Cardiovascular Physiology

Lecture: 8

Electrocardiogram (ECG)

By
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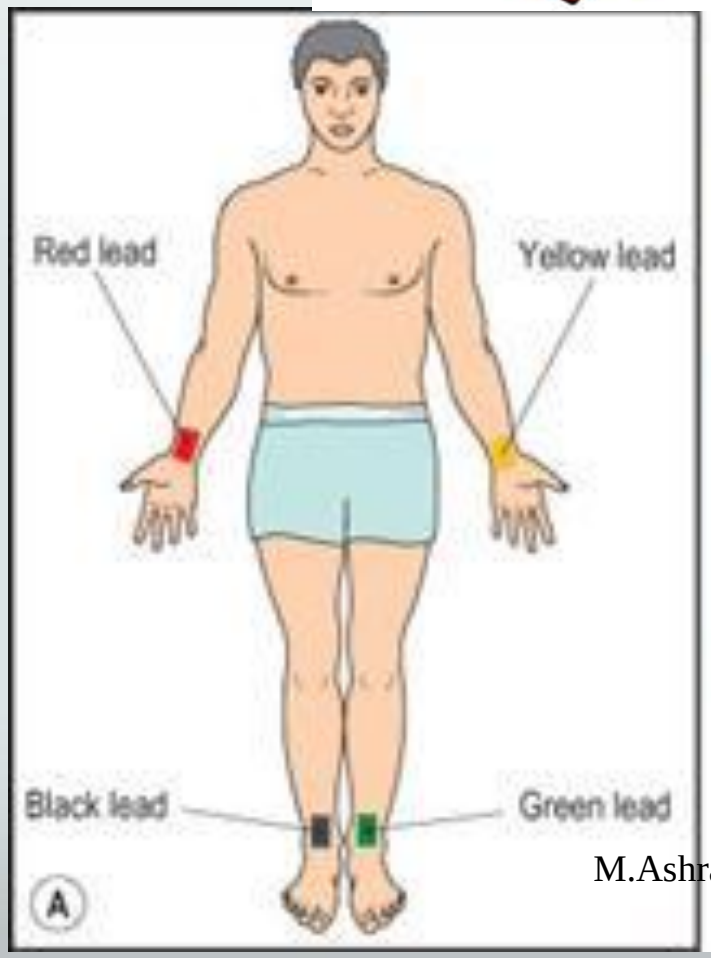
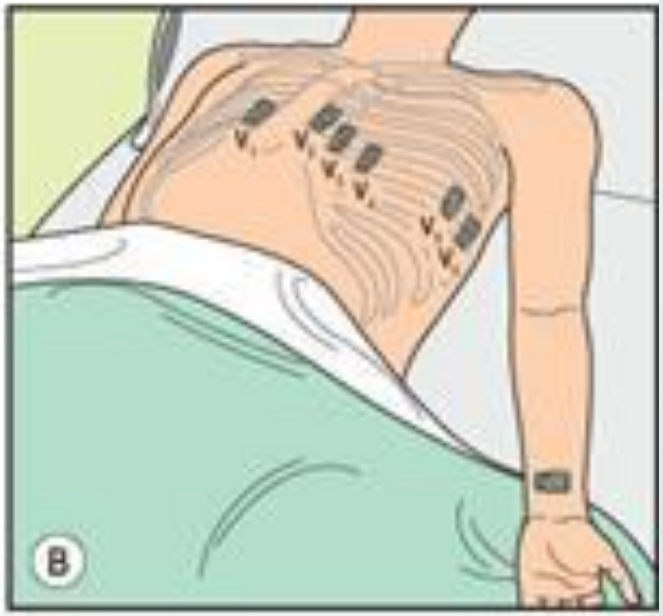
Electrocardiogram (ECG)

- It is a record of the electrical changes of the heart during the cardiac cycle.
- It provides important information about cardiac structure and function.
- ECG is a sensitive galvanometer which records the potential differences by its 2 electrodes.
- As the tissues and tissue fluids are good conductors ECG electrodes are placed **on the skin** of the chest wall and extremities.

Electrocardiogram Leads

- The particular arrangement of the 2 electrodes is called ***the lead.***
- Each leads takes a “snapshot” from a different angle of the heart’s net electrical activity.
- This provides useful information about location of myocardial infarction (MI), assessing for Left Ventricular or Right Ventricular hypertrophy).



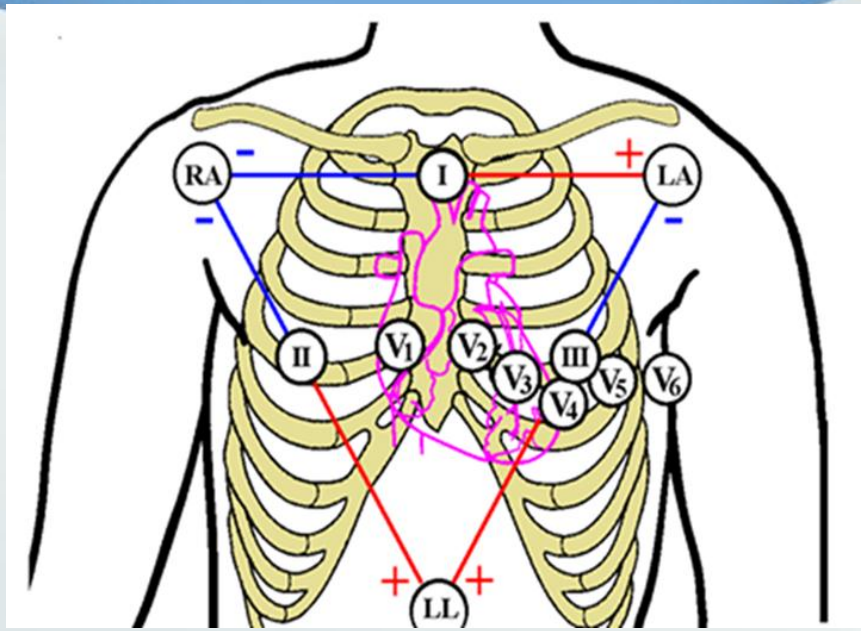


ECG leads in the conventional 12 lead ECG

I. Bipolar leads:

1) **Lead I:** between the ***right arm*** to the –ve electrode and the ***left arm*** to the +ve electrode (-R , +L)

2) **Lead II:** between the ***right arm*** to the –ve electrode and the ***left foot*** to the +ve electrode. (- R , + F)

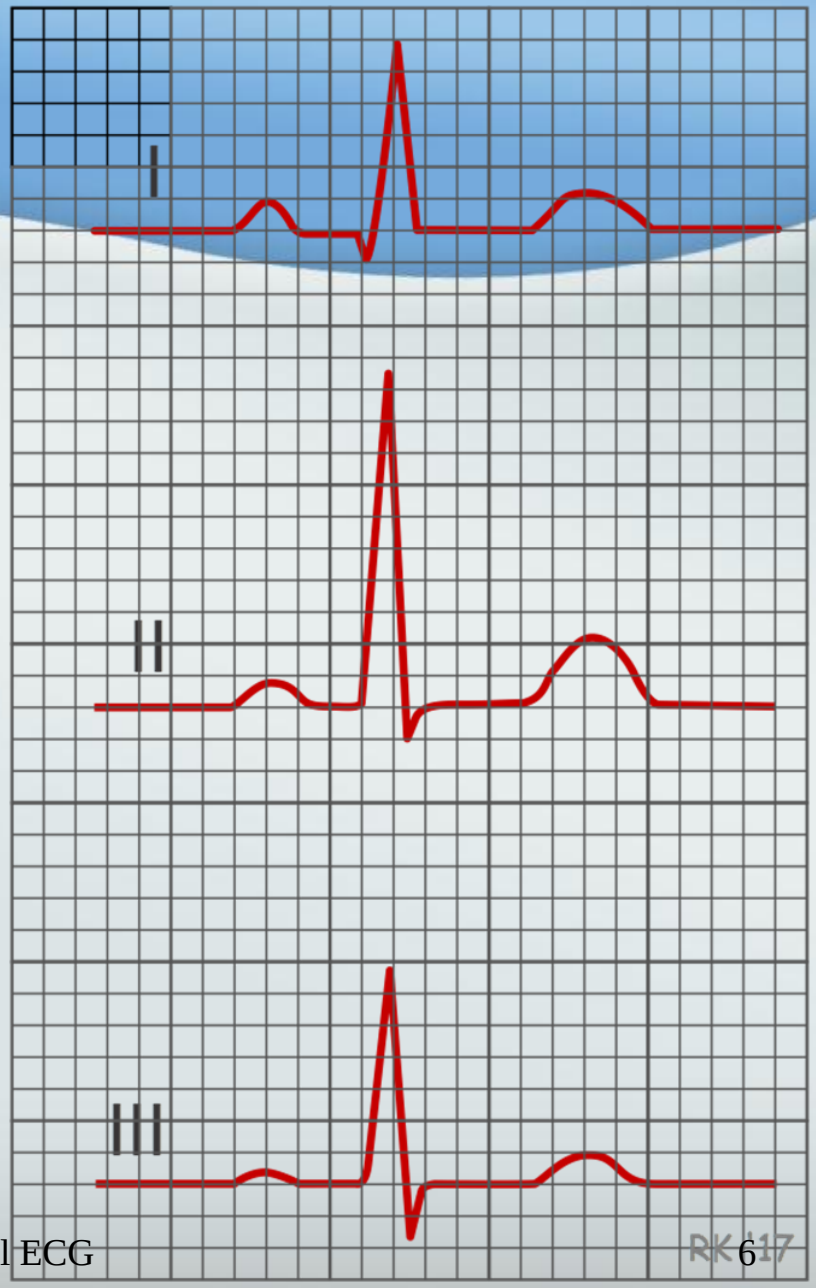


3) **Lead III:** between the ***left arm*** to the –ve electrode and the ***left foot*** to the +ve electrode. (- L , + F)

Einthoven´s law

"the sum of voltages in lead I & III equals the voltage in lead II".

