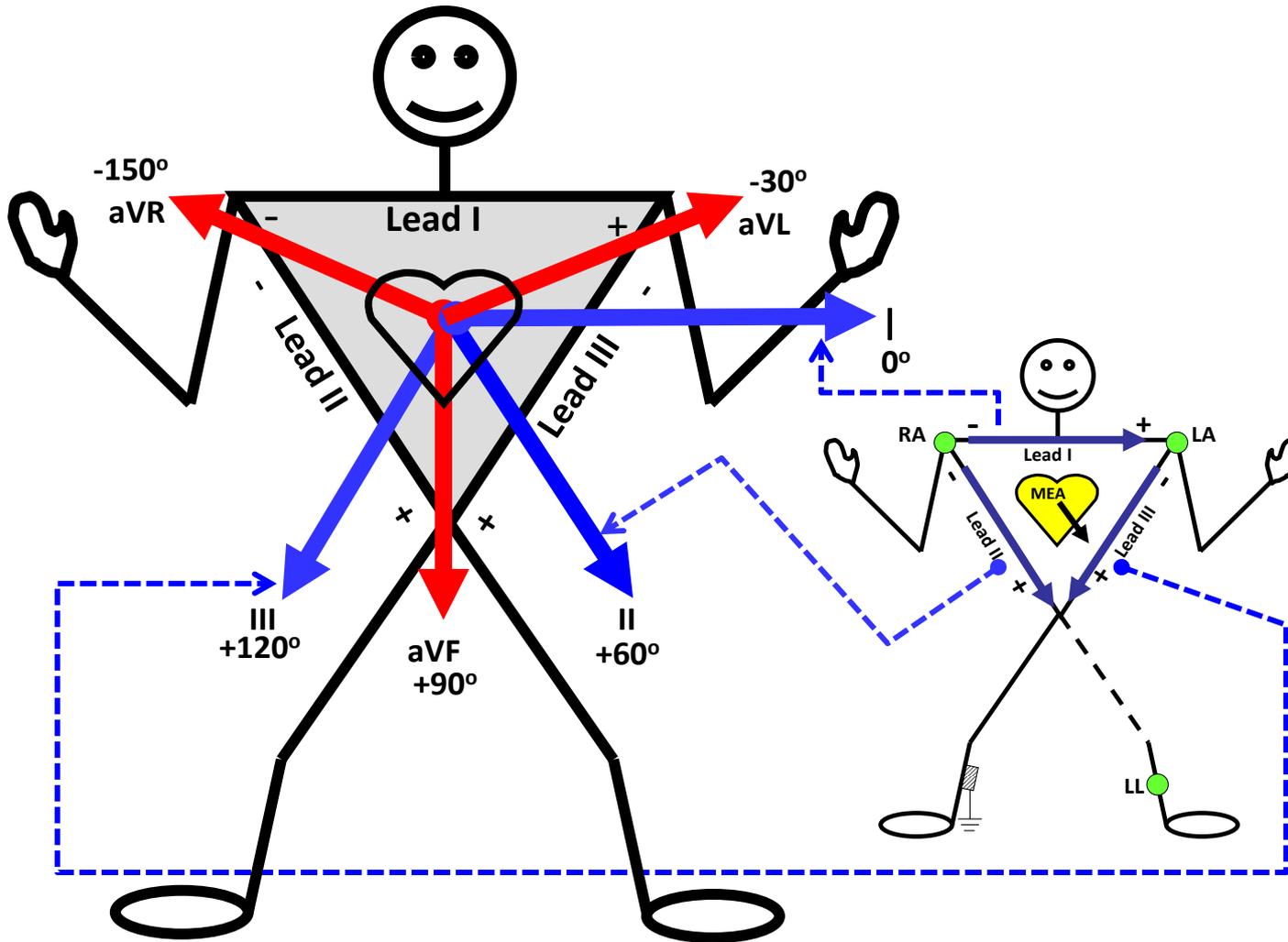
- Constant PR intervals with Intermittent drop of QRS after a P-wave
- Block almost always below the AV (In the His-Purkinje system)

**Mobitz 2 / Hay**

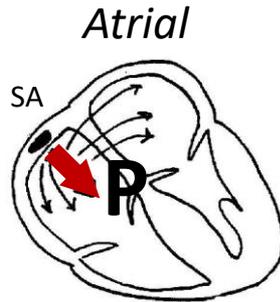
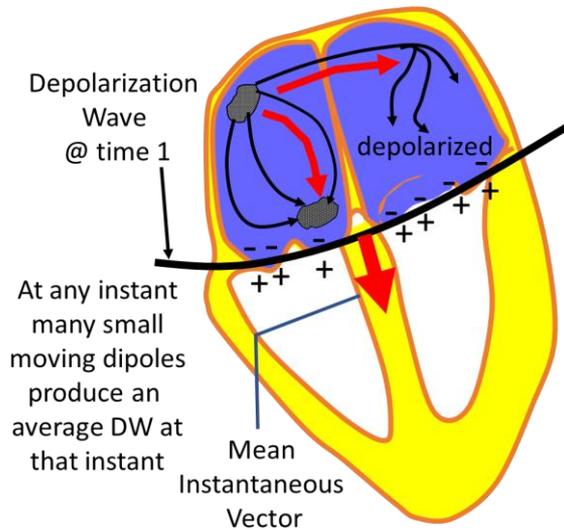


# Leads and Axes

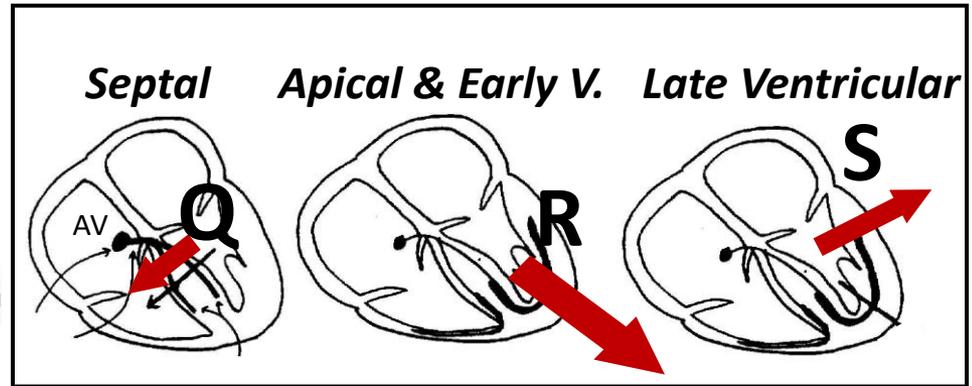
# Frontal Plane Leads and Axes



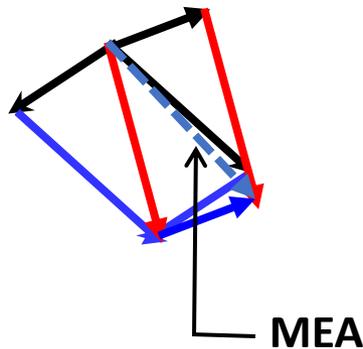
# QRS Vector = Mean Electrical Axis (MEA)



