Physiology of the Cardiovascular system

Conduction system of the heart

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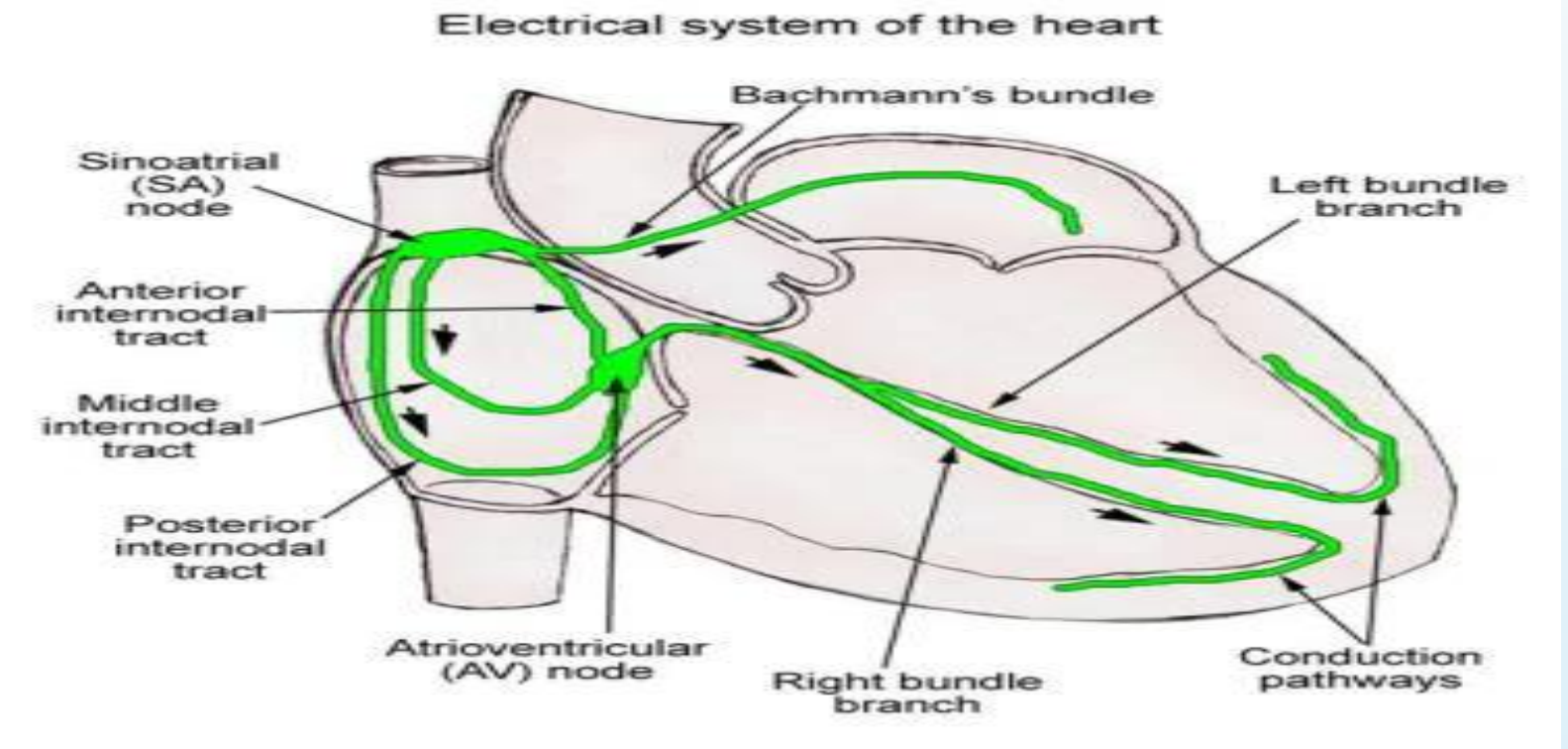
Cardiac conductivity

- It is it is the ability of the cardiac muscle to transmit the excitation wave all over the heart.
- Conductivity is a property of all cardiac muscles
- Atrial muscles conducts at 0.3 m\sec.
- Ventricular muscles conduct at 0.5 m\sec.

The conducting system of the heart

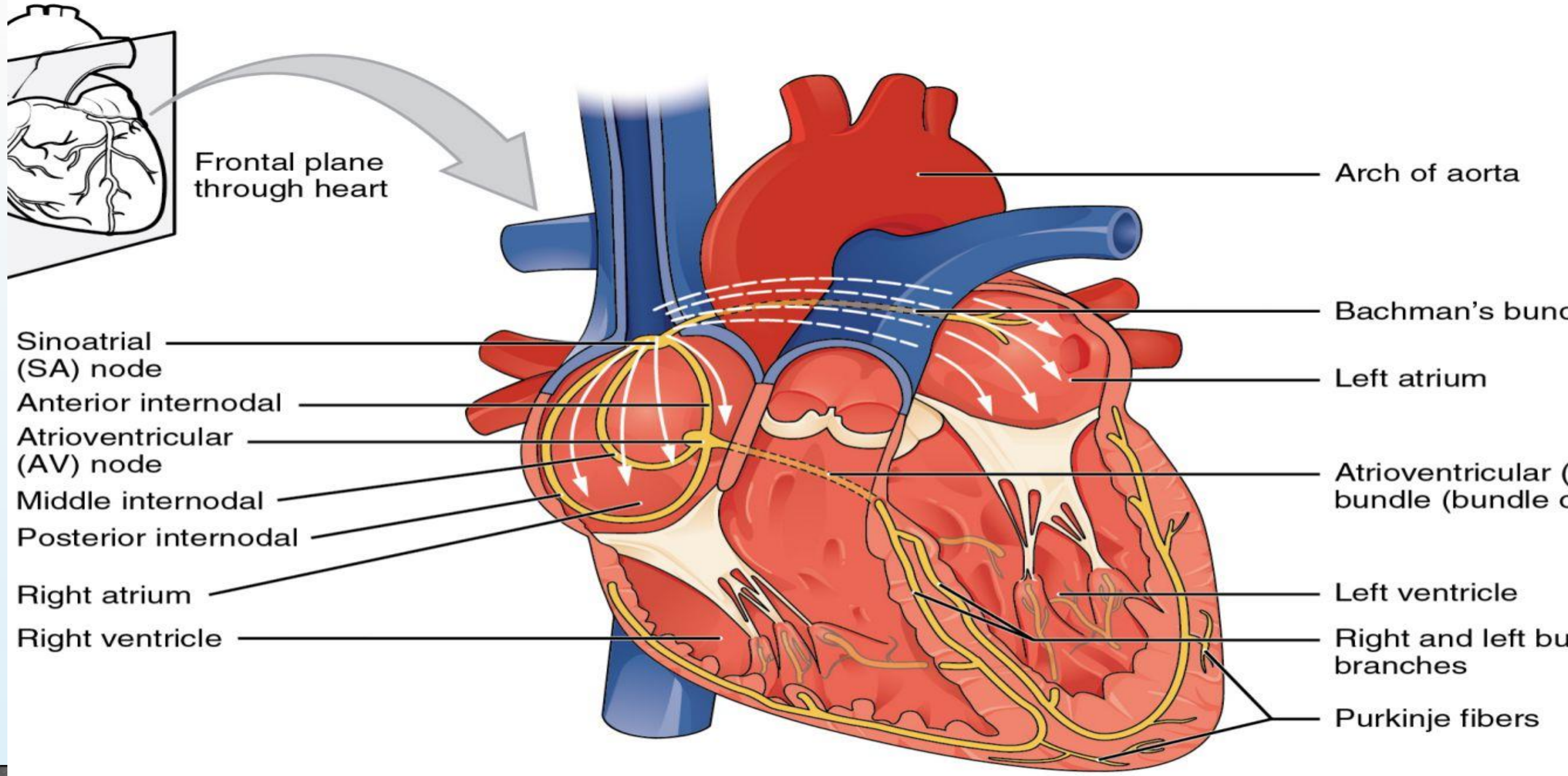


The conducting system inside the heart consisting of:

1. **Sinoatrial node (SAN):** postero-lateral superior wall of rt atrium at the opening of SVC.
2. **Internodal pathways**: anterior interatrial band +anterior (Bachman), middle (Wenckebach) & posterior (Thorel) internodal fibers →facilitate conduction in the right and left atria for the impulse to reach the AVN. conduction velocity is 1 meter / second.
3. **AVN:** the only conducting route through the annulus fibrosus which separates the atria from ventricles. situated near the interatrial septum. Conduction velocity is 0.05 meter / second
4. **A.V. bundle (bundle of His) & Purkinje fibers:**

A.V. bundle (bundle of His) & Purkinje fibers

- transfers impulses through the annulus fibrosus to the top of the interventricular septum. Then it branches into **right and left bundle branches**. The left bundle divides into anterior and posterior fascicles.
- The bundle travels under the endocardium the walls of the septum and **at the base divides into multiple fibers of the Purkinje system**. This distributes the impulses over the inner walls of the ventricles.
- Cells of bundle of His and Purkinje system have **large diameter and consequently rapid rate of conduction velocity (about 4 m/sec)**
- This allows an immediate transmission of cardiac impulse to both ventricles.