$$Lead\ I + Lead\ III = Lead\ II$$



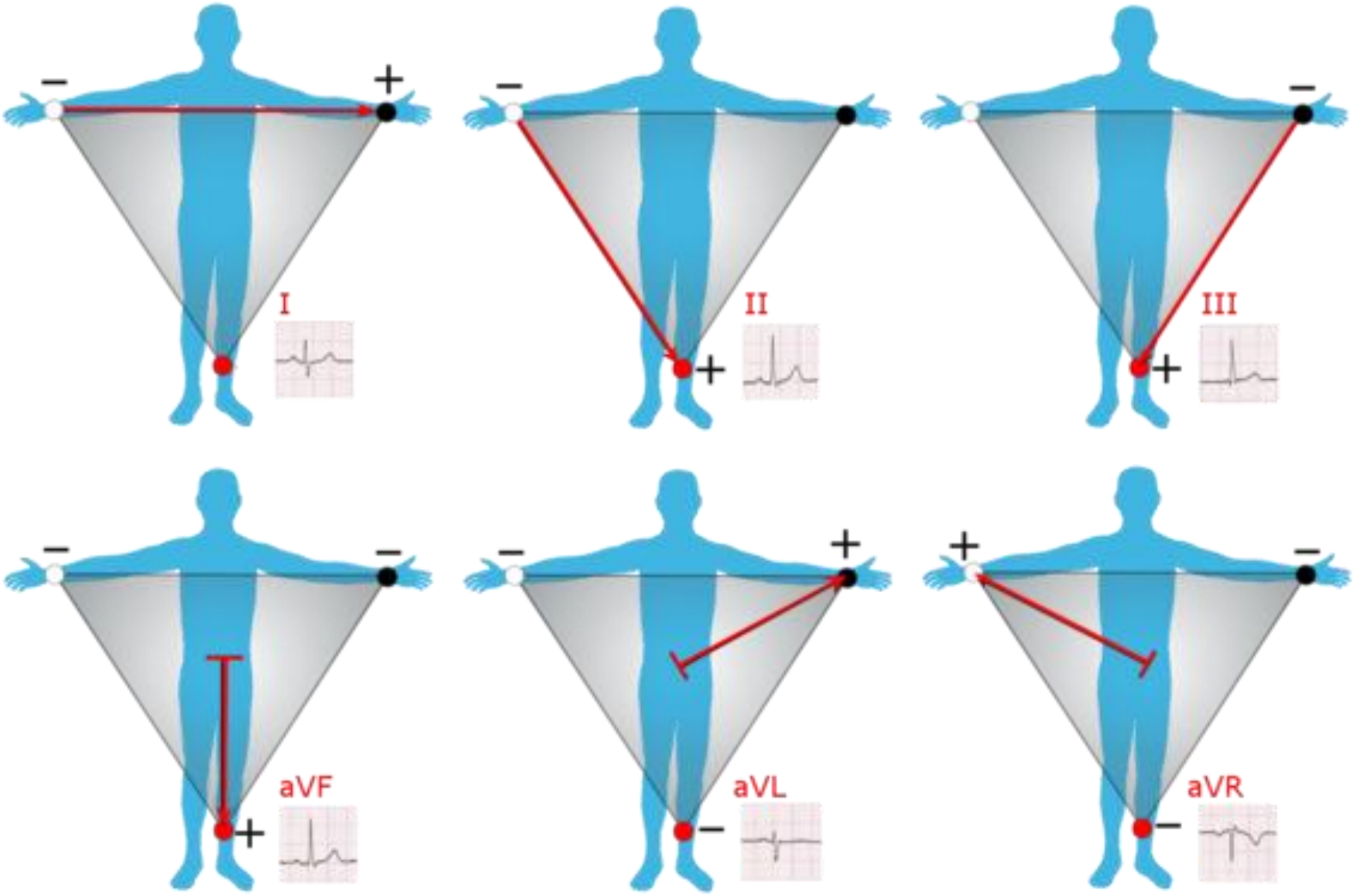
Unipolar leads

A.Limb leads:

1)**aVR**: between the right arm to the +ve electrode and both the left arm & the left foot to the -ve electrode.

2)**aVL**: between the left arm to the +ve electrode and both the right arm & the left foot to the -ve electrode.

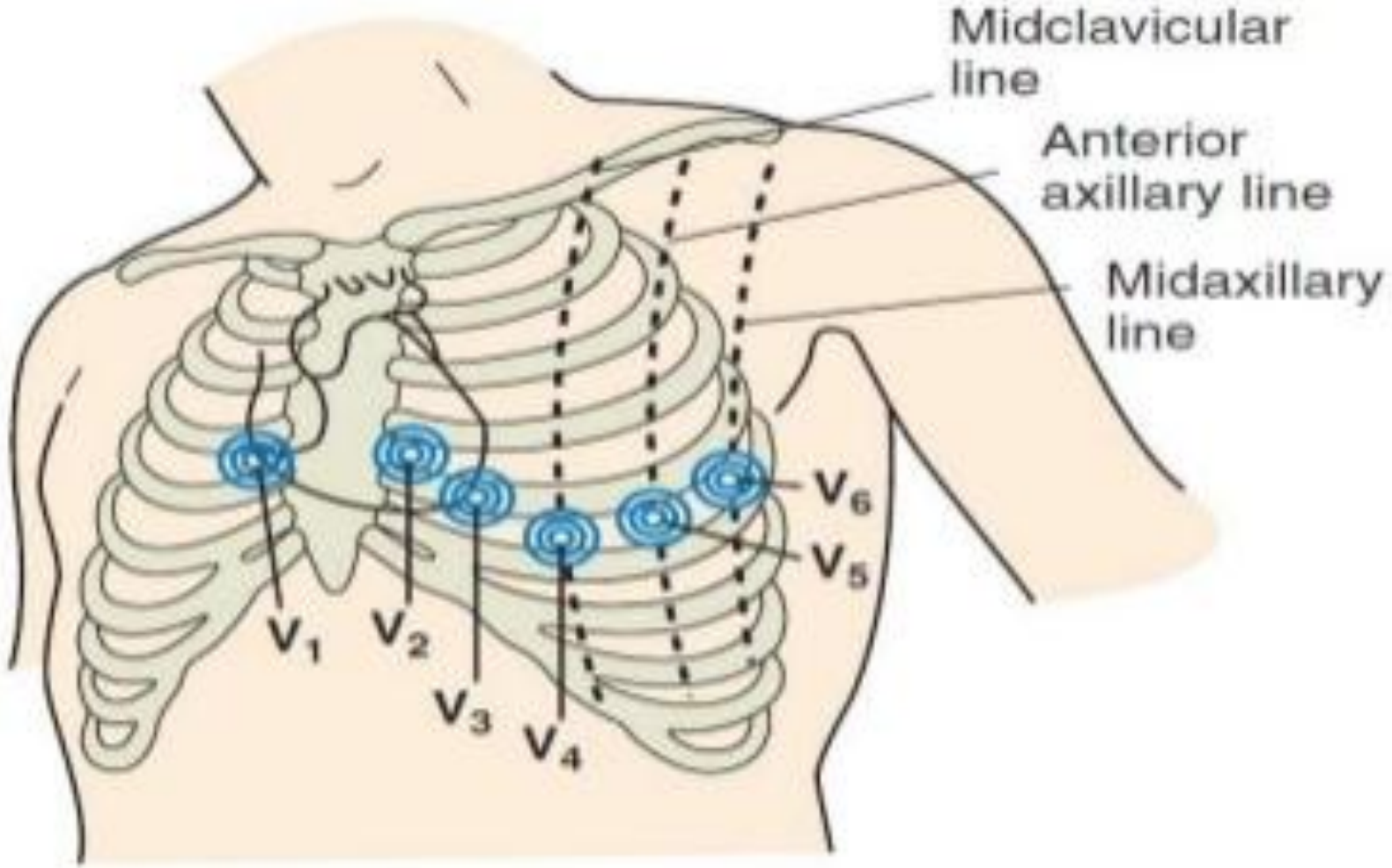
3)**aVF**: between the left foot to the +ve electrode and both the right arm & the left arm to the -ve electrode.


I
II
III
aVF
aVL
aVR

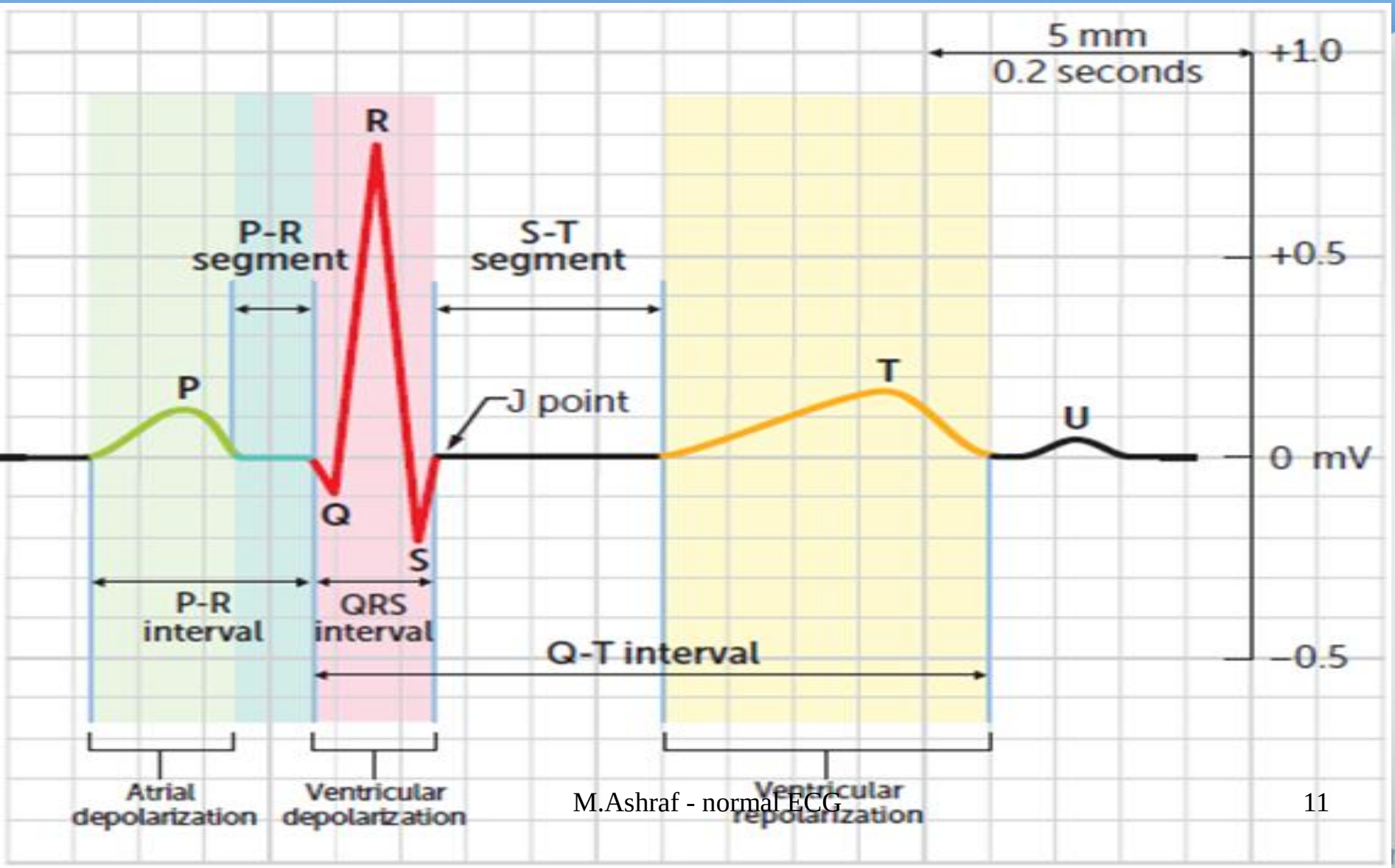
B. Chest leads:

- **V_1**: right 4th intercostal space near the sternum.
- **V_2**: left 4th intercostal space near the sternum.
- **V_3**: midway between V_2 & V_4.
- **V_4**: left 5th intercostal space midclavicular line.
- **V_5**: left 5th intercostal space anterior axillary line.
- **V_6**: left 5th intercostal space midaxillary line.