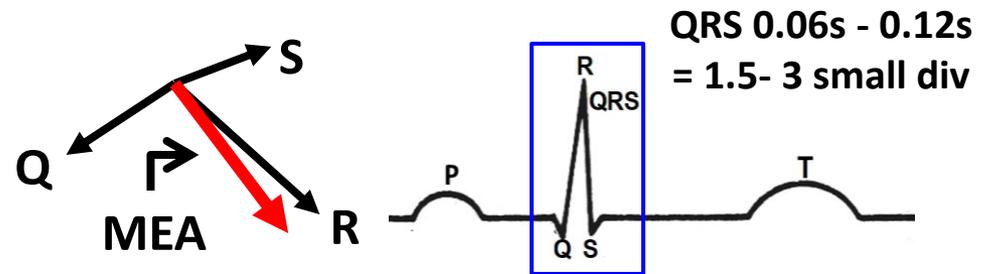
## Occur During the QRS Complex



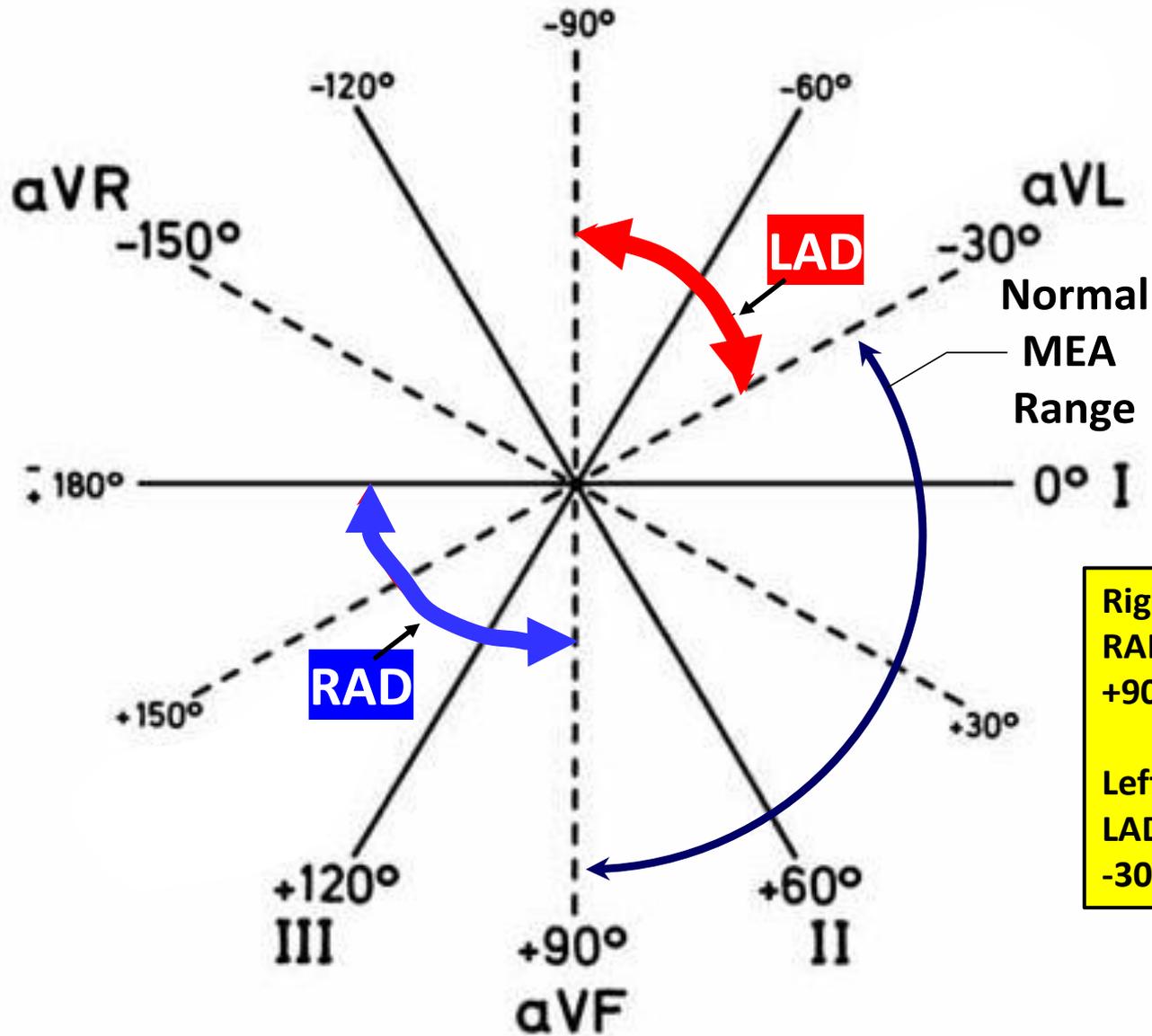
## Adding Components



## Vector addition determines MEA



# Axis Deviations

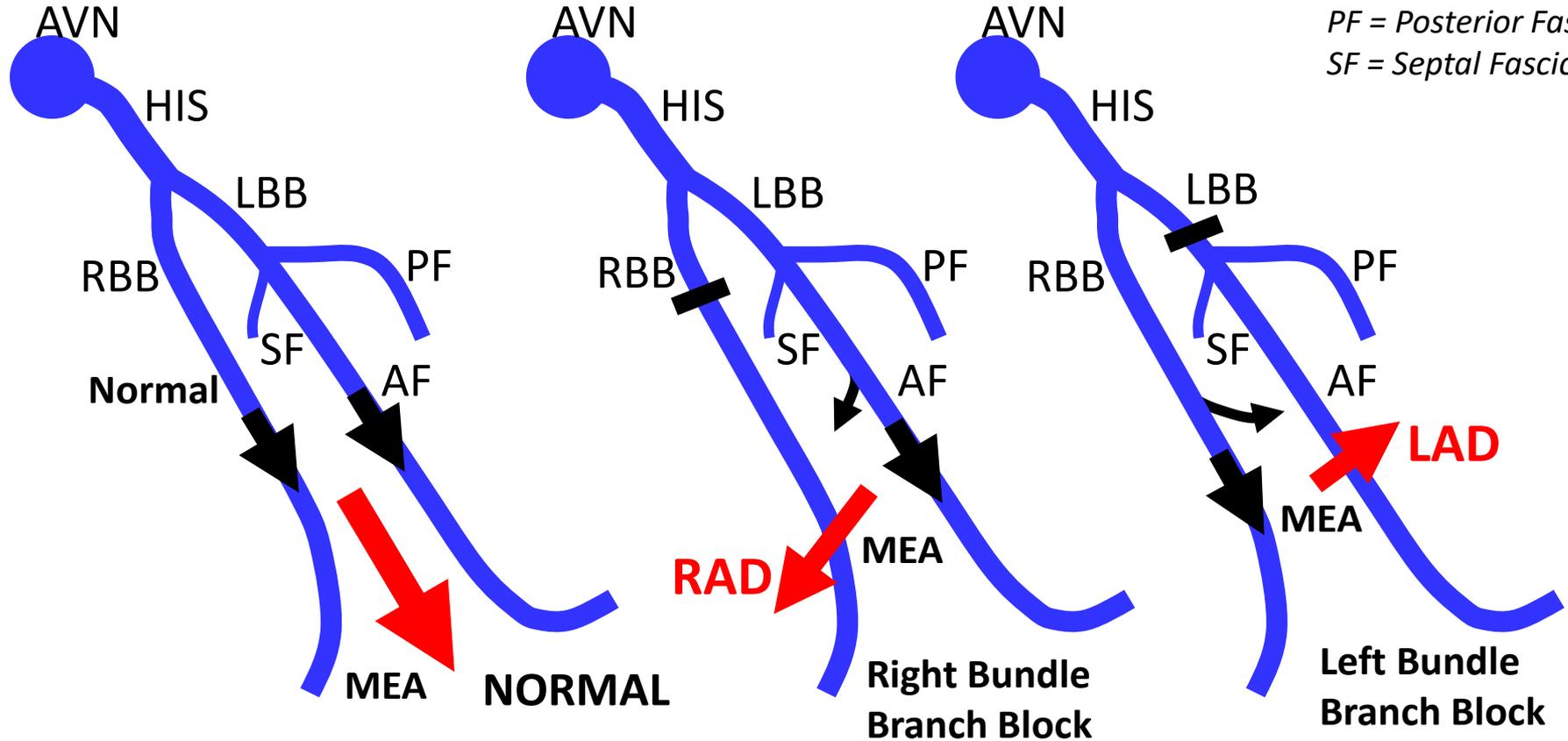


Right Axis Deviation  