Anterior view of frontal section

AV nodal delay

- The slowest conduction is at the AVN, impulse conduction delayed 0.16 sec at the av node, This is because the fibers of AVN are of:

1- Very small diameter (velocity a r).

2- Complex arrangement.

3- Less gap junctions between these fibers.

- Significance of AV nodal delay:
- a) Delay ventricular contraction to the end of atrial contraction i.e. gives time for atria to empty their content in ventricles.
- b) Protect the ventricles from high pathological atrial rhythm.

Defects of conduction:

1. Heart block.
2. Bundle branch block
3. Congenital accessory conduction pathways:

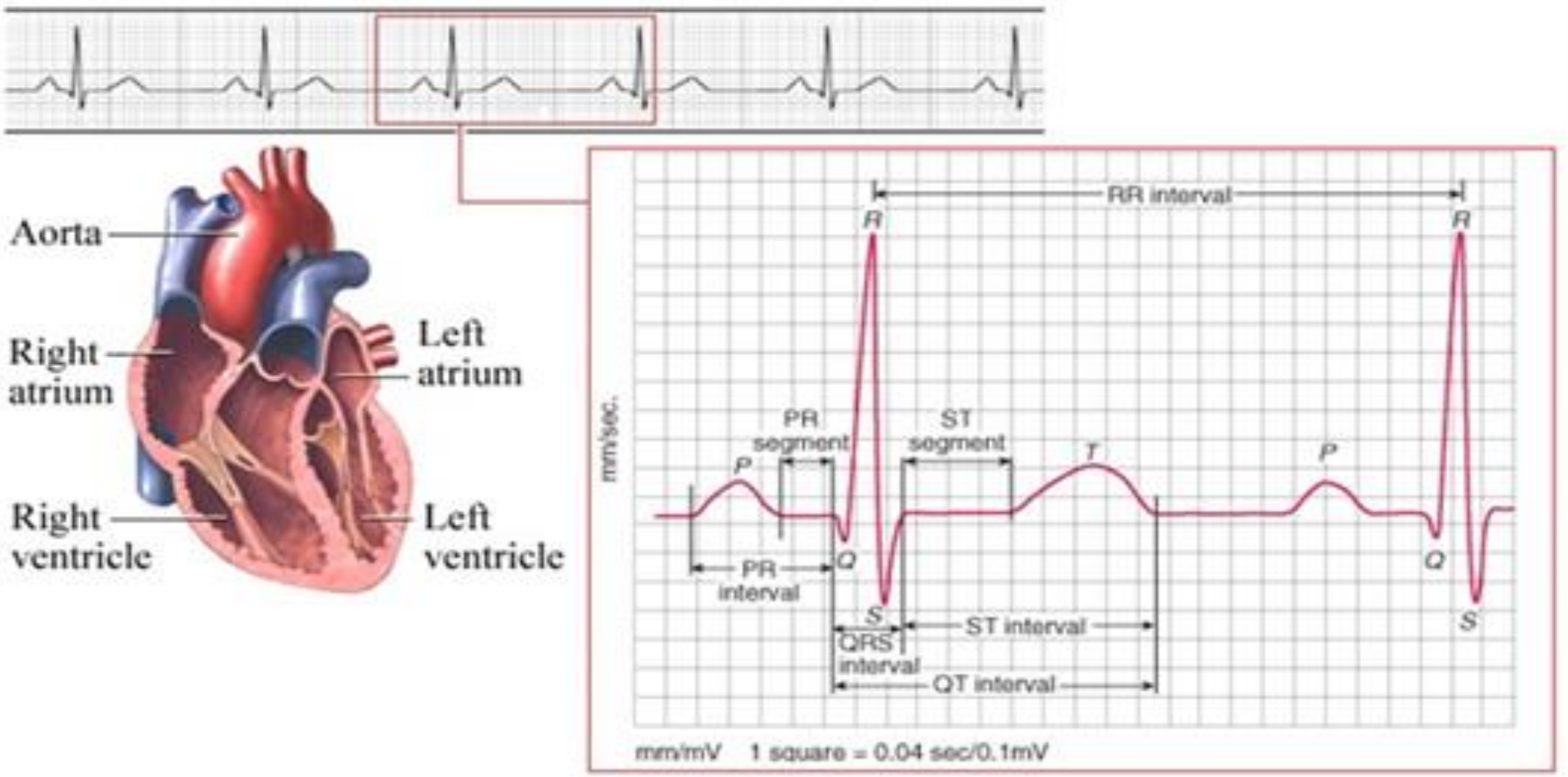
→**AV nodal re-entrant tachycardia (AVNRT)**

→**Wolff- Parkinson – white syndrome: It is due to abnormal fast accessory conducting pathway between atrium and ventricle (bundle of Kent) predisposing to a re-entry circuit and SVT.**

The normal ECG

Normal 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, there is no need to put ECG electrodes on the heart directly but ECG→ electrodes are placed on the skin of the chest wall and extremities.


Aorta
Right atrium
Left atrium
Right ventricle
Left ventricle
RR interval
R
R
PR segment
ST segment
P
T
P
Q
Q
PR interval
S
S
ST interval
QRS interval
QT interval
mm/sec.
mm/mV
1 square = 0.04 sec/0.1mV

Electrocardiogram Leads

- The particular arrangement of the 2 electrodes is called the lead.
- Each leads takes a —snapshotll from a different angle of the heart‘s net electrical activity.
- There 12 leads bipolar limb leads I,II,III unipolar lib leads (aVR, aVF, aVL) & chest leads V1-6).

Summary of Leads

	Limb Leads	Precordial Leads
Bipolar	**I, II, III** (standard limb leads)	-
Unipolar	**aVR, aVL, aVF** (augmented limb leads)	**V_1-V_6**