Standard Chest Lead Electrode Placement



Normal ECG


5 mm
0.2 seconds
+1.0
+0.5
0 mV
−0.5
R
P-R segment
S-T segment
P
J point
T
U
Q
S
P-R interval
QRS interval
Q-T interval
Atrial depolarization
Ventricular depolarization
Ventricular repolarization

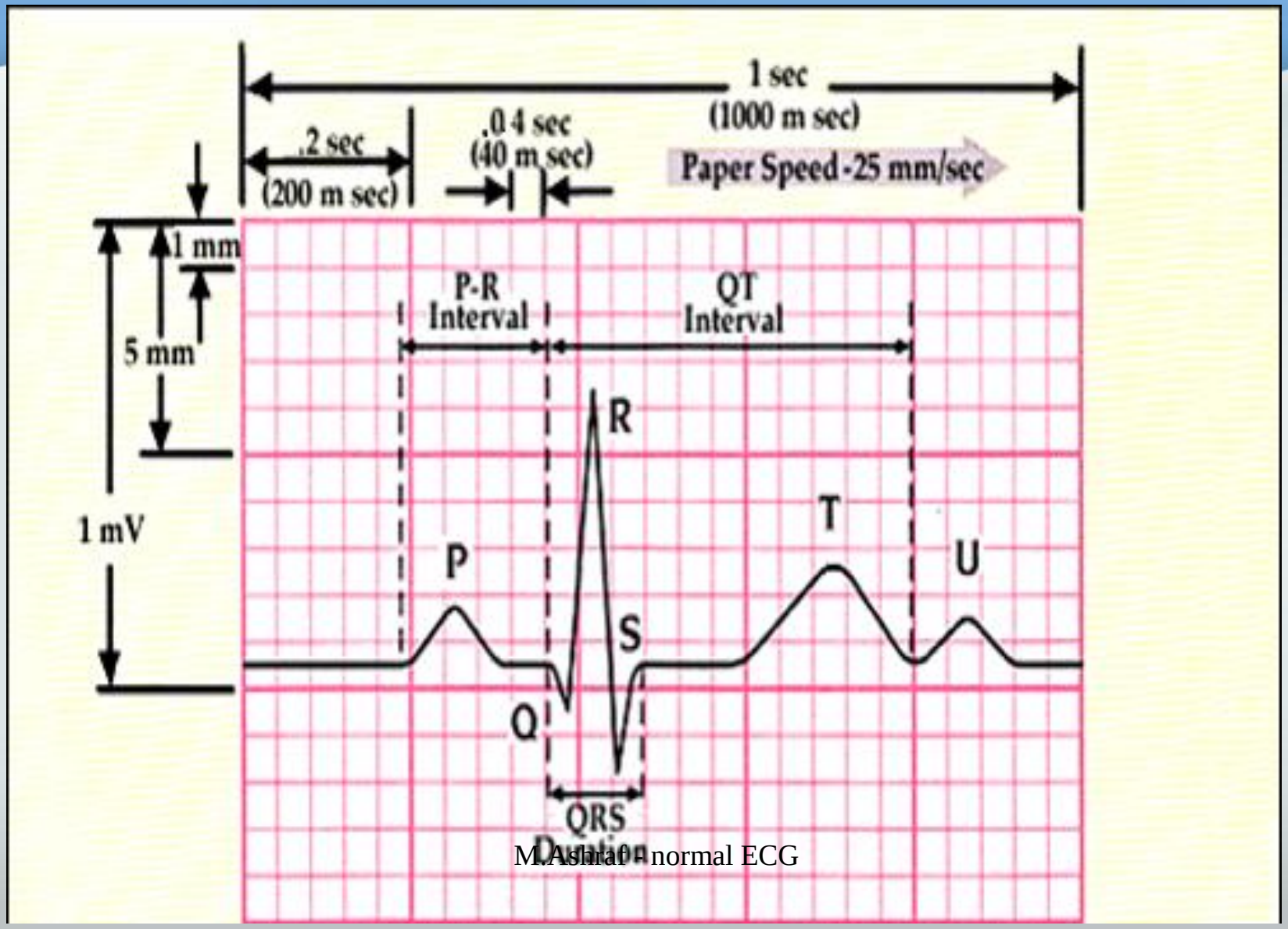
Normal ECG waves

- There are 3 positive waves (P, R & T waves) and 2 negative waves (Q & S waves) in normal ECG.
- rarely seen tiny wave called (U wave). Appears prominent in hypokalemia (think hyp“U”kalemia) & bradycardia.
- **P wave** represents atrial depolarization.
- **QRS complex** represents ventricular depolarization.
- **T wave** represents ventricular Repolarization.
- **J point**—junction between end of QRS complex and start of ST segment.
- There is no wave for atrial Repolarization because it is masked by the QRS complex and of low voltage.

P wave

- Appears clearly in lead II and V1.
- Represents **atrial depolarization**.
- It precedes atrial systole by 0.02 second.
- **Duration** = 0.1 second.
- **Voltage** = 0.1- 0.2 mv.

Electrocardiogram Interpretation



Abnormalities of P wave

- ***Large P wave***: occurs in atrial hypertrophy.
- ***Absent P wave***: in atrial fibrillation (it is replaced by fine irregular (f waves).
- ***Abnormal shaped***: in atrial ectopic.
- ***Inverted***: in A-V nodal rhythm.

QRS complex

- ⇨ Represent ventricular depolarization.
- ⇨ It starts 0.02 second before the beginning of ventricular contraction.
- ⇨ **Duration** = 0.08 second. (*Less than that of P wave due to the passage of impulses in high speed Purkinje fibers*).
- ⇨ **Voltage**: 1.2 mv.

- **Q wave:** it is a small (often inconspicuous) downward deflection, caused by depolarization of interventricular septum.
- **R wave:** it is a prominent upward deflection, caused by depolarization of the apex, lateral walls & most of ventricular base.
- **S wave:** it is a downward deflection, caused by depolarization of remaining part of ventricular base.

Abnormalities of QRS

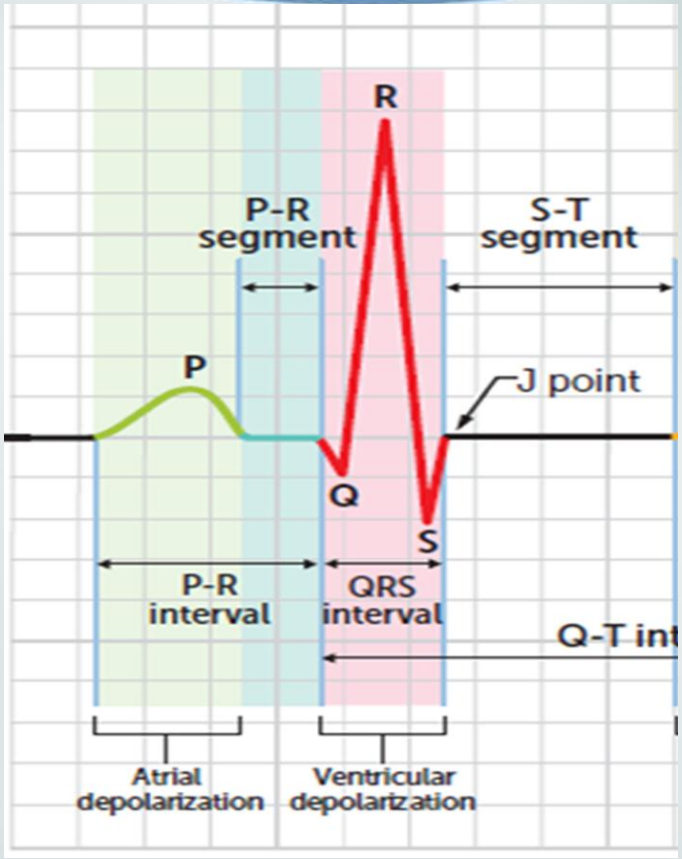
- ***Large QRS***: occurs in ventricular hypertrophy.
  - ✓ In Left ventricular hypertrophy as in hypertension gives an abnormally tall R wave in V6. In Right ventricular hypertrophy gives an abnormally tall R wave in V1.
  - ✓ Rt or Lt ventricular hypertrophy can be also differentiated by axis deviation.
- ***Stunted R wave***: in extensive infarction.
- ***Prolonged duration***: in slow ventricular depolarization as in BBB or in ventricular ischemia.

T wave

- ⇨ Represents ventricular repolarization.
- ⇨ **Duration** = 0.25 second.
- ⇨ **Voltage** = 0.2- 0.3 mv.
- ⇨ **Abnormalities**:
  - ✓ ***Inverted***: In BBB, ventricular ischemia or recent MI.

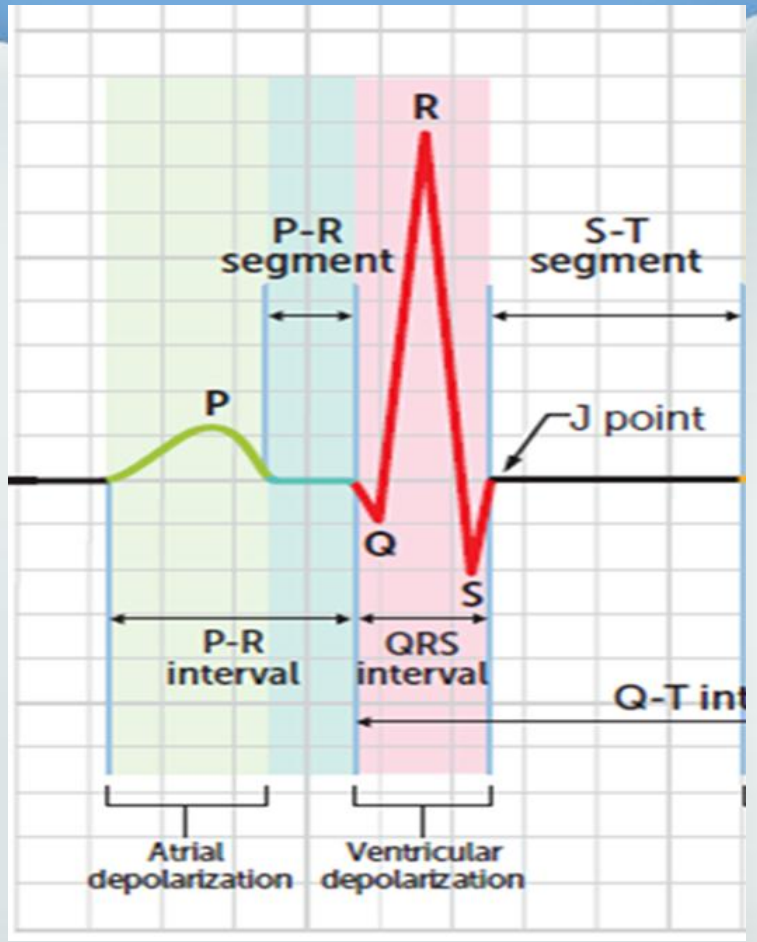
ECG intervals and segments

- **Intervals** include a portion of the ECG baseline and at least one wave.
- **Segments** (eg, ST segment) only include portions of the ECG baseline and do not include waves.



P-R interval

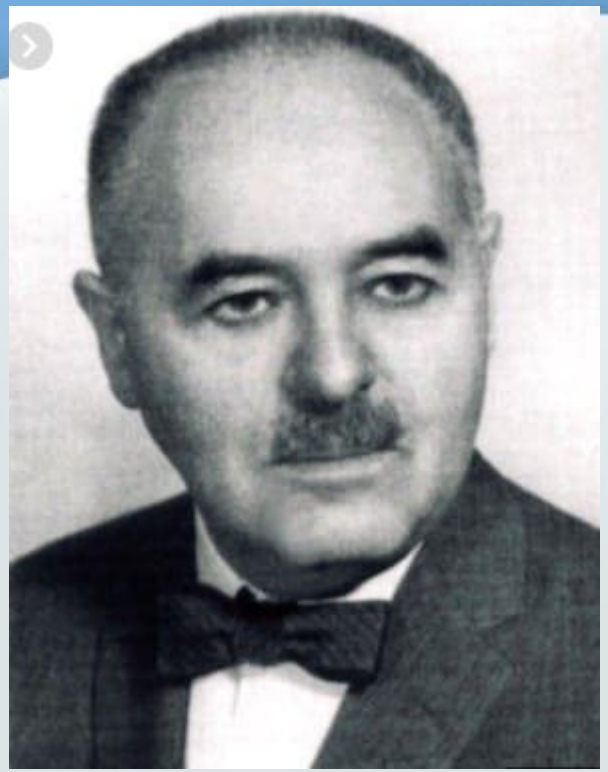
- Measured from the **beginning of P** wave to the **beginning of the QRS** complex.
- It represents the time of conduction of impulses from the atria to the ventricles through the conducting system.
- Normally = **0.12 – 0.20 sec** (3–5 small boxes).