RAD if MEA beyond  
+90 to +180

Left Axis Deviation  
LAD if MEA beyond  
-30 to -90

# Conduction Blocks as Source of Axis Deviation

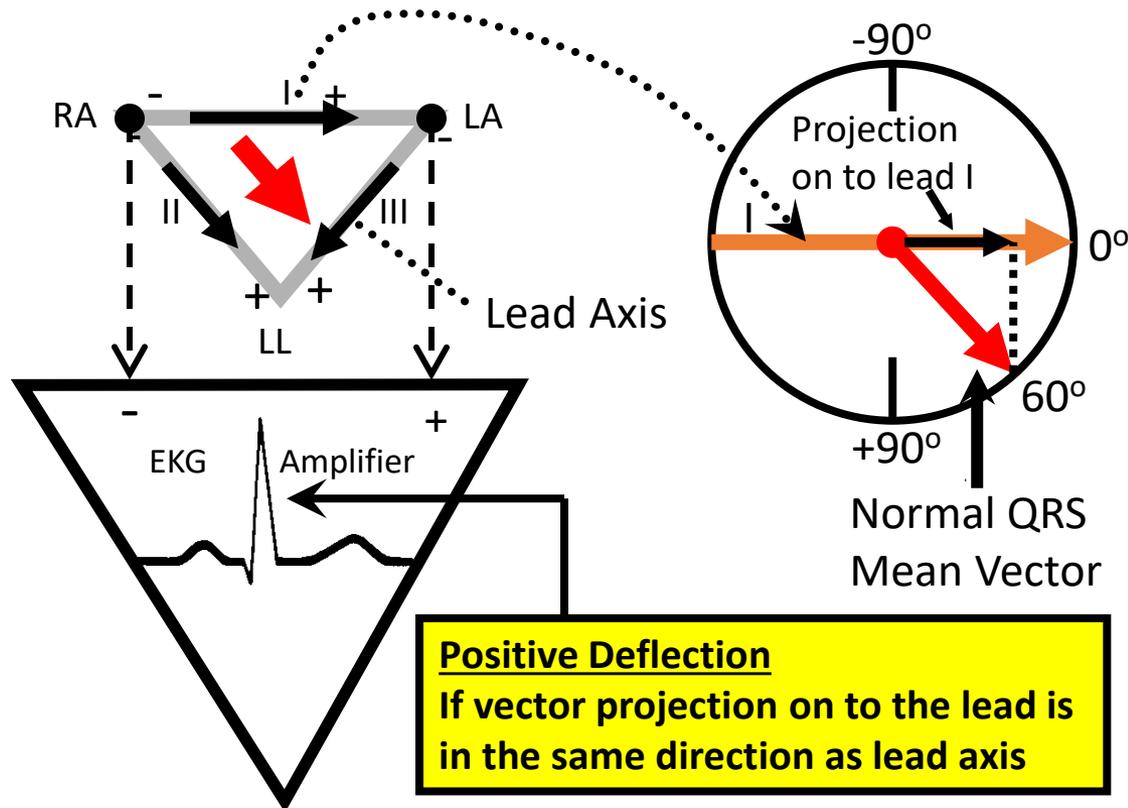
AF = Anterior Fascicle  
 PF = Posterior Fascicle  
 SF = Septal Fascicle