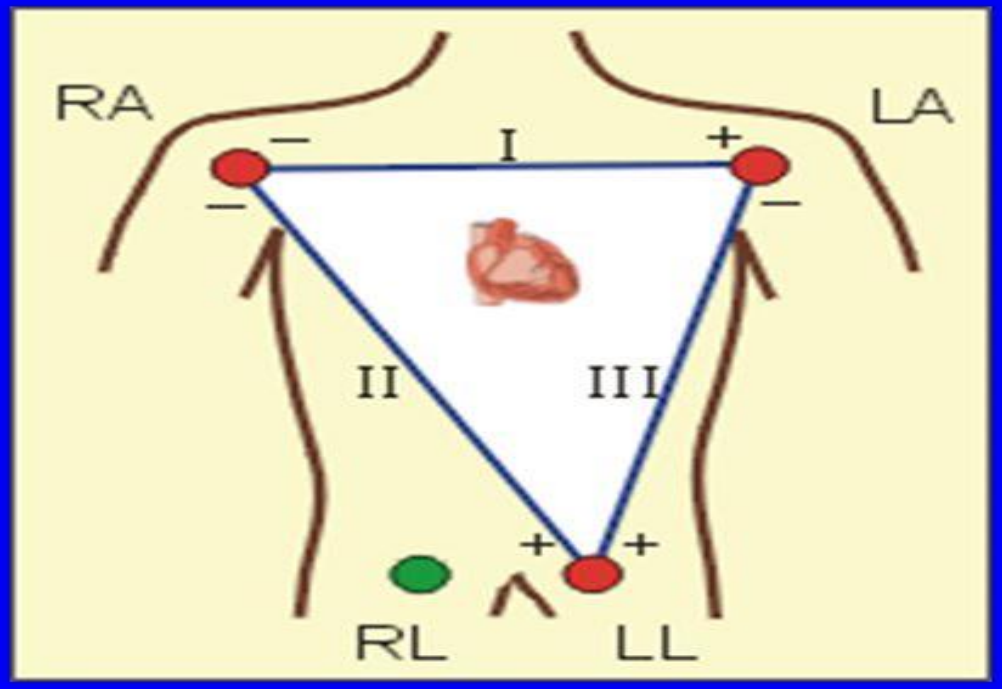
Limb Leads

3 Bipolar Leads
form (Einthovens Triangle)

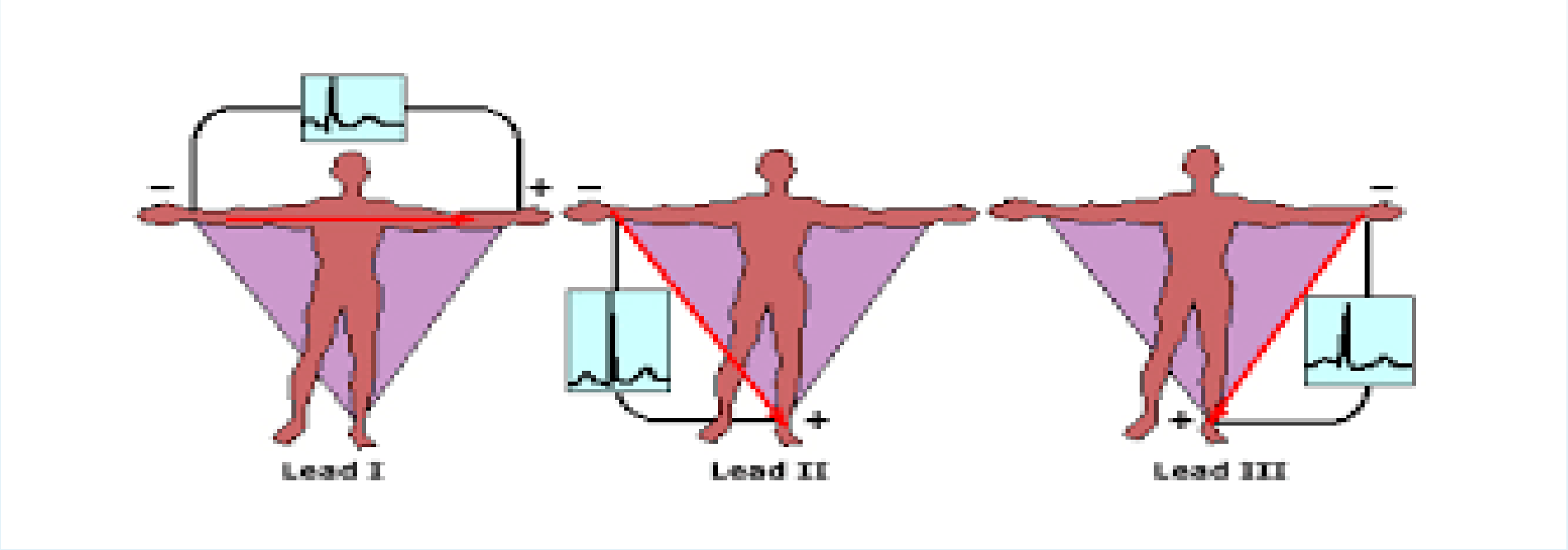
Lead I - measures electrical potential between right arm (-) and left arm (+)

Lead II - measures electrical potential between right arm (-) and left leg (+)

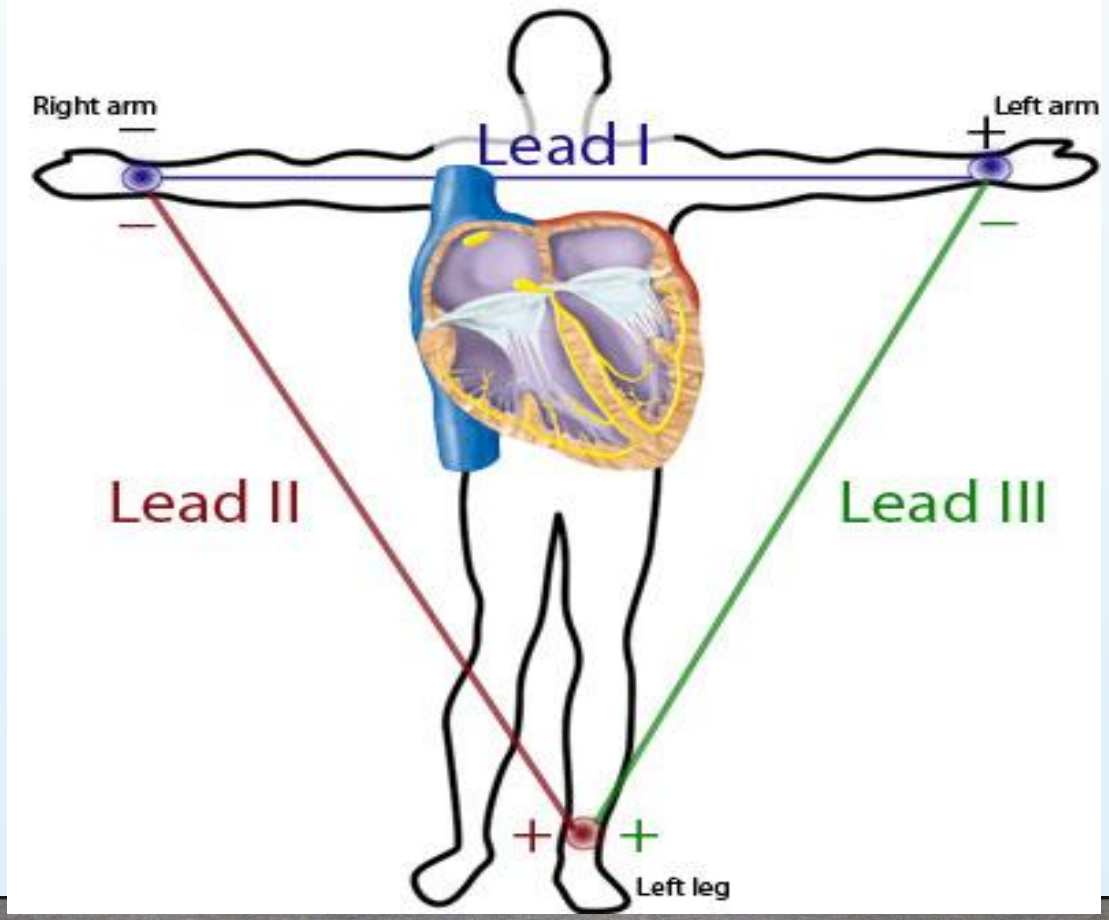
Lead III - measures electrical potential between left arm (-) and left leg (+)