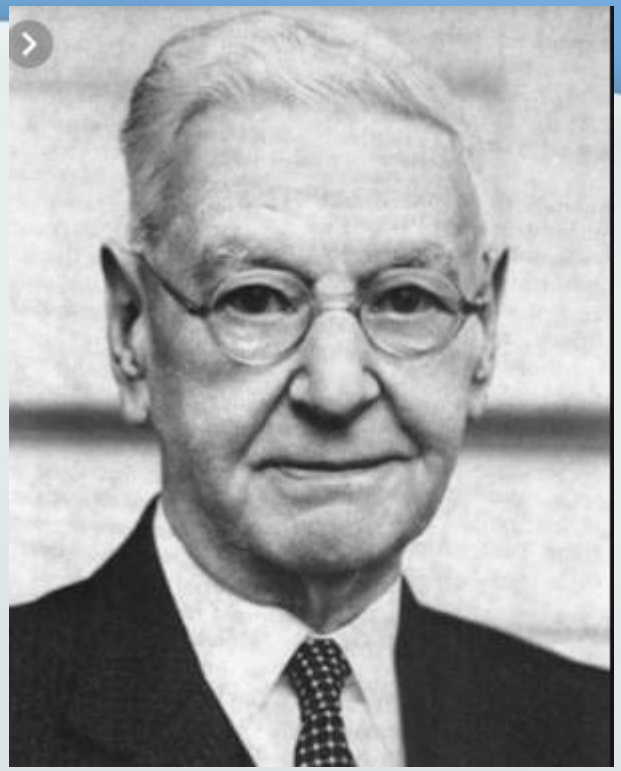


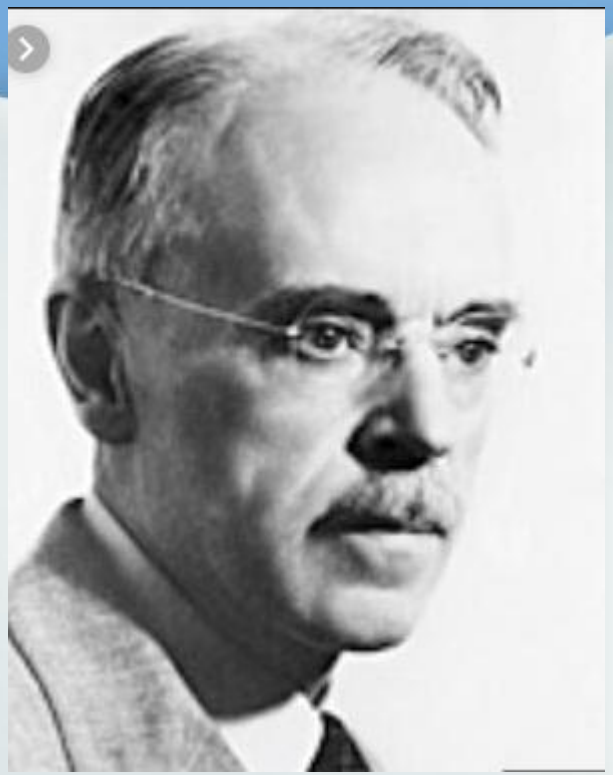
Abnormalities of PR interval

- **Prolonged in:** 1st degree heart block or vagal stimulation.
- **Shortened in:**
  - ***A-V nodal rhythm.***
  - ***pre-excitation syndromes:***
    - *Wolff-Parkinson-White syndrome (WPW).*
    - *Lown-Ganong-Levine (LGL).*

Wolff-Parkinson-White syndrome







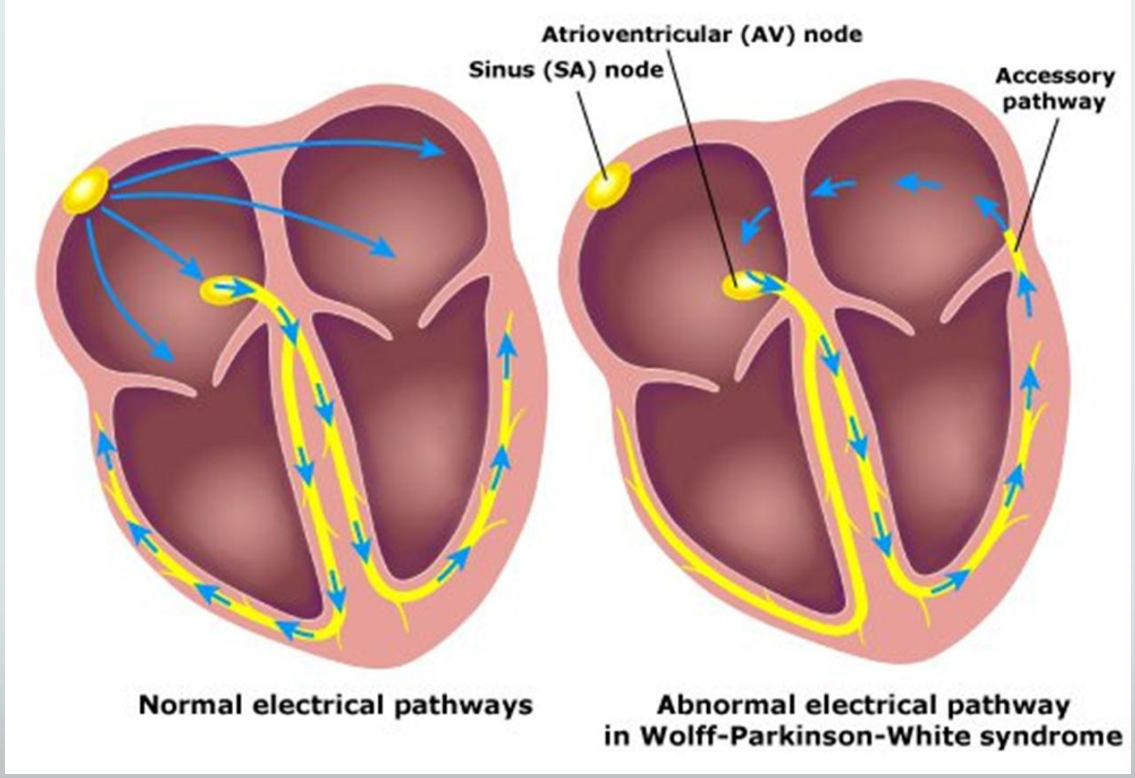
Louis **Wolff**
(1898 – 1972)

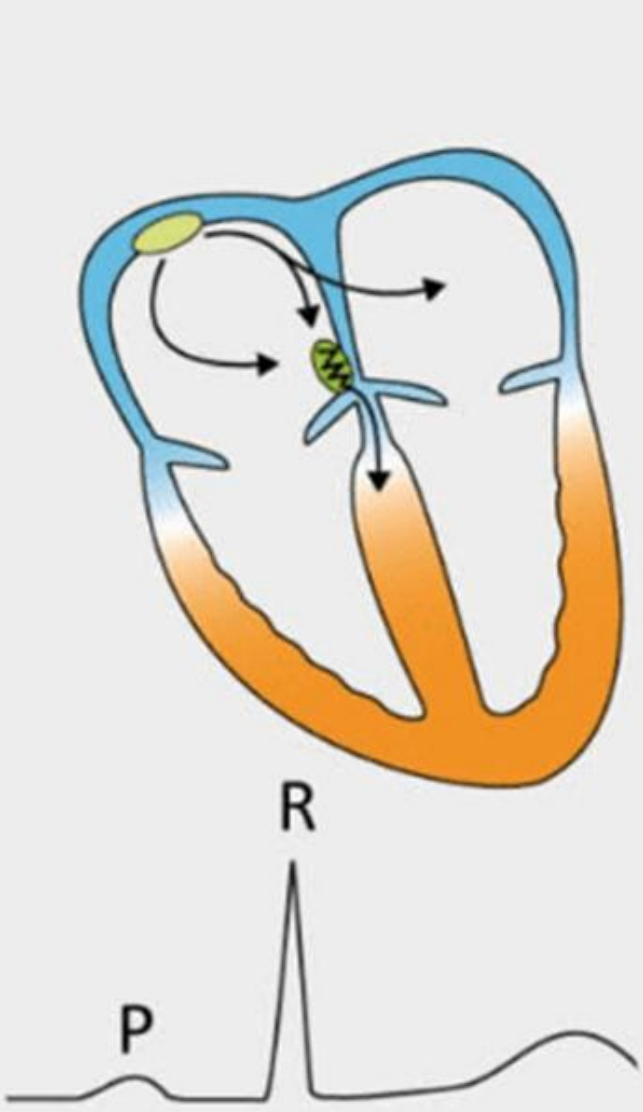
John **Parkinson**
(1885 – 1976)

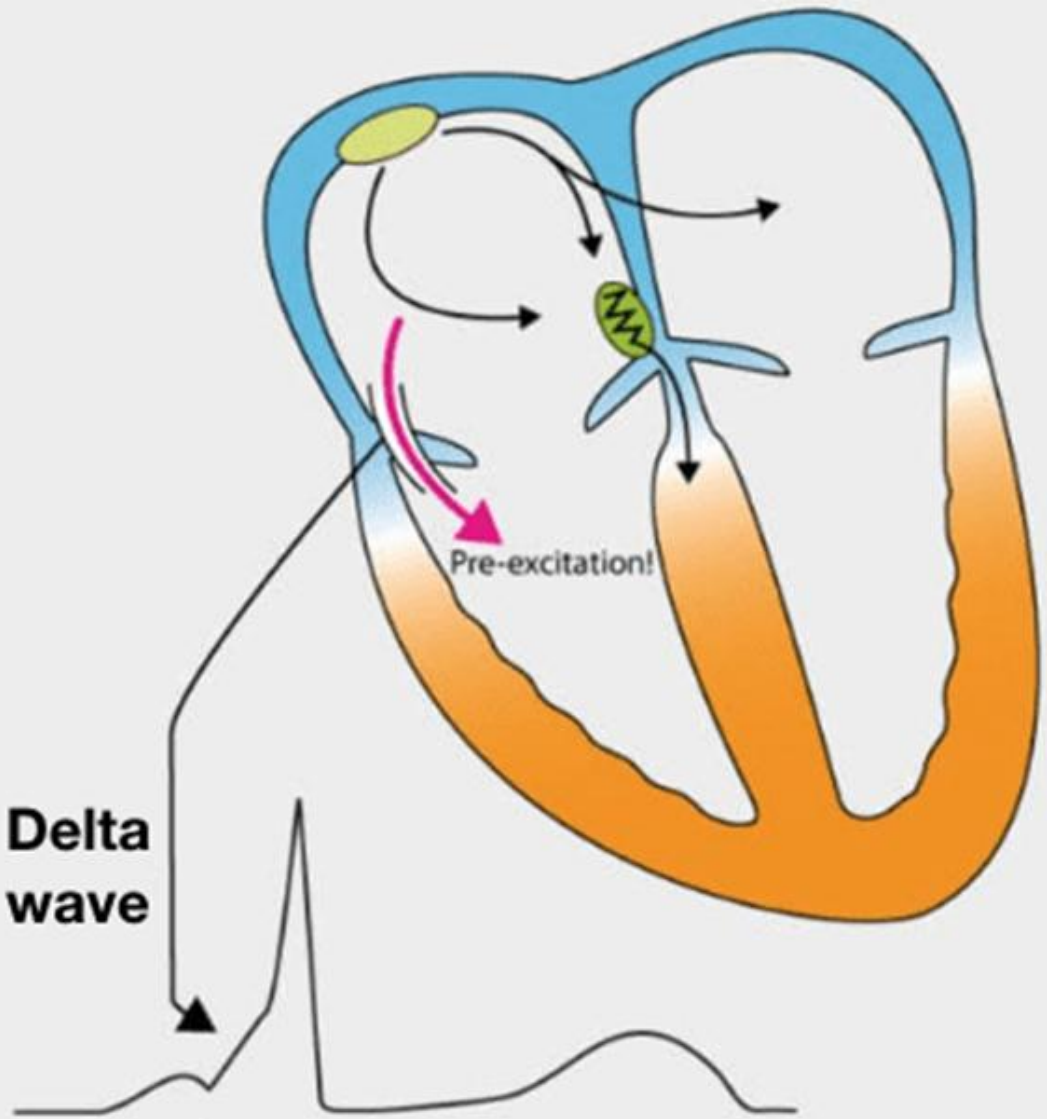
Paul Dudley White
(1886 – 1973)

3 Cardiologists credited with the definitive description of the disorder in 1930

- The most common type of preexcitation syndrome.
- It is due to abnormal fast accessory conducting pathway between atrium and ventricle **(*bundle of Kent*).**
- Short PR interval, characteristic delta wave and abnormal shaped and wide QRS.