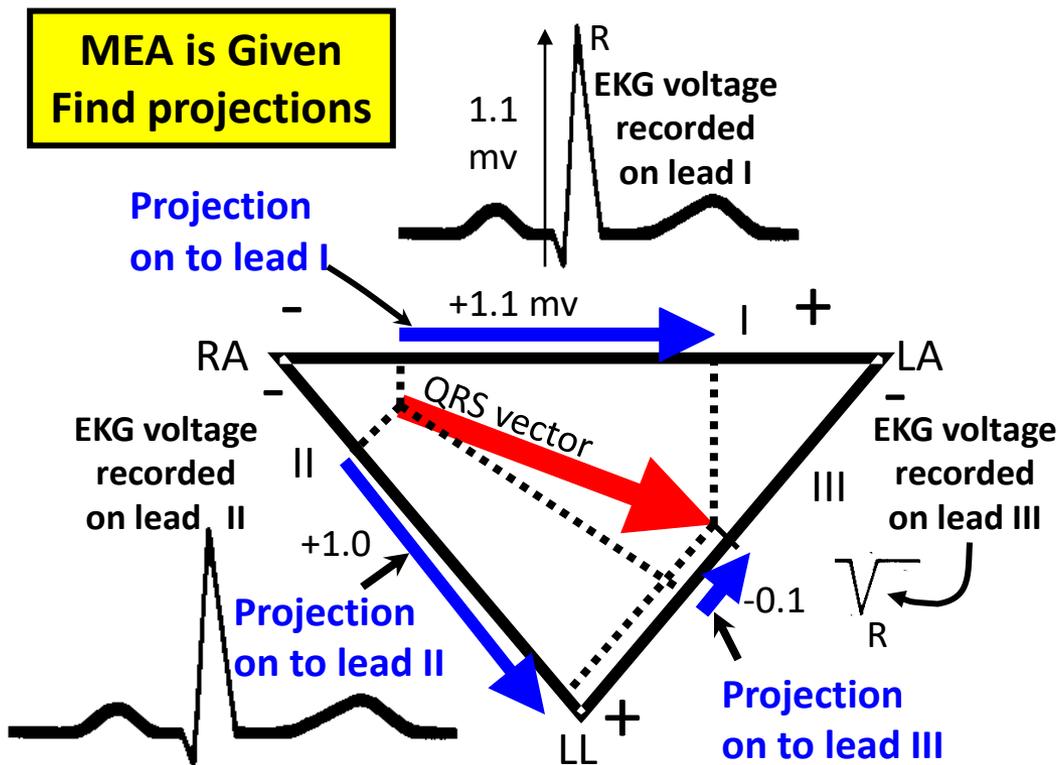
- MEA TIDBITS**
- MEA shift in the direction of a shift in long-axis of the heart
  - MEA shifts toward an area of hypertrophied myocardium
  - MEA shifts away from an area of infarcted myocardium
  - MEA shifts toward the bundle branch block side

# EKG Vector Projection

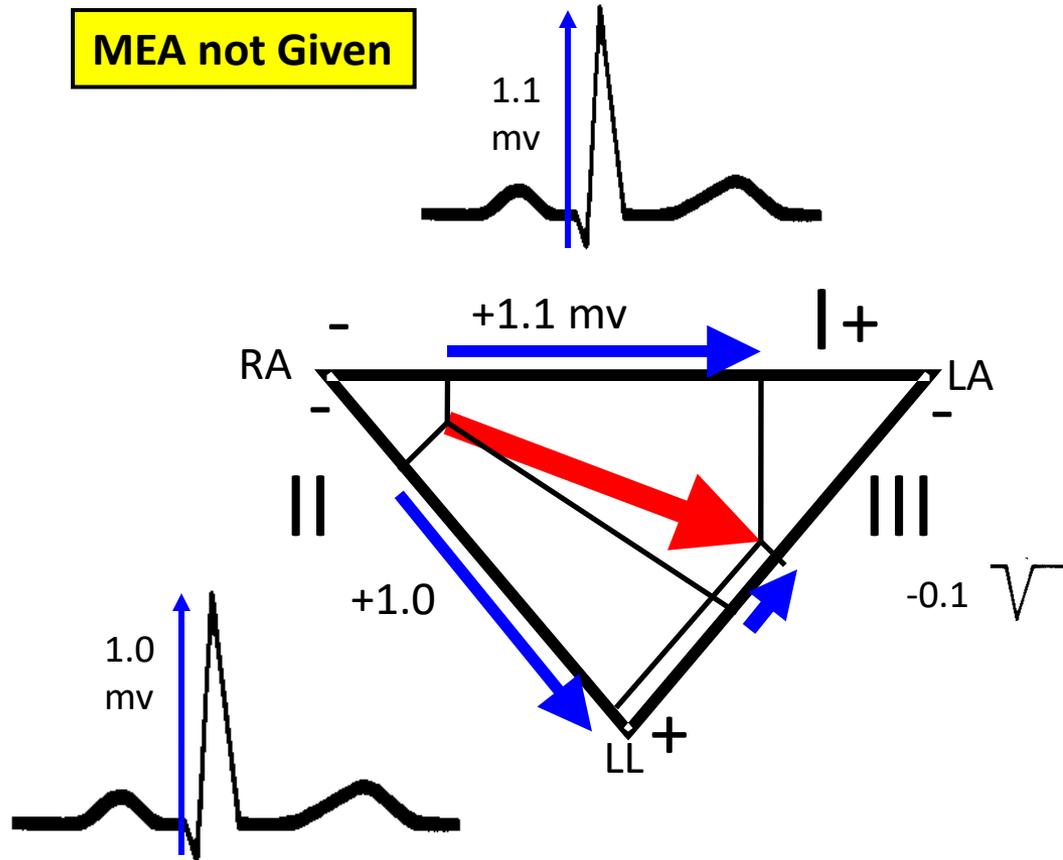
# Cardiac Vector Projection



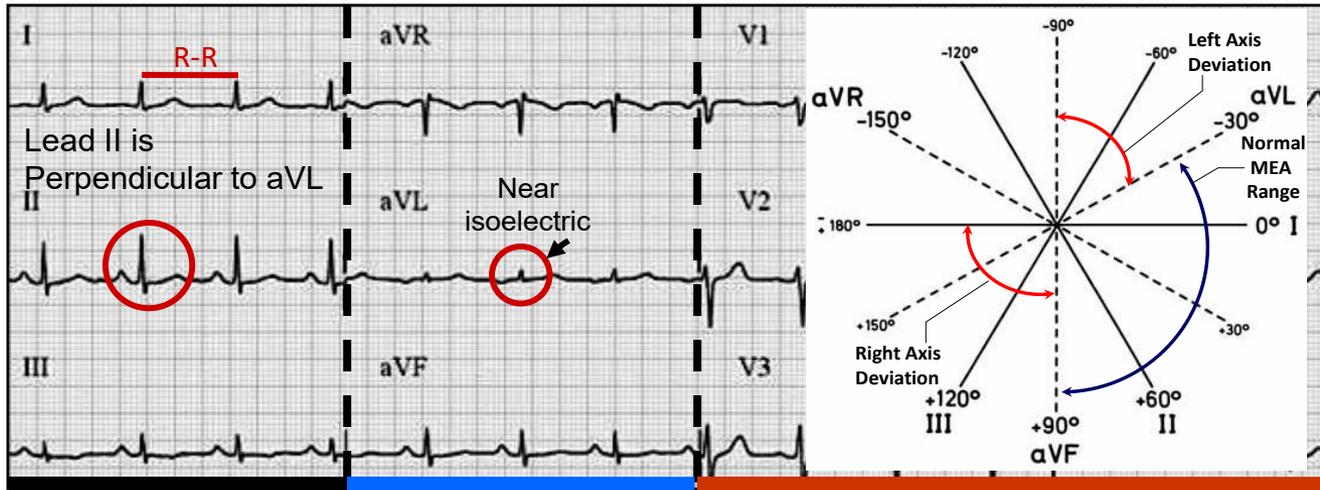
# Cardiac Vector Projection Example



# Cardiac Vector Projection Example Turned Around



# Normal 12-Lead EKG – *Determine MEA*



Standard

Augmented

Precordial

1 mm = 0.1 mv @ 25 mm/sec → 1 mm = 0.04 s or 5 mm = 0.20 s

Projection of *unknown* MEA is most perpendicular to aVL → Therefore MEA is ~ 60° or -120°