Bipolar limb leads



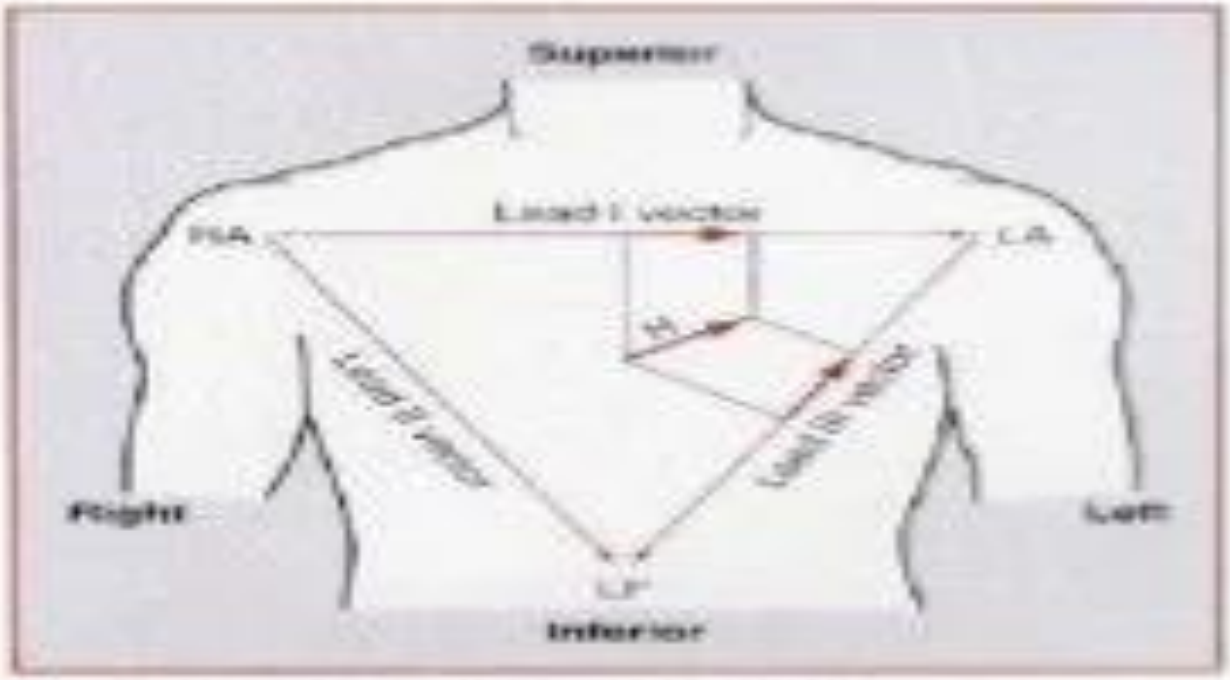
Einthoven's traingle



Einthoven's law

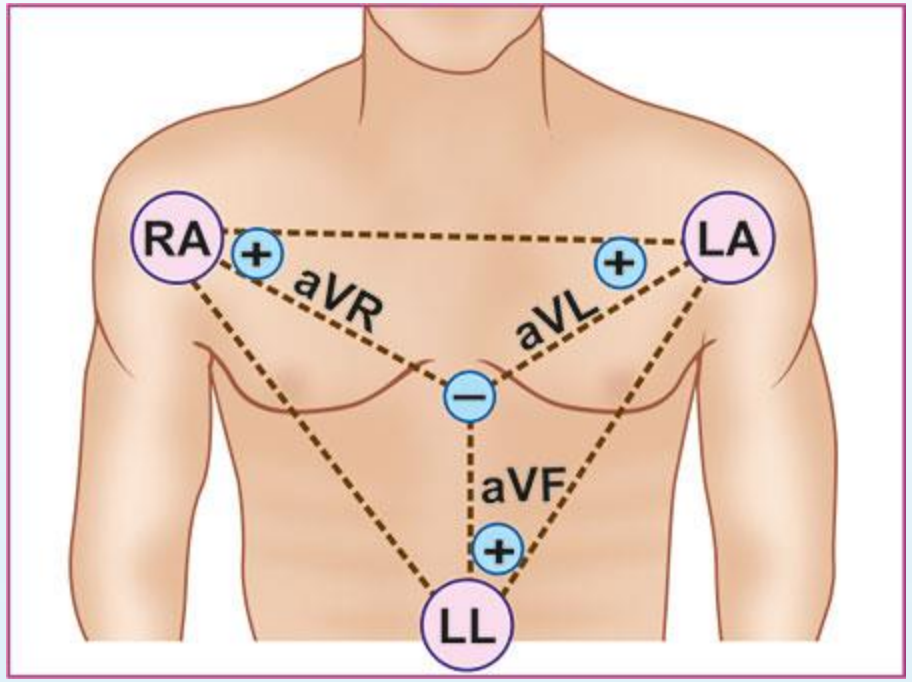
$$I + III = II$$

The heart vector H and its projections on the lead axes of leads I and III. Voltages recorded in lead I will be positive whereas potentials in lead III will be negative

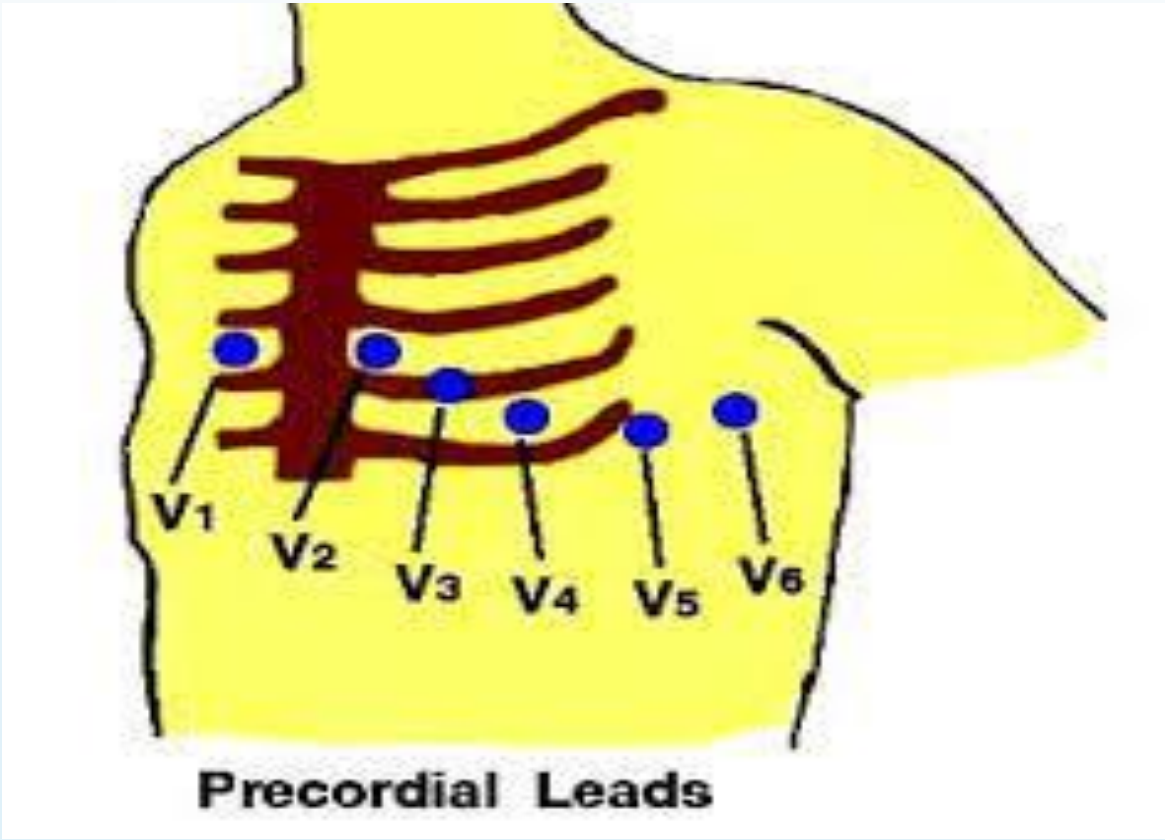


Helpful rule to remember to detect instances in which the technician has attached the electrodes to the wring limbs.

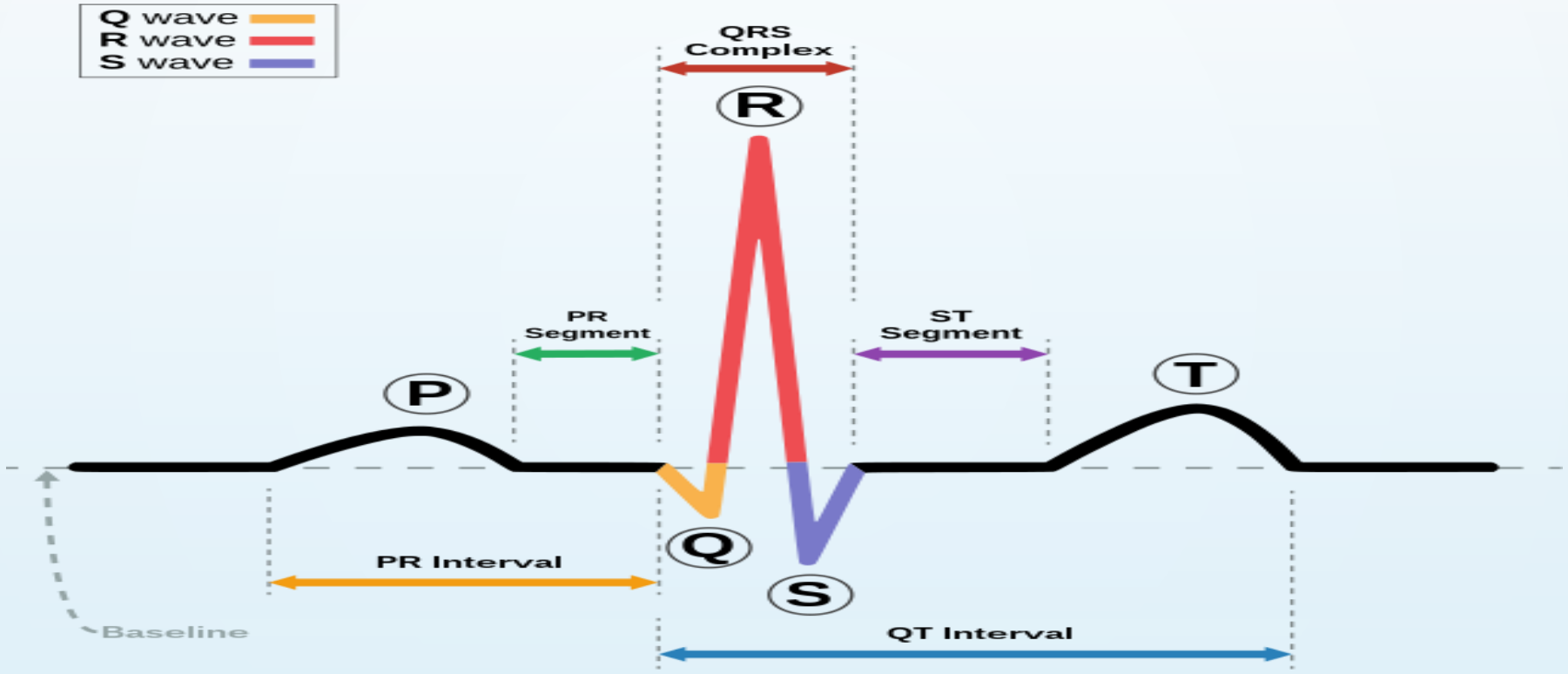
Unipolar limb leads



Unipolar chest lead



Normal ECG waves and intervals



Normal ECG waves

- There are **3 positive waves (P, R & T waves) and 2 negative waves (Q & S waves) in normal ECG.**
- Occasionally, rarely seen tiny wave called **(U wave**). Appears prominent in hypokalemia & 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, most parallel to net electrical vector of atrial depolarization)
- Represents atrial depolarization.
- It precedes atrial systole by 0.02 second.
- Duration = 0.1 second.
- Voltage = 0.1- 0.2 mv.