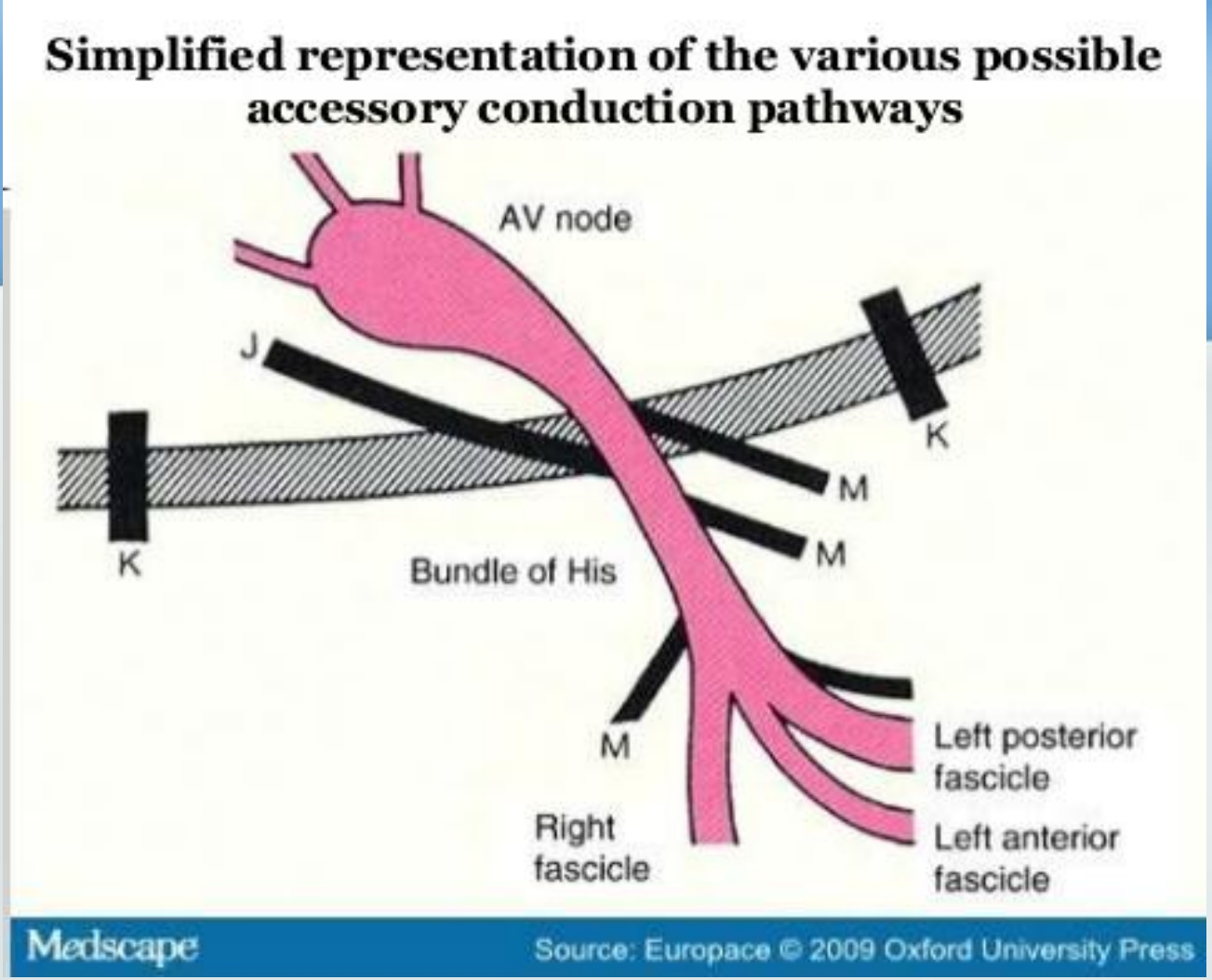
Normal AV transmission

Pre-excitation

Lown-Ganong-Levine syndrome (LGL)

- less is known about the structural anomalies underlying the LGL.
- It may be due to abnormal conducting pathway between SAN & the main stem of AV bundle **(bundle of James)**
- ECG: short PR interval with normal QRS.

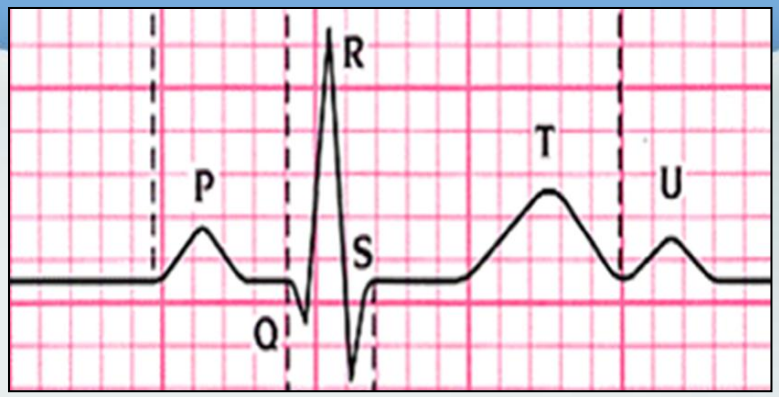
Simplified representation of the various possible accessory conduction pathways



K = bundle of Kent; J = bundle of James; M = Mahaim fibres.
The hatched area represents the atrioventricular border

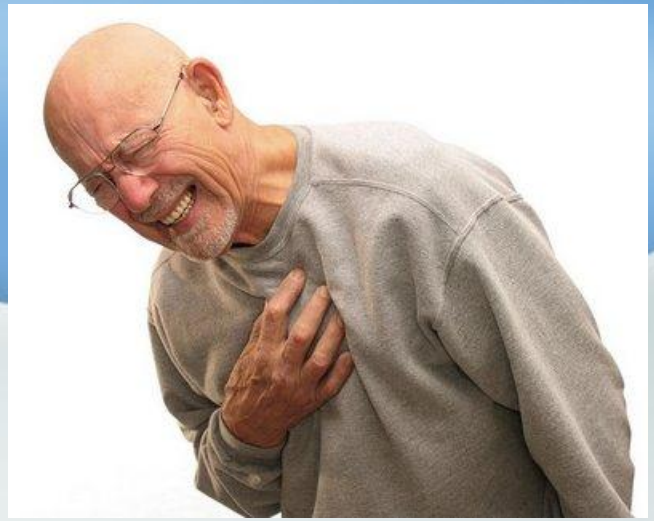
S-T segment

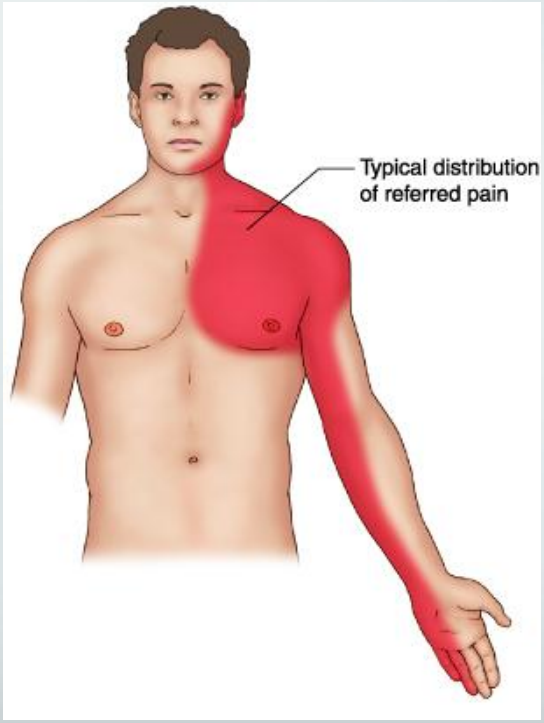
- Measured from the end of S wave to the beginning of the T wave.
- It represents the period during which the ventricle is completely depolarized.
- Normally it is on the isoelectric line.
- If displaced above or below this line → this indicates myocardial ischemia or infarction.



Myocardial infarction can be diagnosed by (2 of 3):

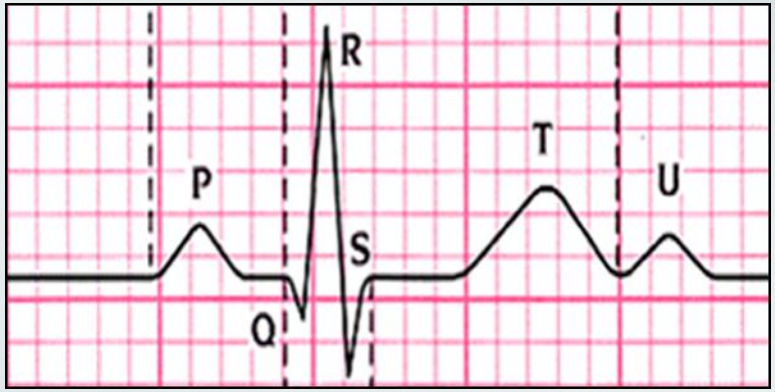
- Characteristic compressing or burning diffuse Chest pain that radiate to the left shoulder.
- Raised ST segment in ECG.
- Raised cardiac enzymes in the blood as troponin, creatine phosphate or lactate dehydrogenase.





QT interval

- The time between the start of the **Q wave** and the end of the **T wave**.
- Represents electrical activity of the ventricles & Corresponds to mechanical contraction of the ventricles.
- The duration of QT interval is inversely proportional to HR.
- Normal duration: when Heart rate between 60–100 bpm: QT ≤ half (R-R distance).