But, since lead II is + MEA is normal ~60°

# **EKG Patterns**

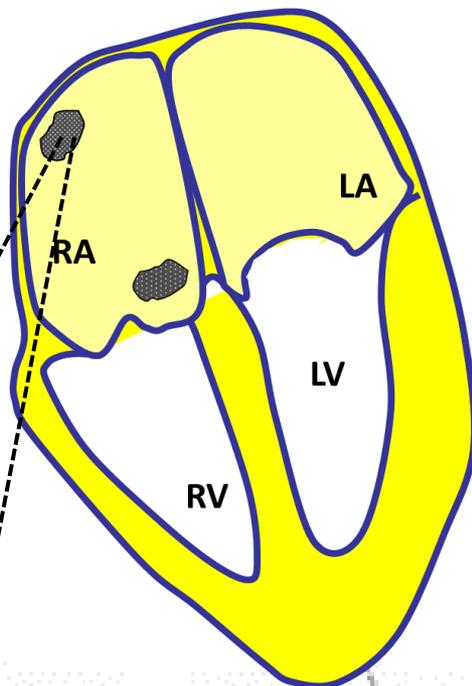
## **Normal and Not-So-Normal**

### **(as time permits)**

# Normal

Sinus Rate  
 $60/(P-P)$  in sec

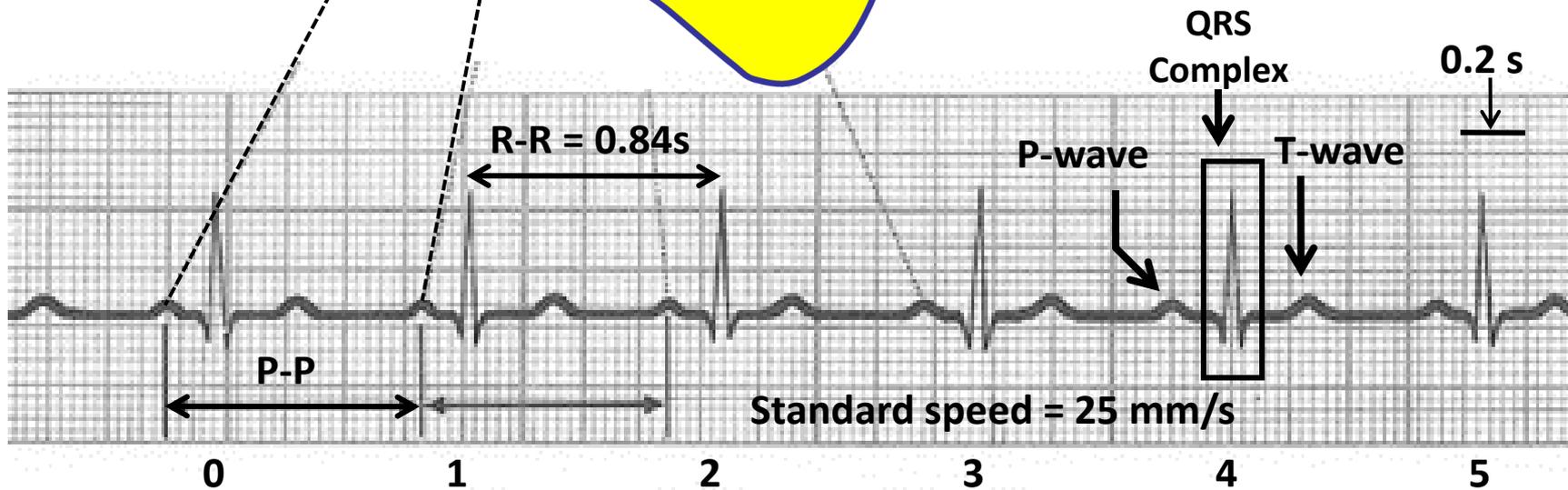
Ventricular Rate  
 $60/(R-R)$  in sec



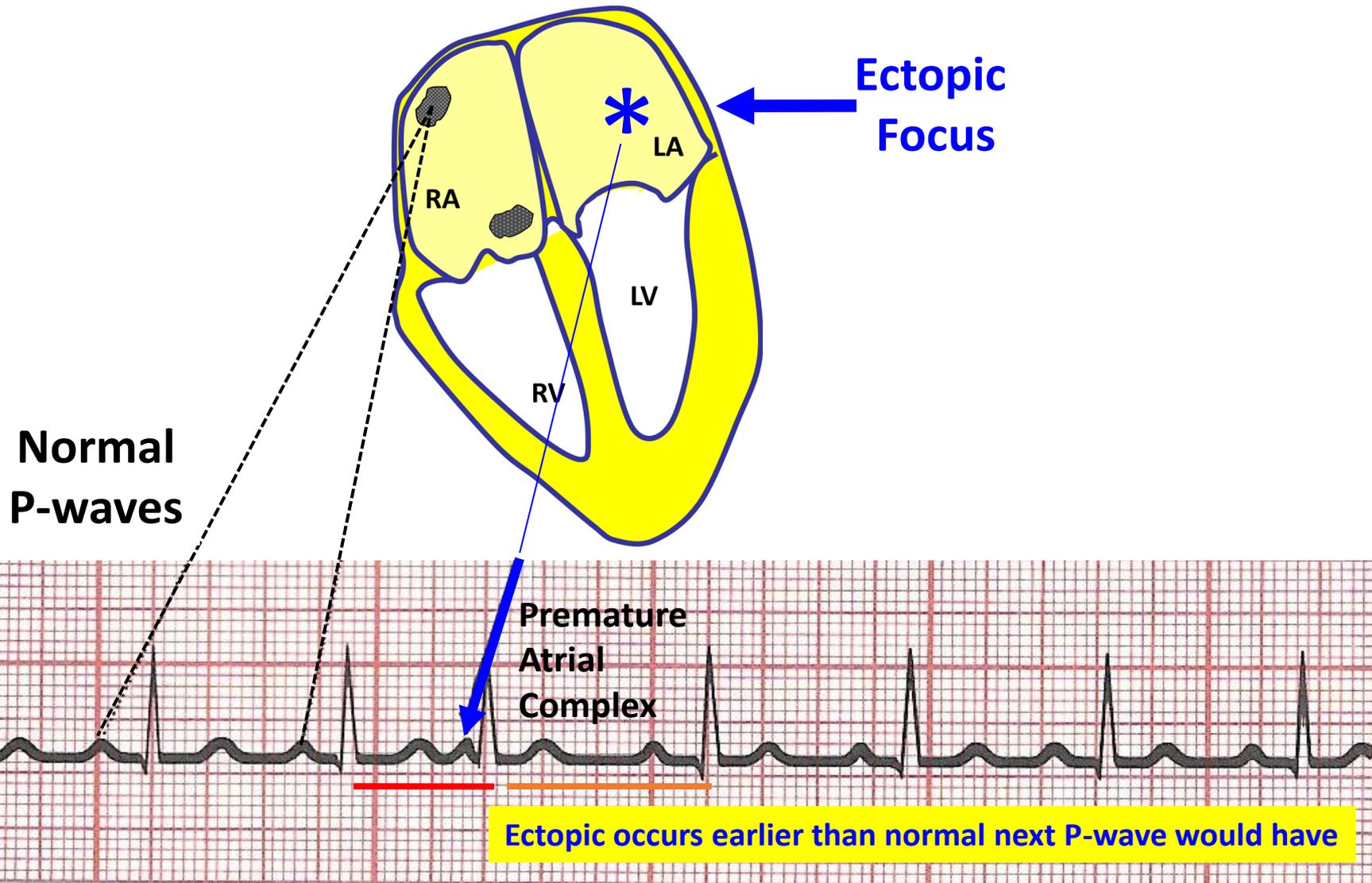
5 beats in  $\times 21.2 \times 0.2$  sec = 4.24 sec  
= how many per minute?  
=  $(60/4.24) \times 5 = 70.8$  bpm