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.

QRS complex

- **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.

T wave

- Represents ventricular repolarization.
- Duration = 0.25 second.
- Voltage = 0.2- 0.3 mv.

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).
- Prolonged in: **1st degree heart block or vagal stimulation.**
- Shortened in: A-V nodal rhythm.

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.

QT interval:

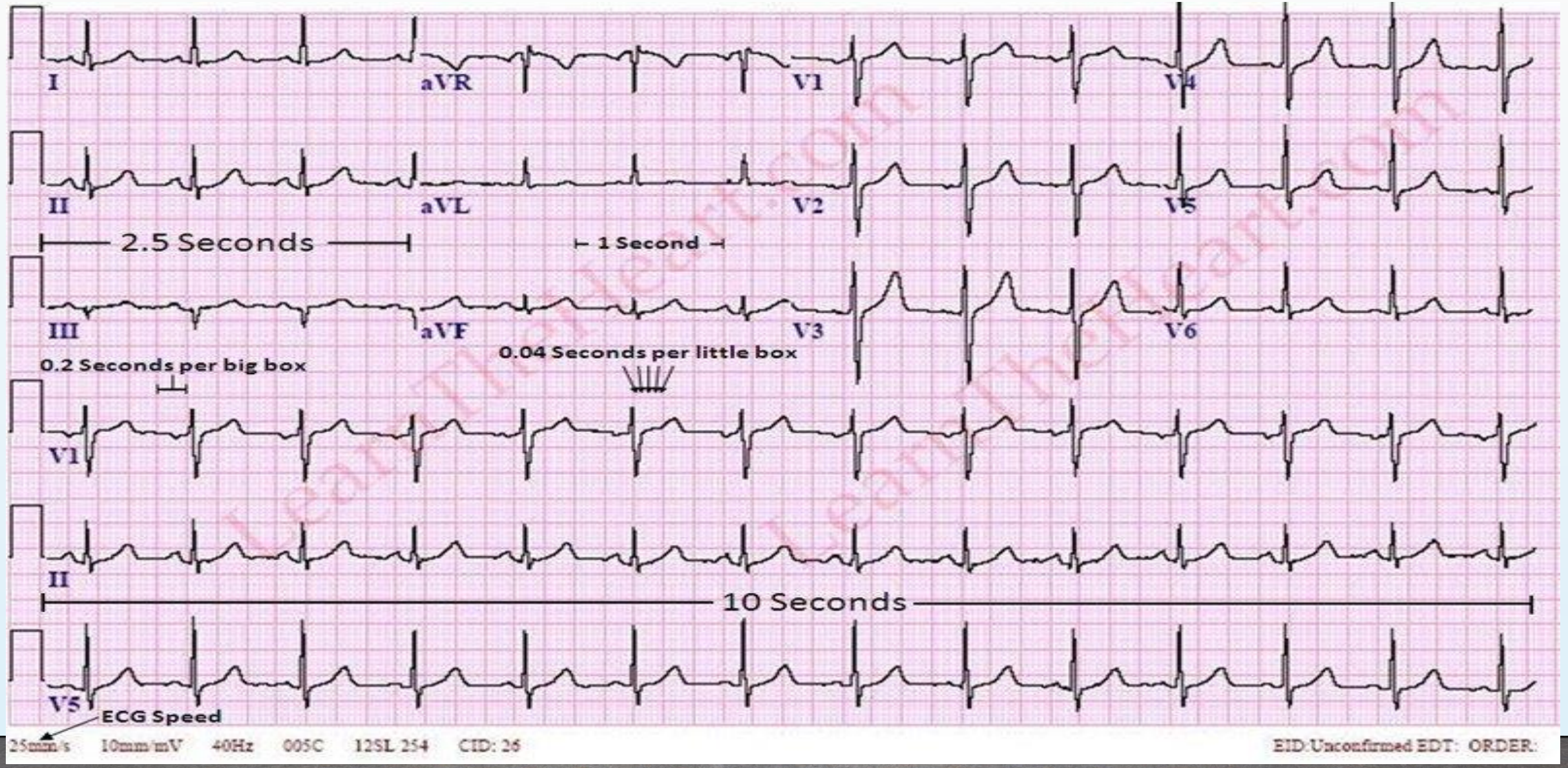
- The time between the start of the Q wave and the end of the T wave.
- Represents electrical activity of the ventricles & Corresponds to mechanical contraction of the ventricles.
- The duration of QT interval is inversely proportional to HR.
- Normal duration: when Heart rate between 60–100 bpm: QT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

Spread of excitation wave

- Depolarization started in the SA node-→ Rt to left atria →interventricular septum from left to RT → apex →ventricular walls from endocardium to epicardium → last part to be polarized is postrobasal portion of left ventricle and pulmonary conus.

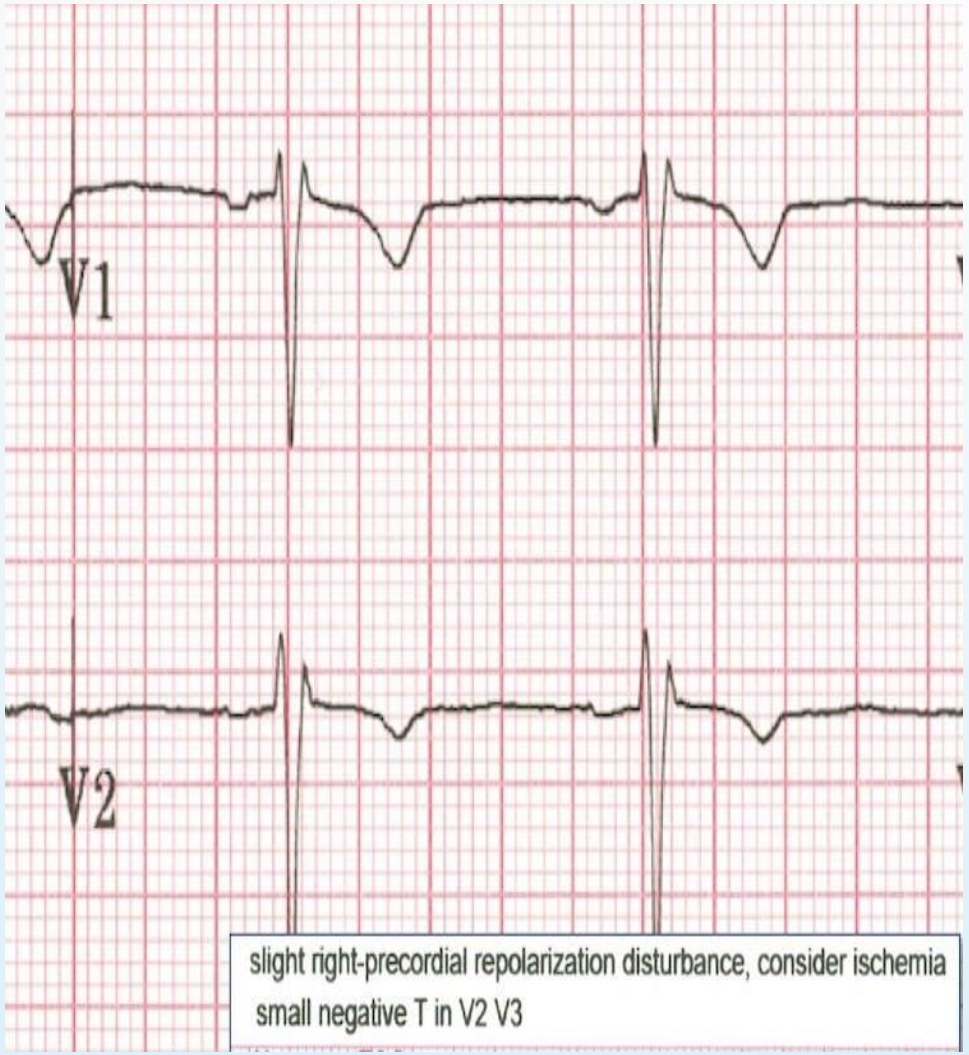
Four golden rules of ECGs:

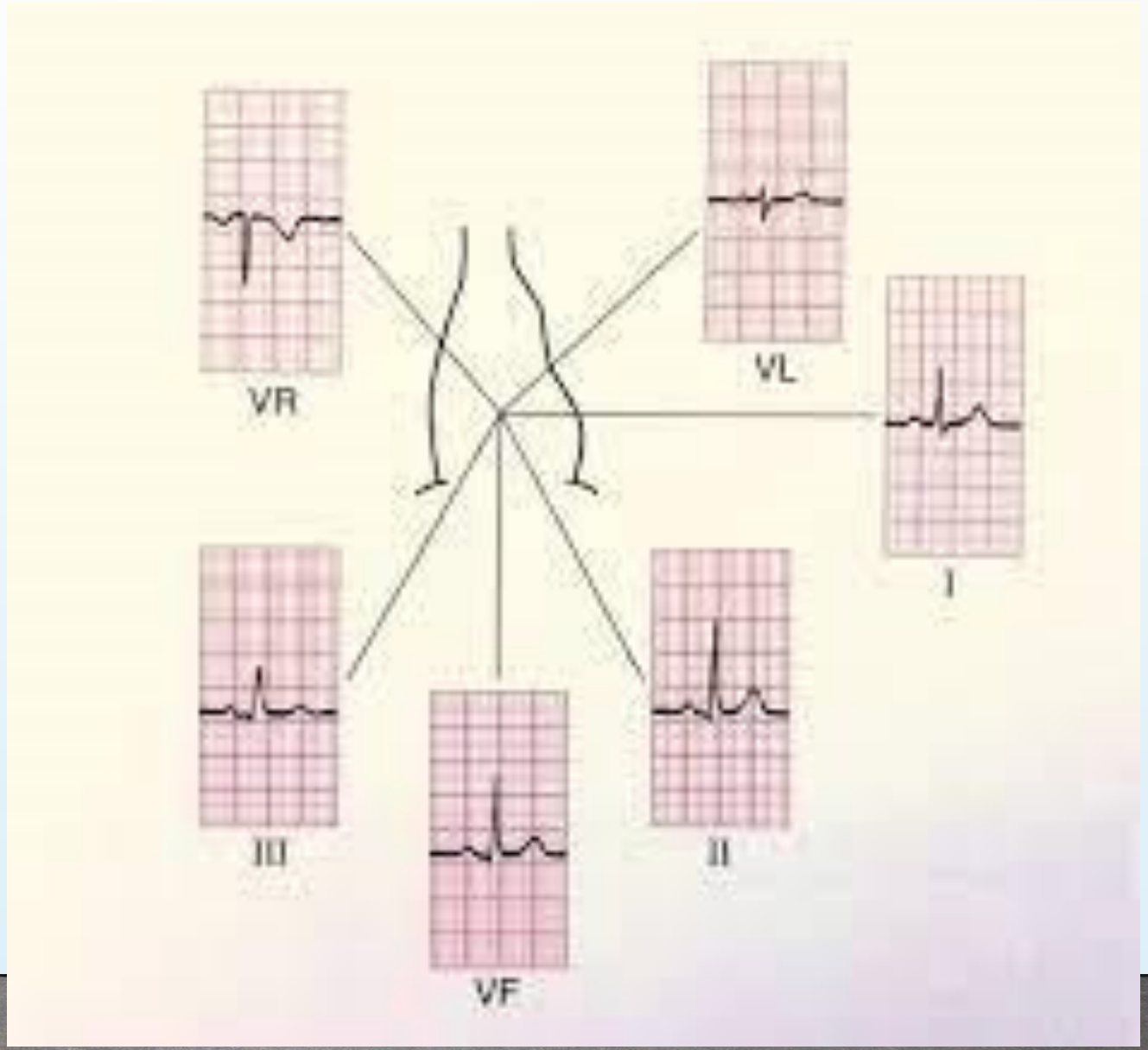
1. Depolarization toward a (+) pole of a lead produces an upward deflection on ECG.
2. Depolarization toward a (–) pole of a lead produces a downward deflection on ECG.
3. The magnitude of deflection (up or down) is proportional to how parallel the net electrical vector is to the lead measuring it.
4. Repolarization toward a (+) and (–) pole produces a downward and upward deflection on ECG, respectively. This is why (T wave) is the same direction as QRS complex


I
aVR
V1
V4
II
aVL
V2
V5
2.5 Seconds
1 Second
III
aVF
V3
V6
0.2 Seconds per big box
0.04 Seconds per little box
V1
II
10 Seconds
V5
ECG Speed
25mm/s 10mm/mV 40Hz 005C 12SL 254 CID: 26
EID:Unconfirmed EDT: ORDER:

Normal ECG variation in different leads

- Classic ecg →left precordial leads v5, v6 → small Q and big R.
- aVR→ P, QRS T waves are inverted.
- aVR→ small R and deep S wave


V1
V2
slight right-precordial repolarization disturbance, consider ischemia
small negative T in V2 V3


VR
VL
I
III
II
VF

Vectorial analysis of the heart

- Vector is an arrow that points in the direction of the electrical potential generated by the current flow.
- The length of the arrow is drawn proportional to the voltage of the potential

Mean vector

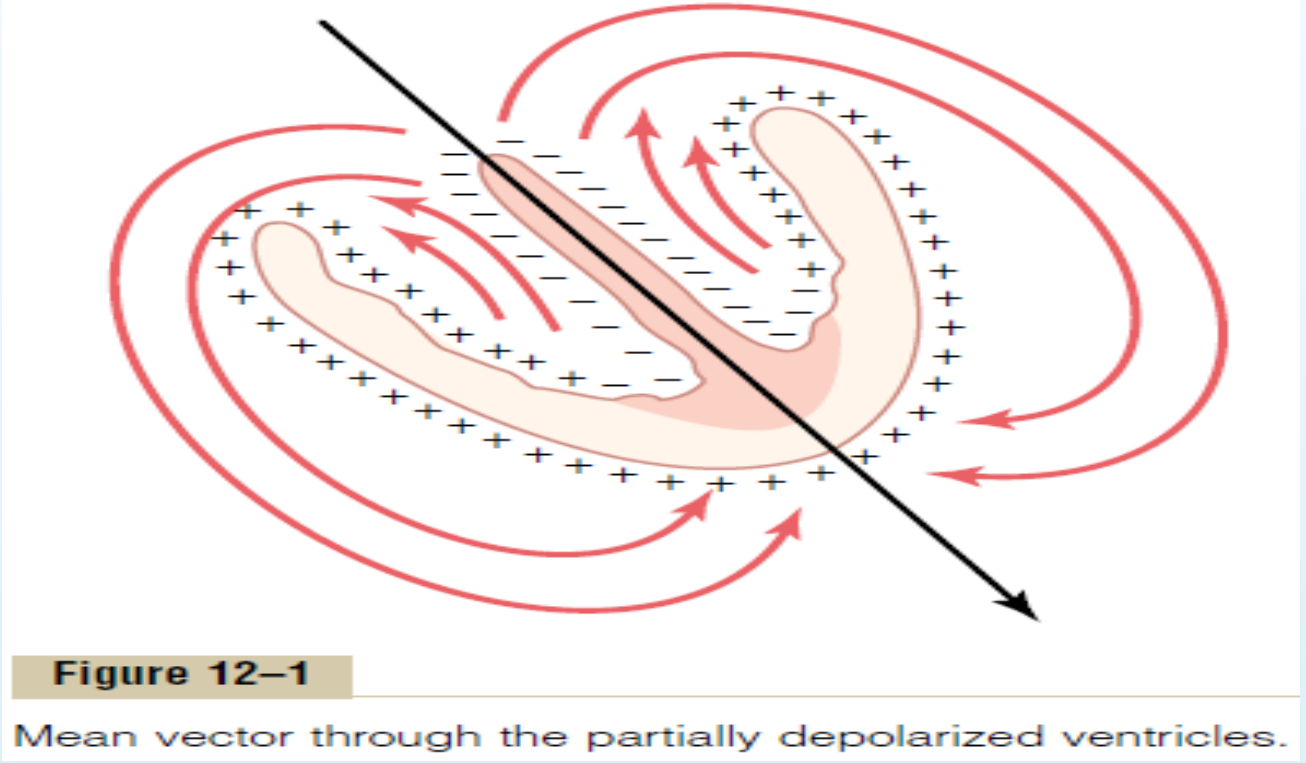
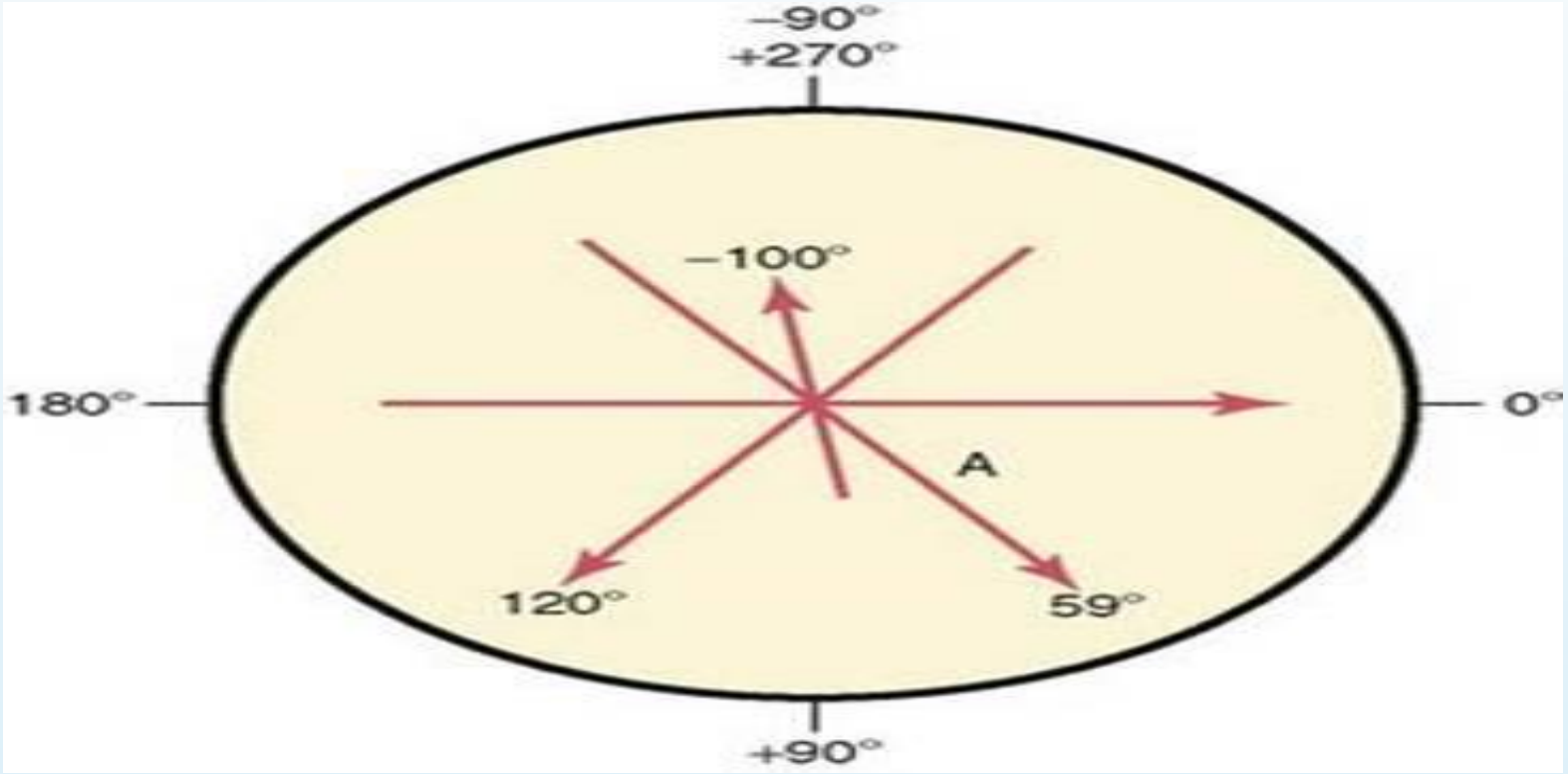