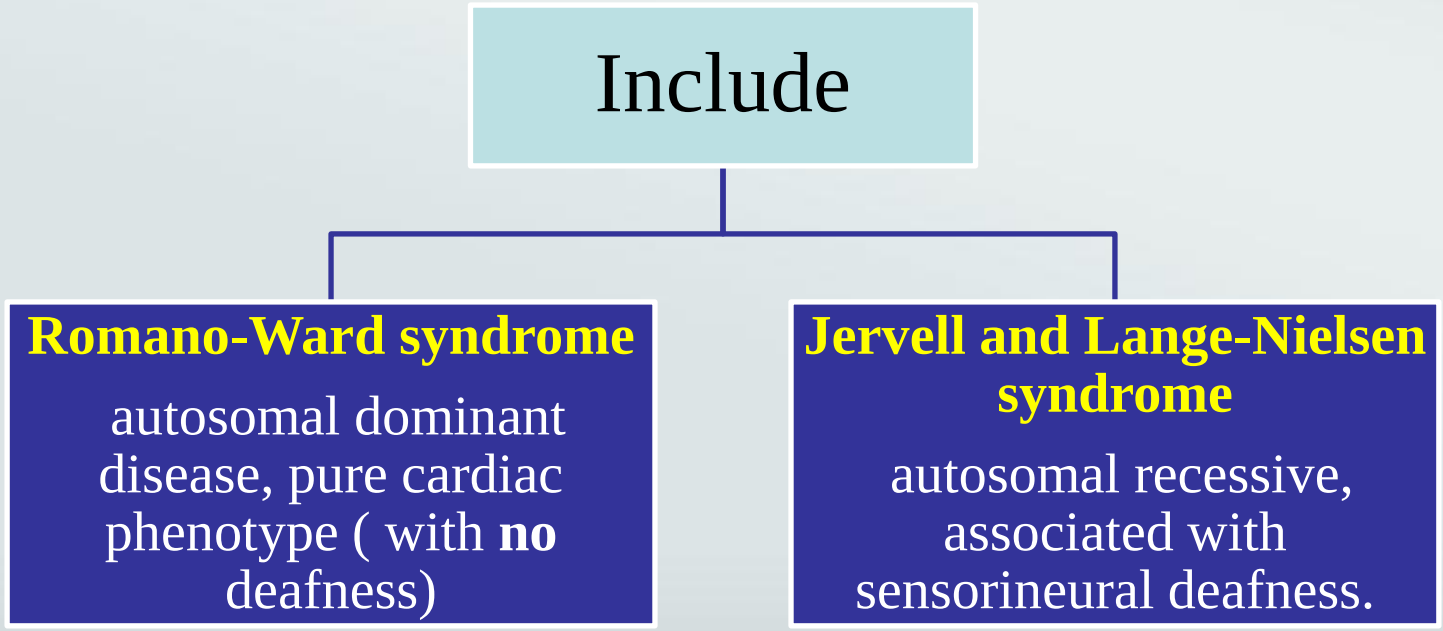


Prolonged QT interval may be

- ***Hereditary* (congenital):**

  - Inherited disorder of myocardial repolarization, typically due to ion channel defects.

  - At risk of sudden cardiac death (SCD) due to **torsades de pointes.**

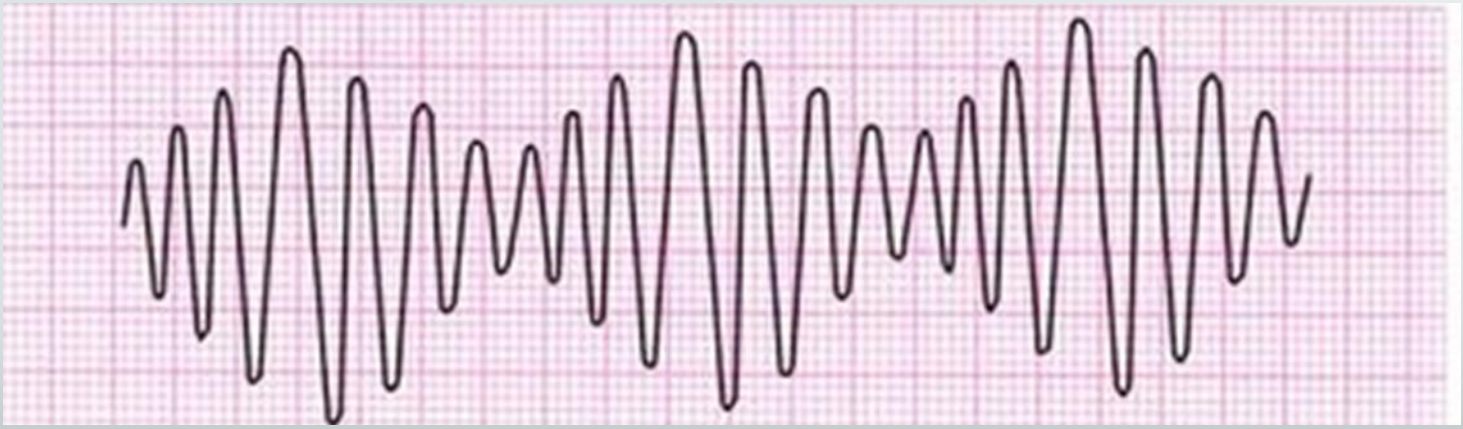


- ***Acquired prolonged QT interval:***
  - **Drugs induced (ABCDE):**
    - Anti**A**rrhythmics (class IA, III)
    - Anti**B**iotics (eg, macrolides)
    - Anti“**C**”ychotics (eg, haloperidol)
    - Anti**D**epressants (eg, TCAs)
    - Anti**E**metics (eg, ondansetron)
  - **Electrolyte abnormalities** (↓ K^{+}, ↓Ca^{++}, ↓Mg^{++})

⇨ First-line of treatment is usually by magnesium sulfate.

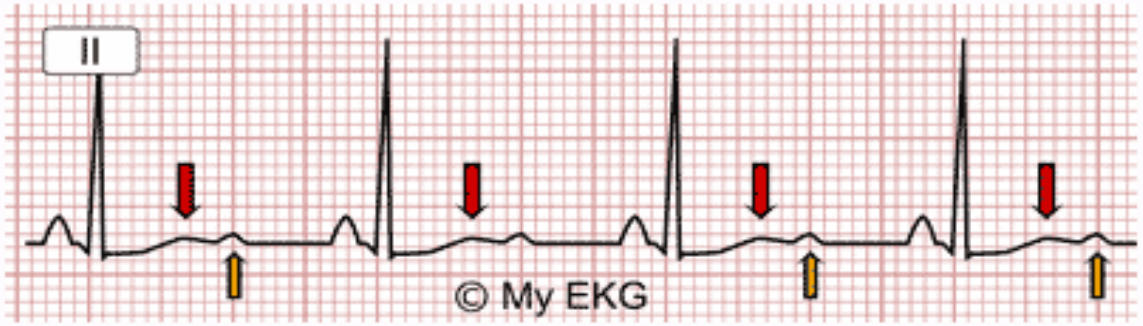
Torsades de pointes

- **Torsades de pointes** = twisting of the points
- Uncommon Polymorphic ventricular tachycardia, characterized by a gradual change in the amplitude and twisting of the QRS complexes around the isoelectric line; can progress to ventricular fibrillation (VF) and leads to sudden cardiac death.



ECG signs of hypokalemia (below 3.5 mEq/L)

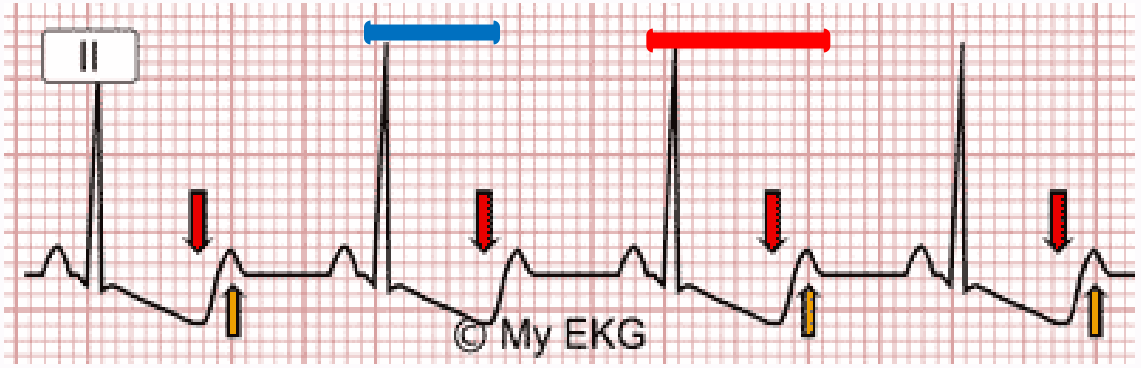
- ⇨ Depressed ST segment.
- ⇨ Decrease in T wave amplitude.
- ⇨ Prominent U wave.
- ⇨ The presence of prominent U gives false QT interval prolongation.
- ⇨ **When K^+ level drops below 2.5 mEq/L**: T wave becomes inverted and the PR interval prolongs.



Moderate hypokalemia:

ST-segment depression, T waves flattening (red arrows), prominent U waves (orange arrows).

QT interval is normal **QU interval is prolonged**



Severe hypokalemia:

ST-segment depression, negative T waves (red arrows), prominent U waves (orange arrows).

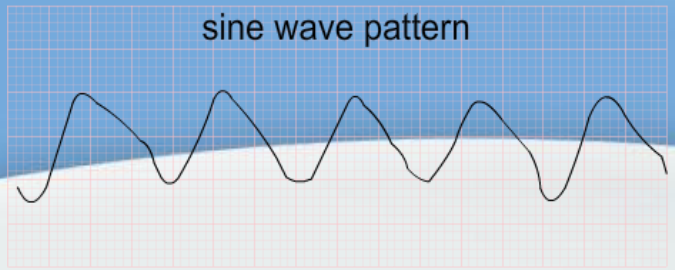
ECG signs of hyperkalemia (above 7 mEq/L)

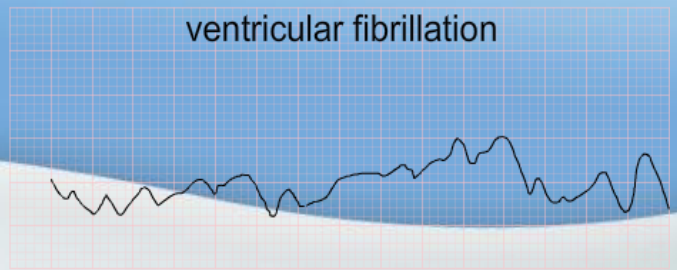
⇨Very tall, slender & peaked T wave.

⇨P wave disappears.

⇨QRS complex is wide and slurred.