Variability is  
Normal

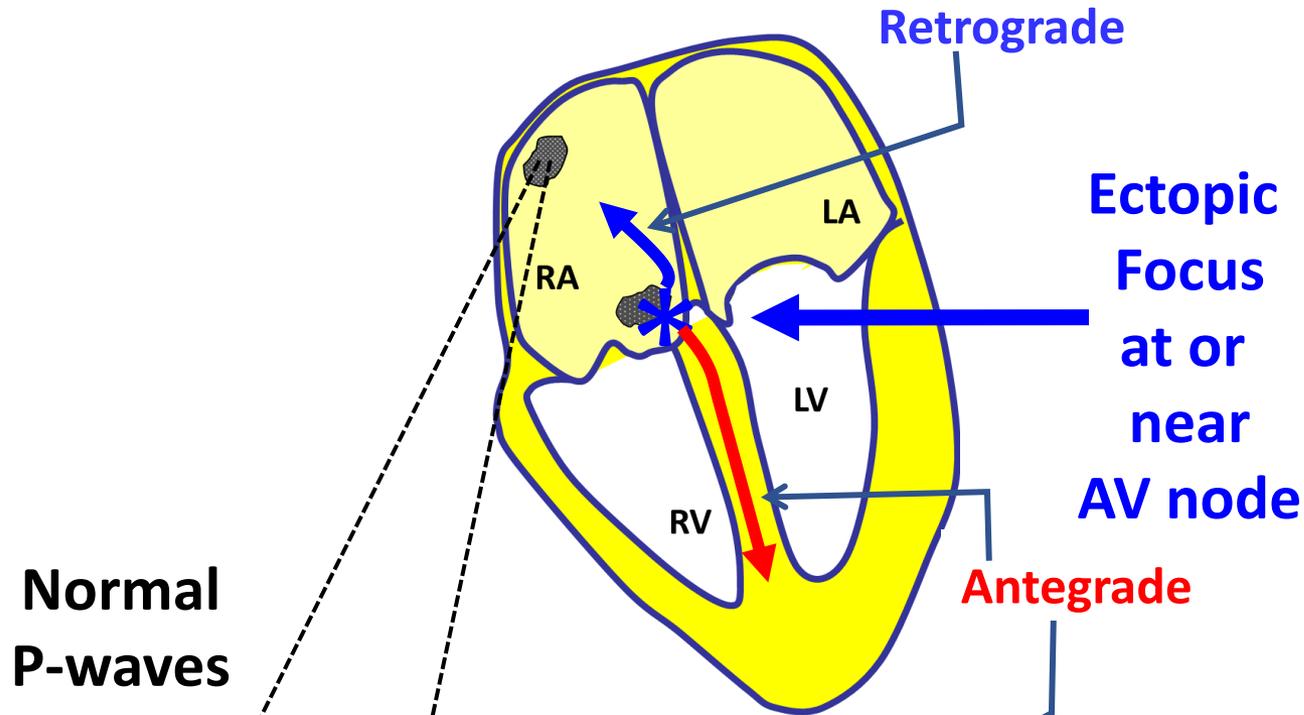
Heart Rate (HR)  
 $60/(R-R)$  in sec  
 $60/0.84 = 71.4$  bpm



# Atrial Ectopic Impulse – Early



# Ectopic Impulse – Negative P-Wave



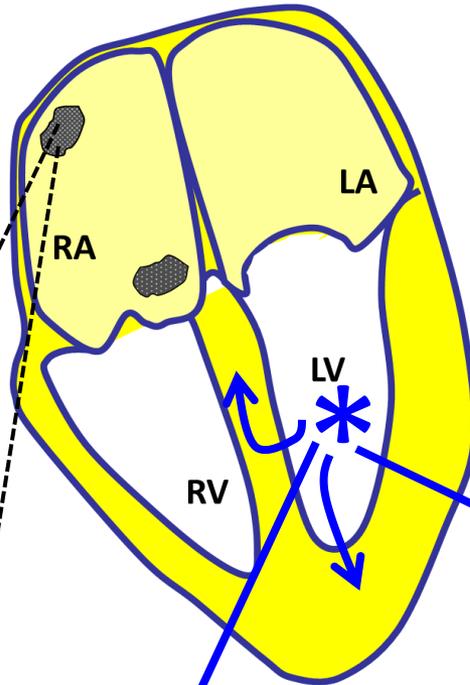
Normal P-waves

Lead II

Ectopic prior to normal P-wave – retrograde conduction – negative “P”