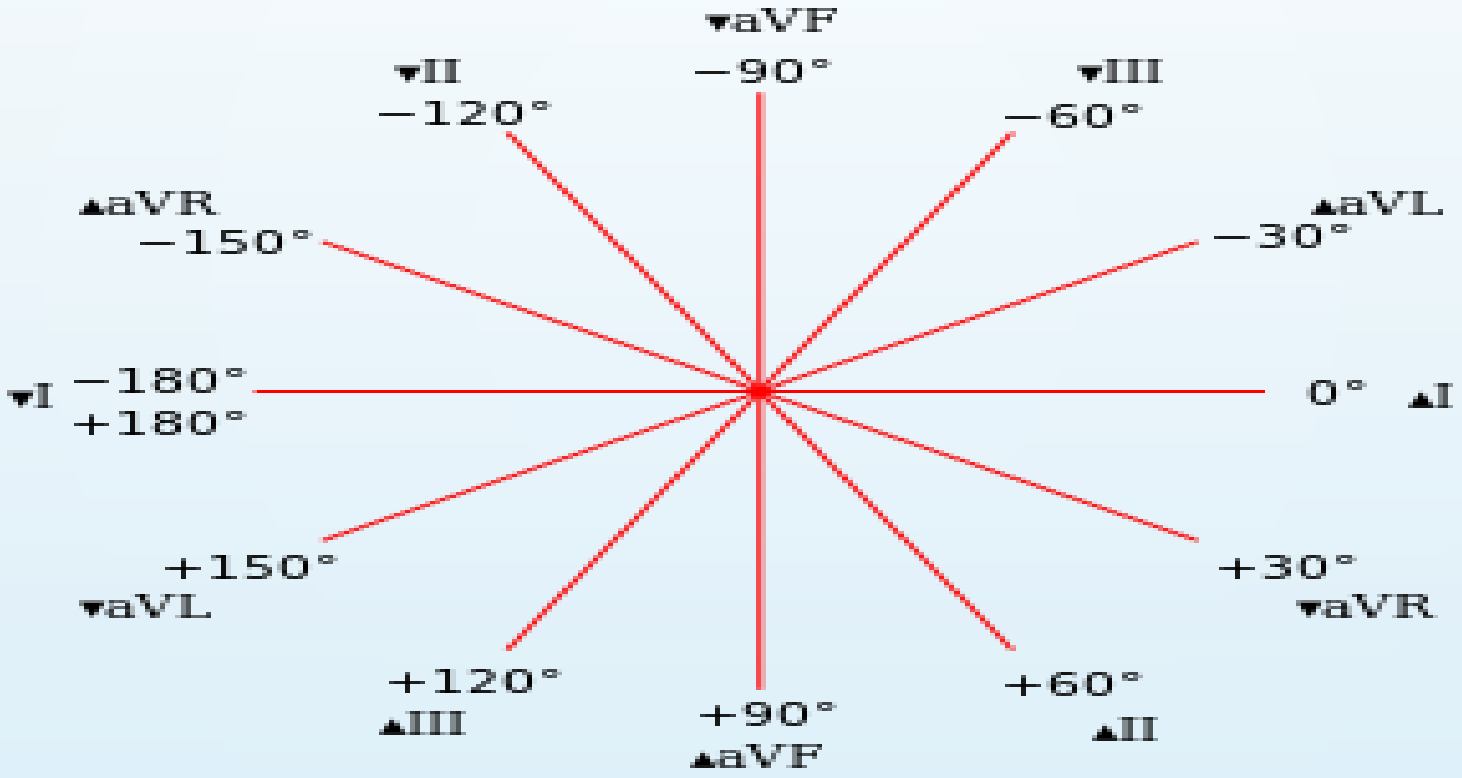
Figure 12–1

Mean vector through the partially depolarized ventricles.