ECG/EKG changes in hyperkalemia





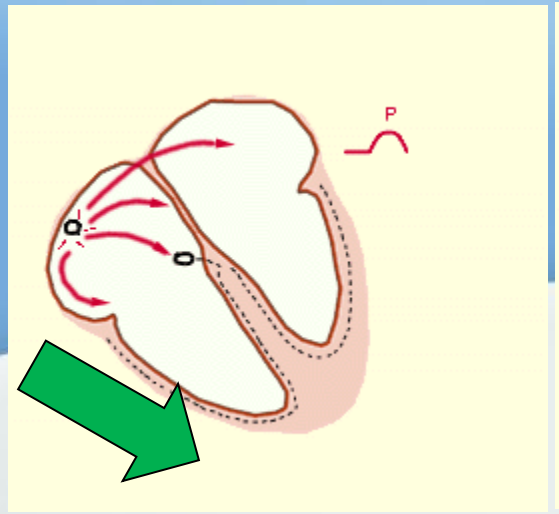

wide qrs

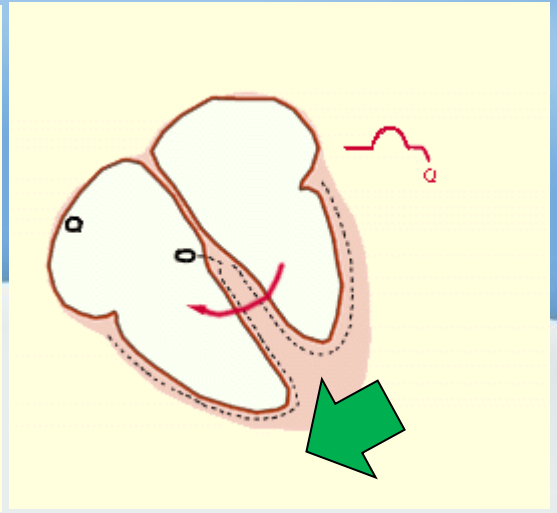

tented T waves

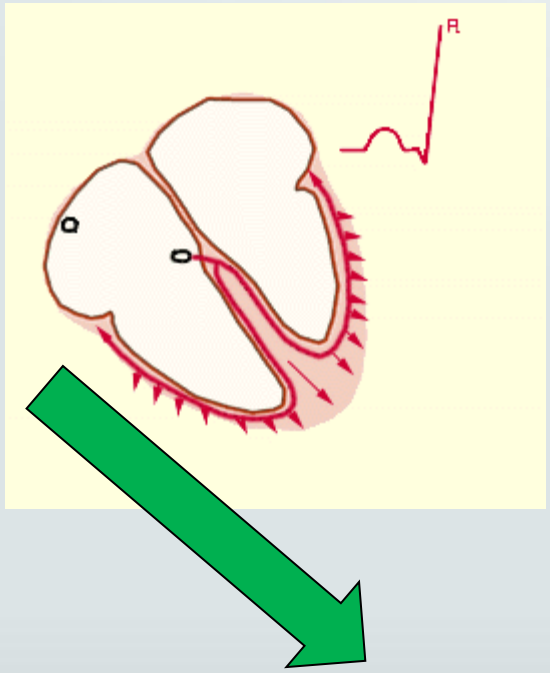

loss of P waves

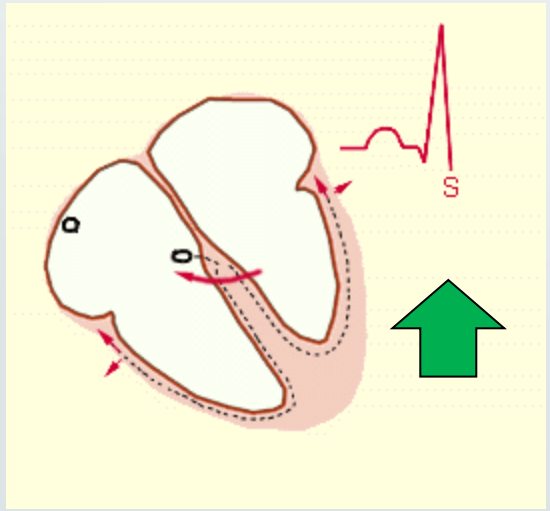
Electrical axis of the heart

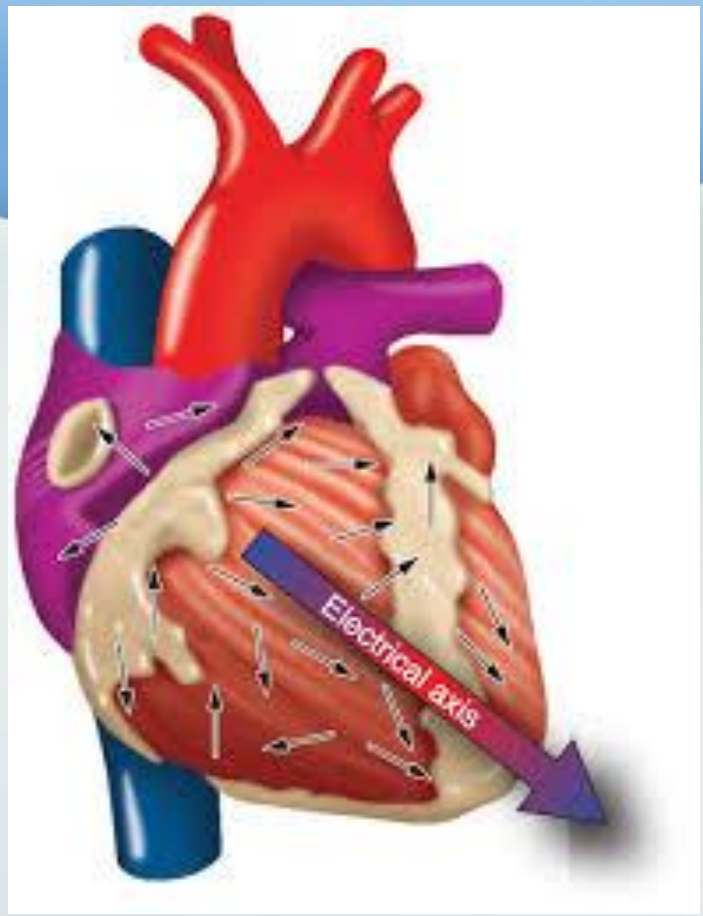
- It is the sum of the electrical directions in the heart.
- The net "electrical axis of the heart" is directed downwards and to the left from SAN to the heart's apex.
- Normally it is between -30 : + 110 ° (average 59°).
- Estimation of mean QRS axis is determined by the direction of the QRS complex in leads I and aVF (some texts suggest using leads I and II).
- The axis may be deviated to the right or to the left.











Causes of axis deviation

Right axis deviation	Left axis deviation
Physiological causes: 1) During inspiration. 2) When the person stands up. 3) Tall and slender person.	1) During expiration. 2) When the person lays down. 3) Short and fatty person.
Pathological causes: 1) Right ventricular hypertrophy. 2) Right bundle branch block. 3) Left ventricular extrasystole.	1) Left ventricular hypertrophy *in some cases.* 2) Left bundle branch block *(the most common cause).* 3) Right ventricular extrasystole.

Determination of electrical axis of the heart

https://www.youtube.com/watch?v=k20D5yEnA8E&t=7s

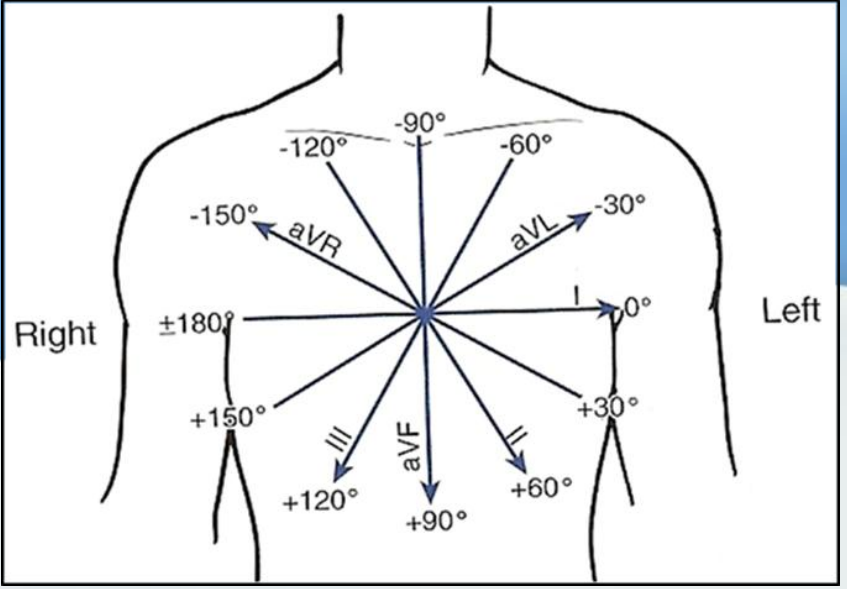
How to measure the Heart Rate from the ECG

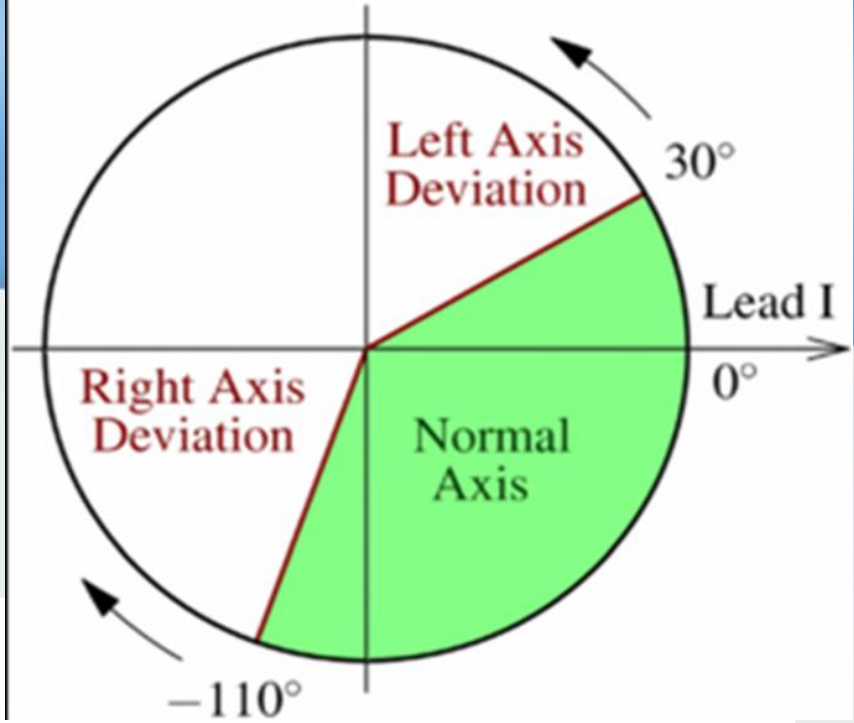
- H.R = $\frac{60}{R-R\ interval\ (in\ seconds)}$
- or HR

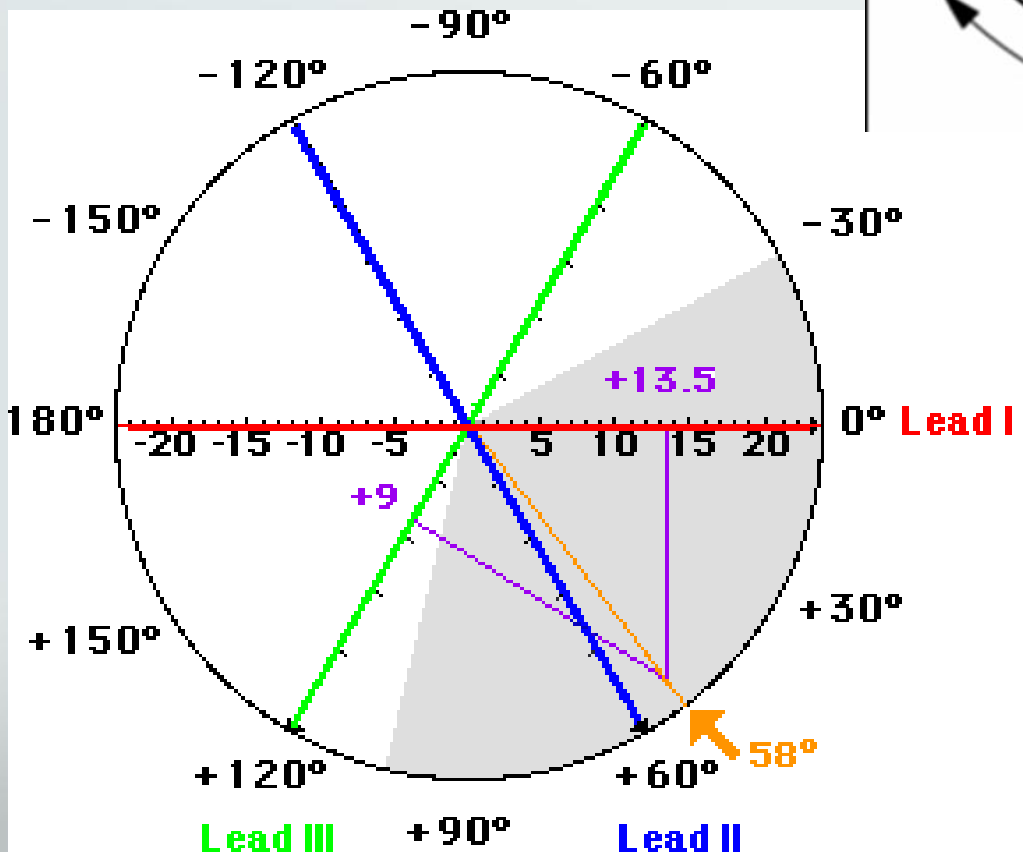
  $= \frac{300}{R-R\ interval\ (NO.of\ large\ squres\ between\ R-R)}$
- or HR =