# Ectopic Impulse – Ventricular

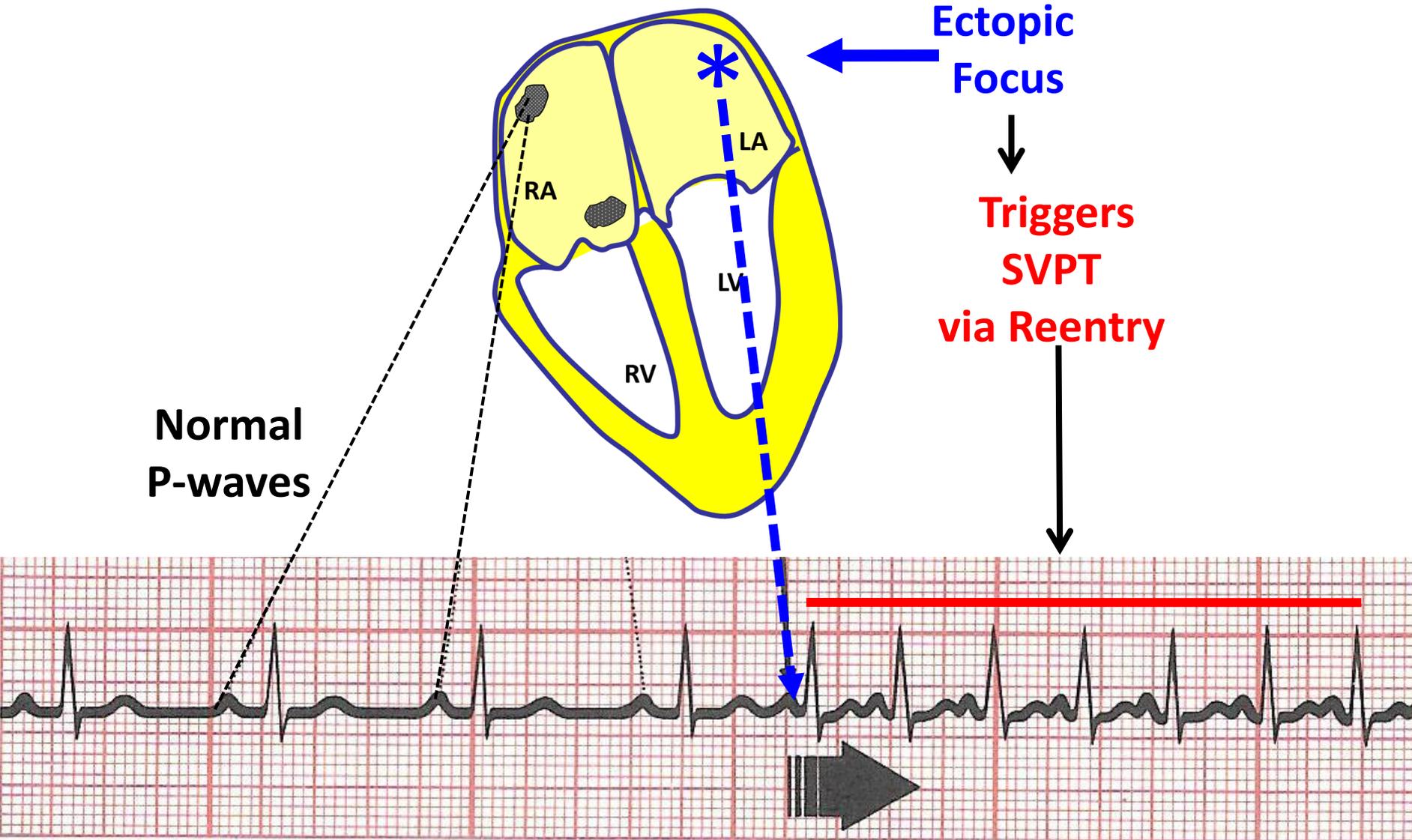
Normal  
P-waves



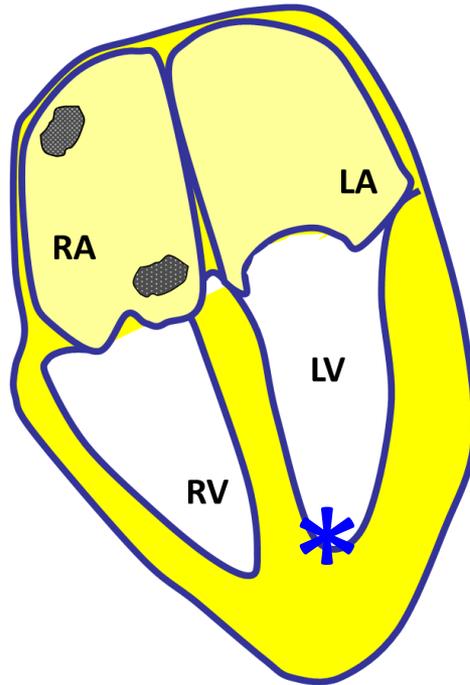
Ectopic  
Focus in  
ventricle  
muscle or  
conduction  
pathway