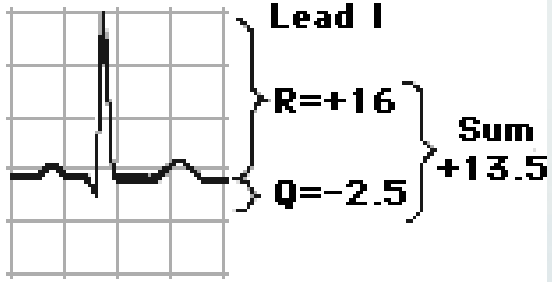
$$\frac{1500}{R-R\ interval\ (NO.of\ small\ squres\ between\ R-R)}$$

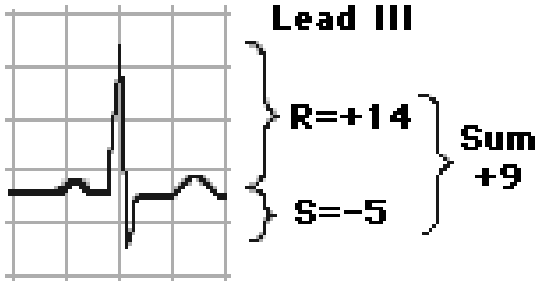
- **If the HR is irregular:**
  - average of 2 largest R-R intervals and 2 smallest R-R intervals.
  - No. of QRS complexes in 6 seconds × 10


-90°
-120°
-60°
-150°
aVR
aVL
-30°
I
0°
Right
±180°
Left
+150°
III
aVF
II
+30°
+120°
+90°
+60°


Left Axis Deviation
30°
Lead I
0°
Right Axis Deviation
Normal Axis
−110°

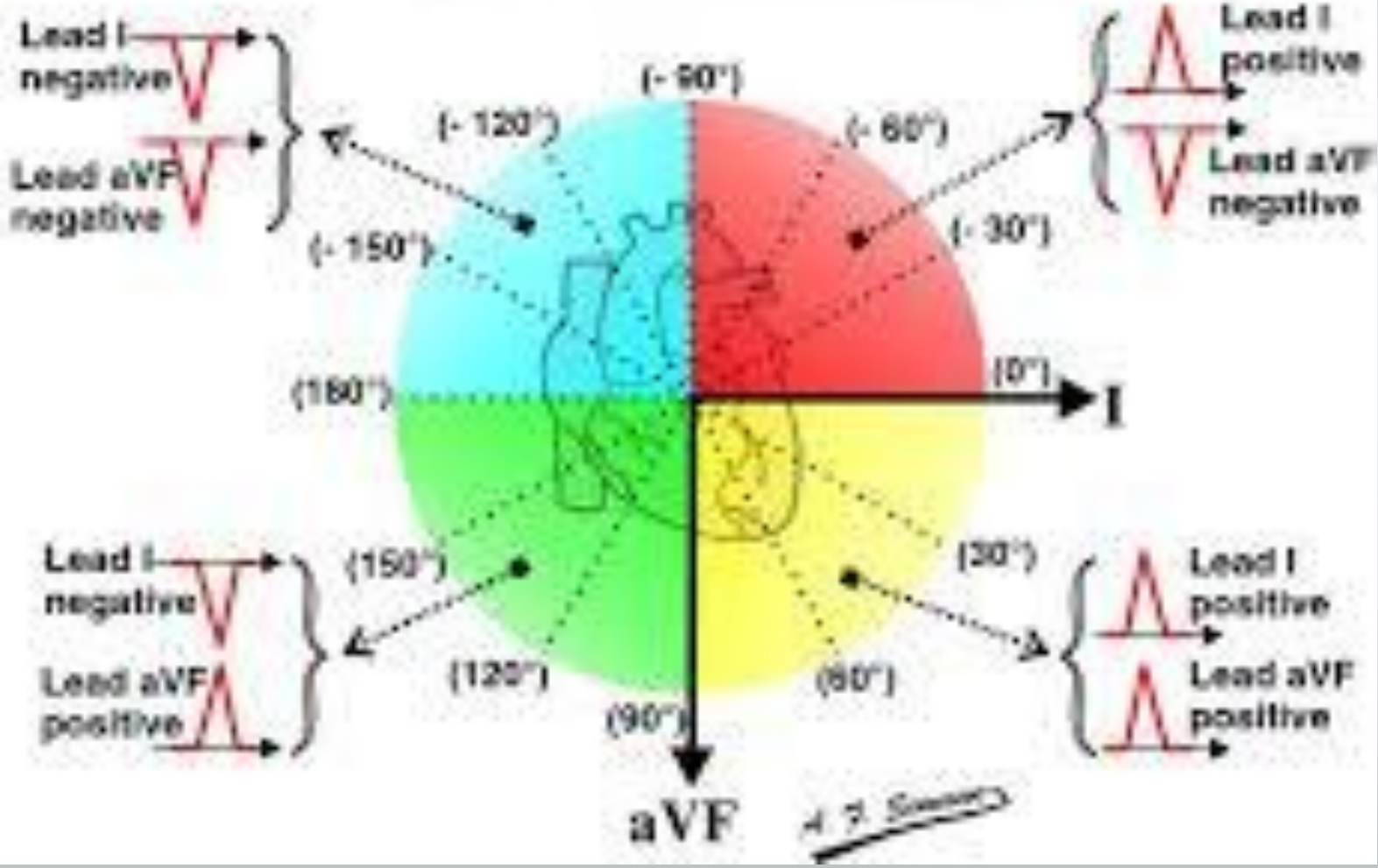

-90°
-120°
-60°
-150°
-30°
+13.5
180°
0° Lead I
-20 -15 -10 -5 5 10 15 20
+9
+30°
+150°
58°
+120°
+60°
Lead III
+90°
Lead II

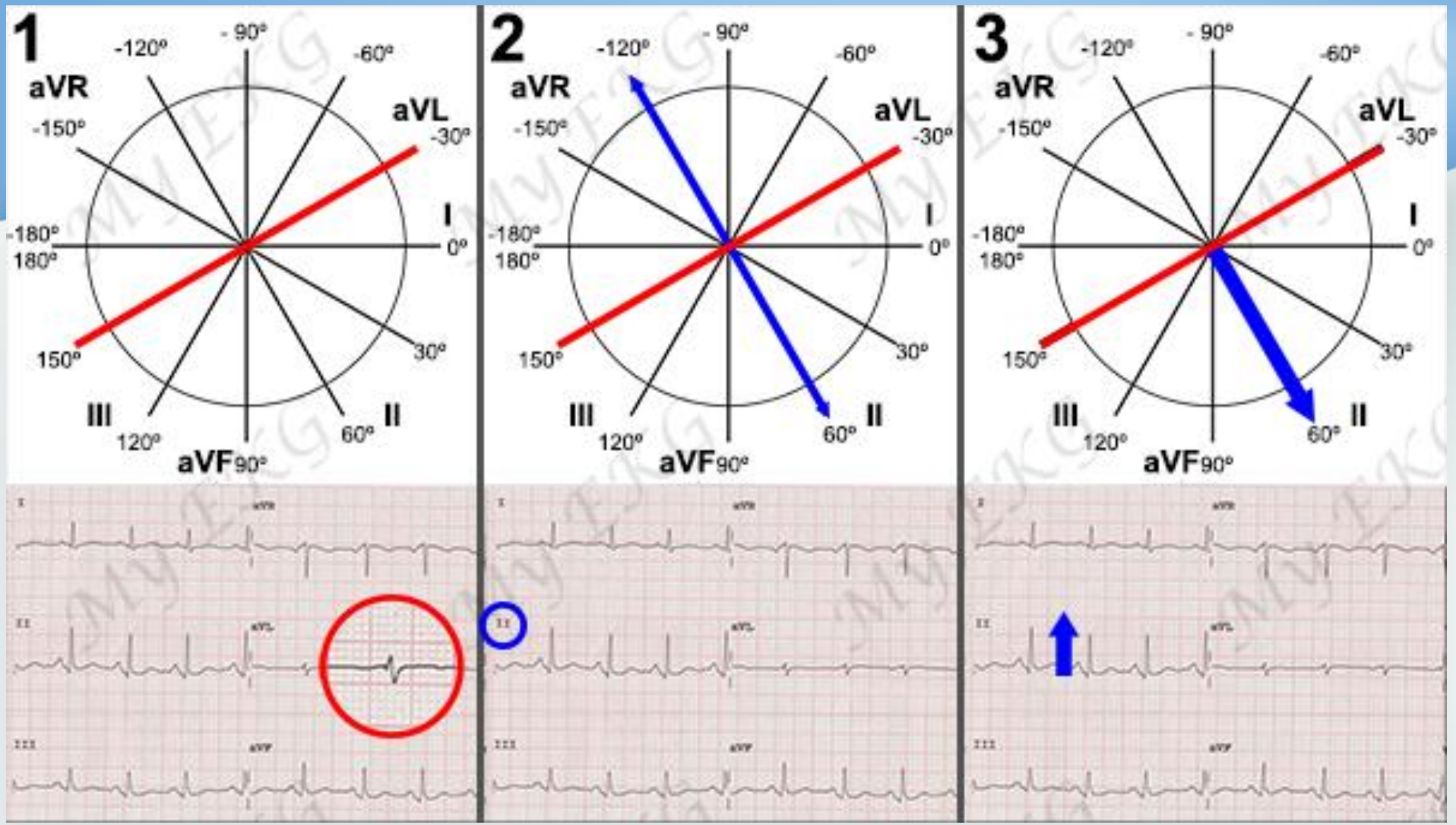

Lead I
R=+16
Q=-2.5
Sum
+13.5


Lead III
R=+14
S=-5
Sum
+9

DETERMINATION OF THE MEAN QRS AXIS IN THE FRONTAL PLANE 1

STEP 1 : LOOK AT LEADS I & aVF TO DETERMINE IN WHICH QUADRANT THE FRONTAL PLANE AXIS IS SITUATED




1
aVR
-120°
- 90°
-60°
aVL
-150°
-30°
I
-180°
180°
0°
150°
30°
III
120°
60°
II
aVF90°
2
aVR
-120°
- 90°
-60°
aVL
-150°
-30°
I
-180°
180°
0°
150°
30°
III
120°
60°
II
aVF90°
3
aVR
-120°
- 90°
-60°
aVL
-150°
-30°
I
-180°
180°
0°
150°
30°
III
120°
60°
II
aVF90°