# Supraventricular Paroxysmal Tachycardia

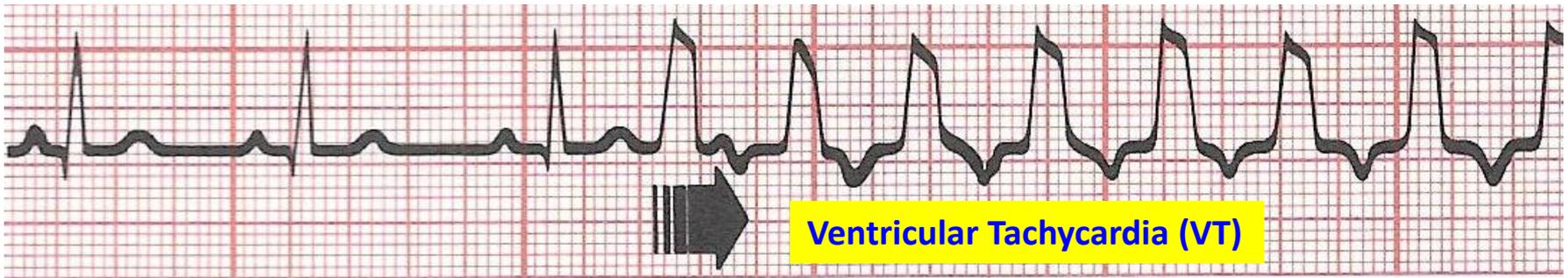


# Ventricular Tachycardia

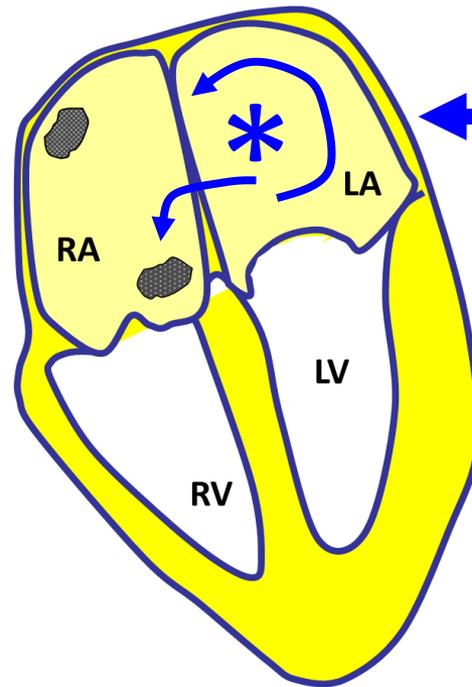


**Ectopic  
Focus  
Ventricle  
Triggers  
VT**

$$\text{HR} \sim 60/0.4 = 150 \text{ bpm}$$



# Flutter Waves



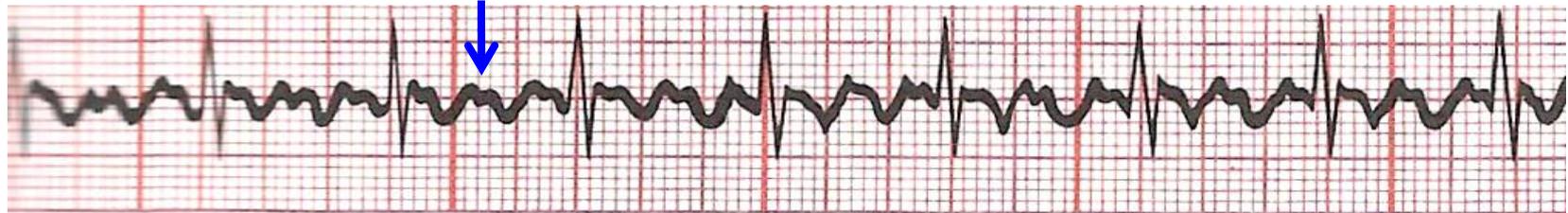
**Ectopic Focus With Reentry and Re-excitation**



**“Flutter Waves”**

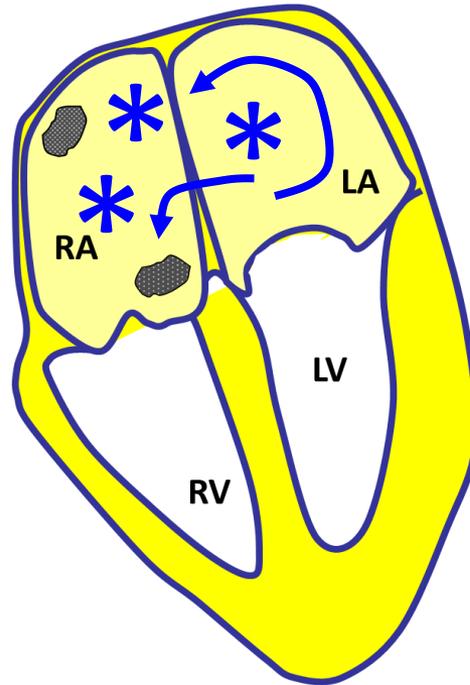
0.6 s

$HR = 60/0.6 = 100$

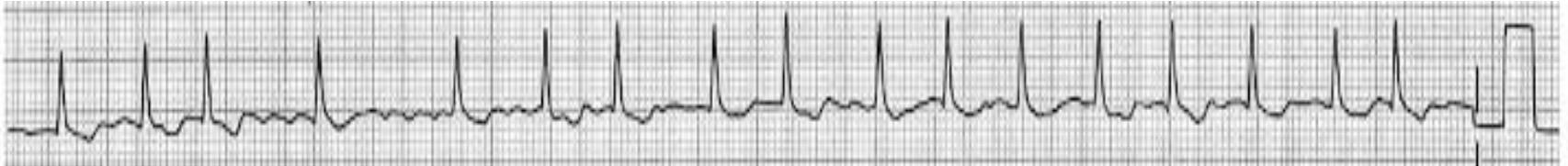


**Atrial depolarizations not passing through AV**

# Atrial Fibrillation

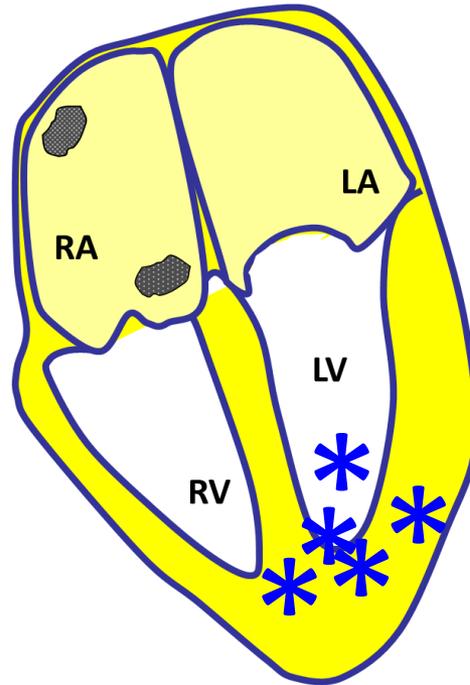


**MULTIPLE  
Ectopic  
Foci  
causing  
uncoordinated  
impulse  
transmission  
through AVN**



**Atrial Fibrillation (aFib) → Rhythm is irregularly irregular**

# Ventricular Fibrillation



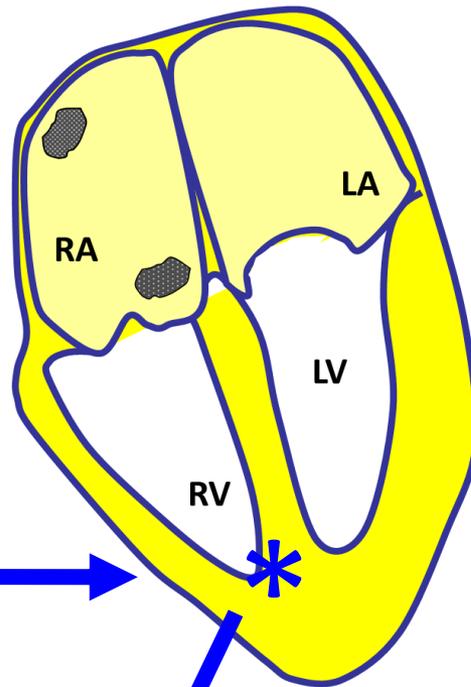
**MULTIPLE  
Ectopic  
Foci**



**Erratic uncoordinated electrical and mechanical activity**

# R on T: Ventricular Fibrillation

Ectopic impulse occurs during a vulnerable interval as ventricle is repolarizing (T-Wave upstroke)



*Similar Effect with Commotio Cordis*



# End CV Physiology Lecture 3