Direction of vectors in degrees



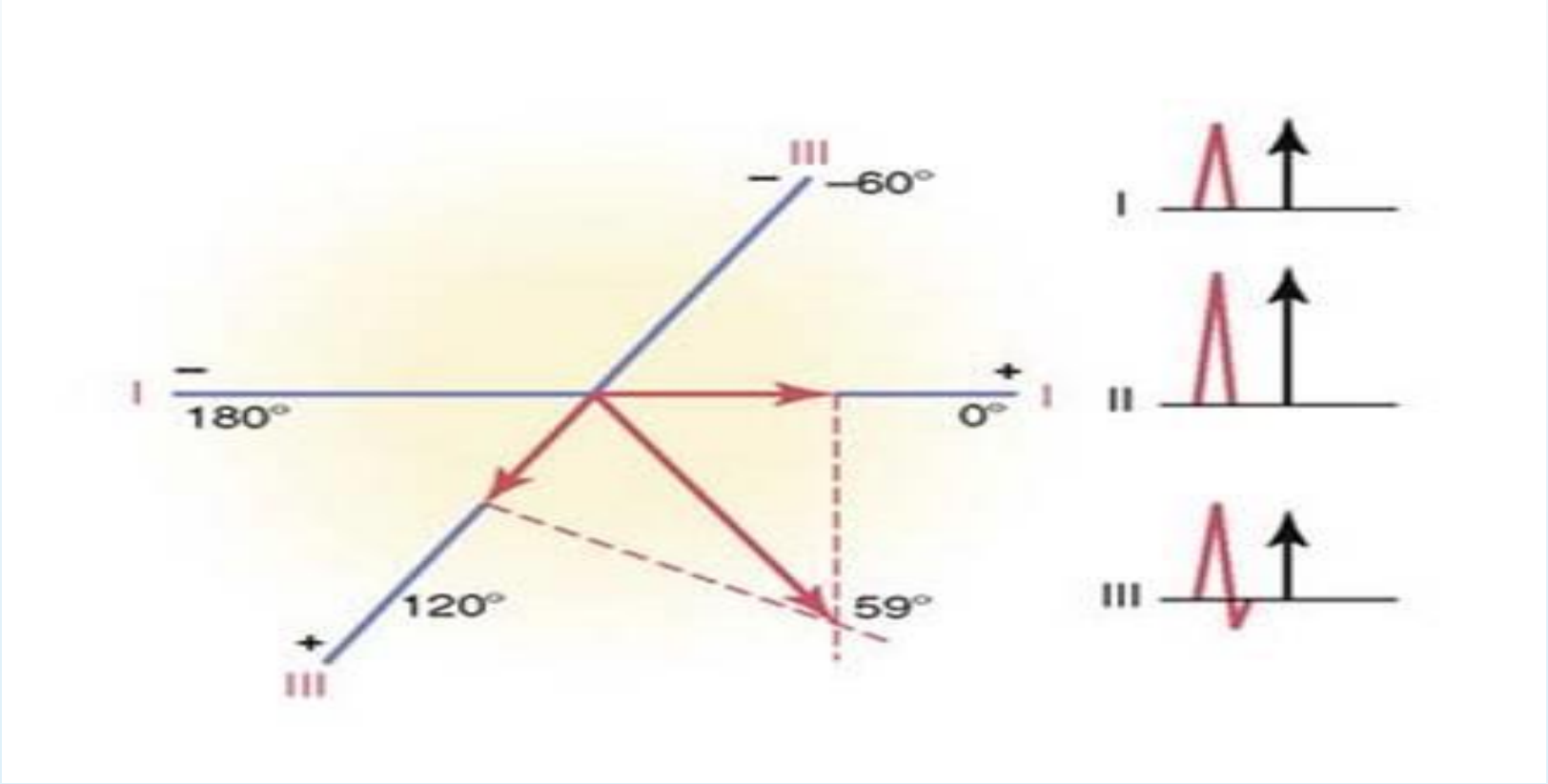
Axes of bipolar and unipolar limb leads



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 leads II.
- The axis may be deviated to the right or to the left.

The mean electrical axis plotting



Causes of axis deviation

- **Right axis deviation**

Physiological causes:

1) During inspiration.
2) When the person stands up.
3) Tall and slender person.

Pathological causes:

1) Right ventricular hypertrophy.
2) Right bundle branch block.
3) Left ventricular extrasystole.

- **Left axis deviation**

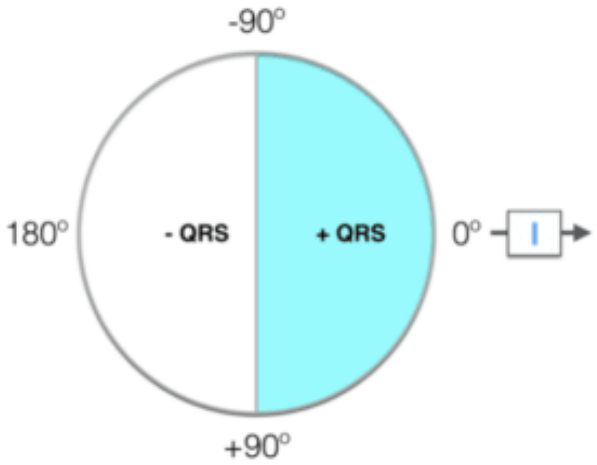
Physiological causes:

1) During expiration.
2) When the person lays down.
3) Short and fatty person.

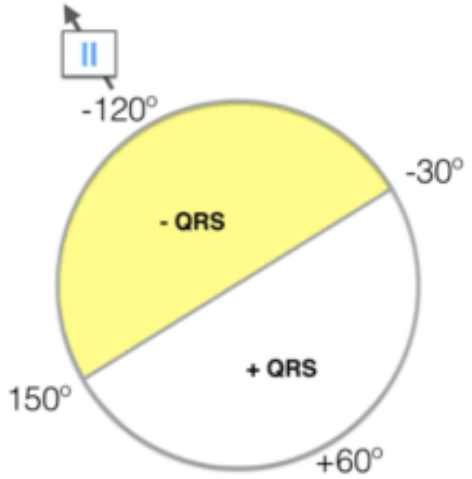
Pathological causes:

1) Left ventricular hypertrophy in some cases.
2) Left bundle branch block (the most common cause).
3) Right ventricular extrasystole.

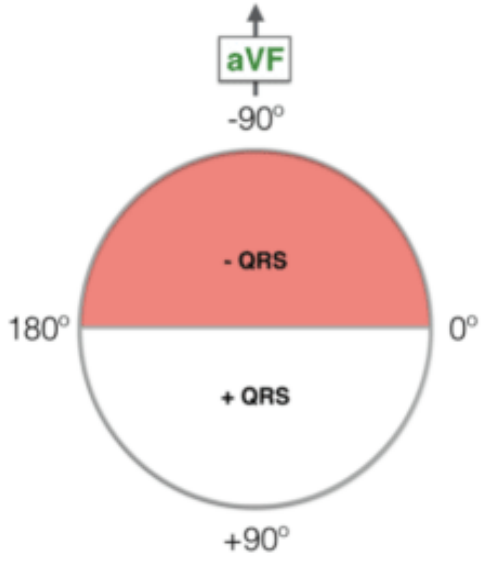
Lead I



Lead II

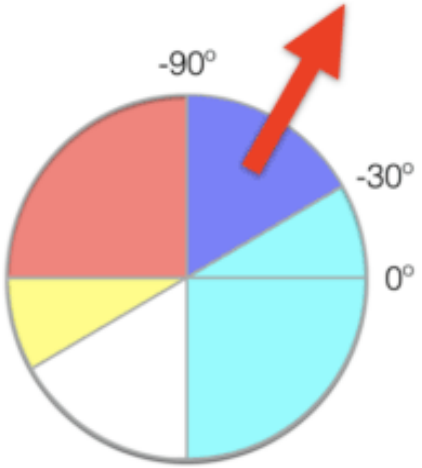


aVF

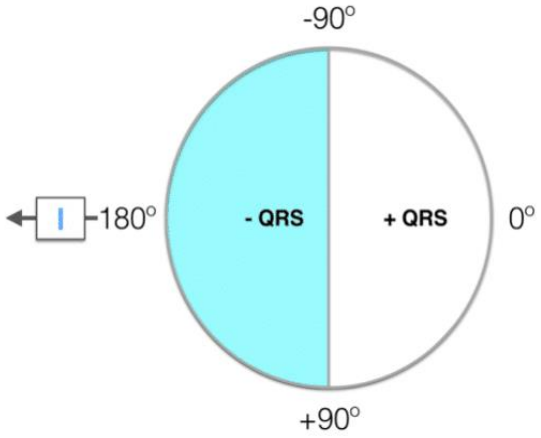


LAD
PATHOLOGICAL

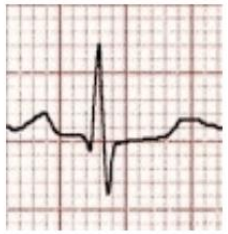
(-30° to - 90°)

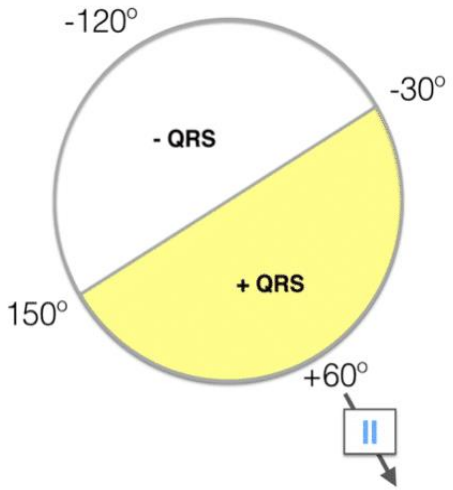


Lead I

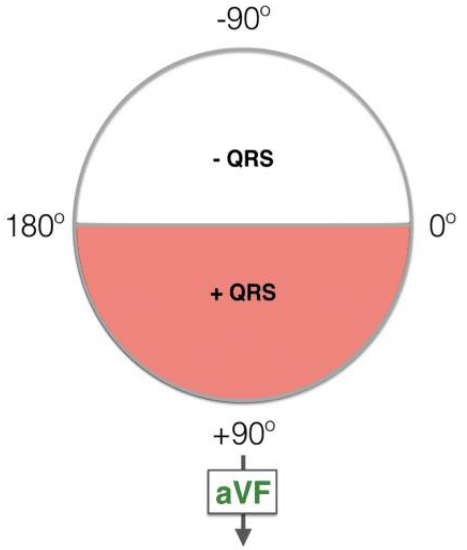


Lead II



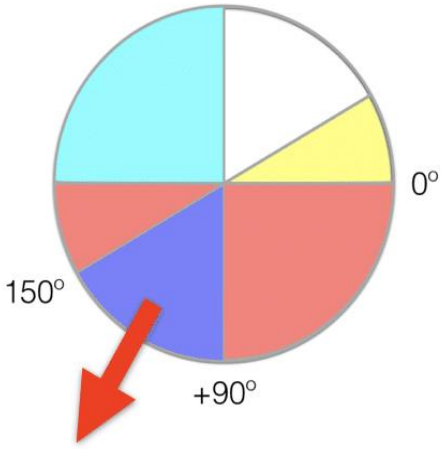


aVF



RAD

(90° to 150°)



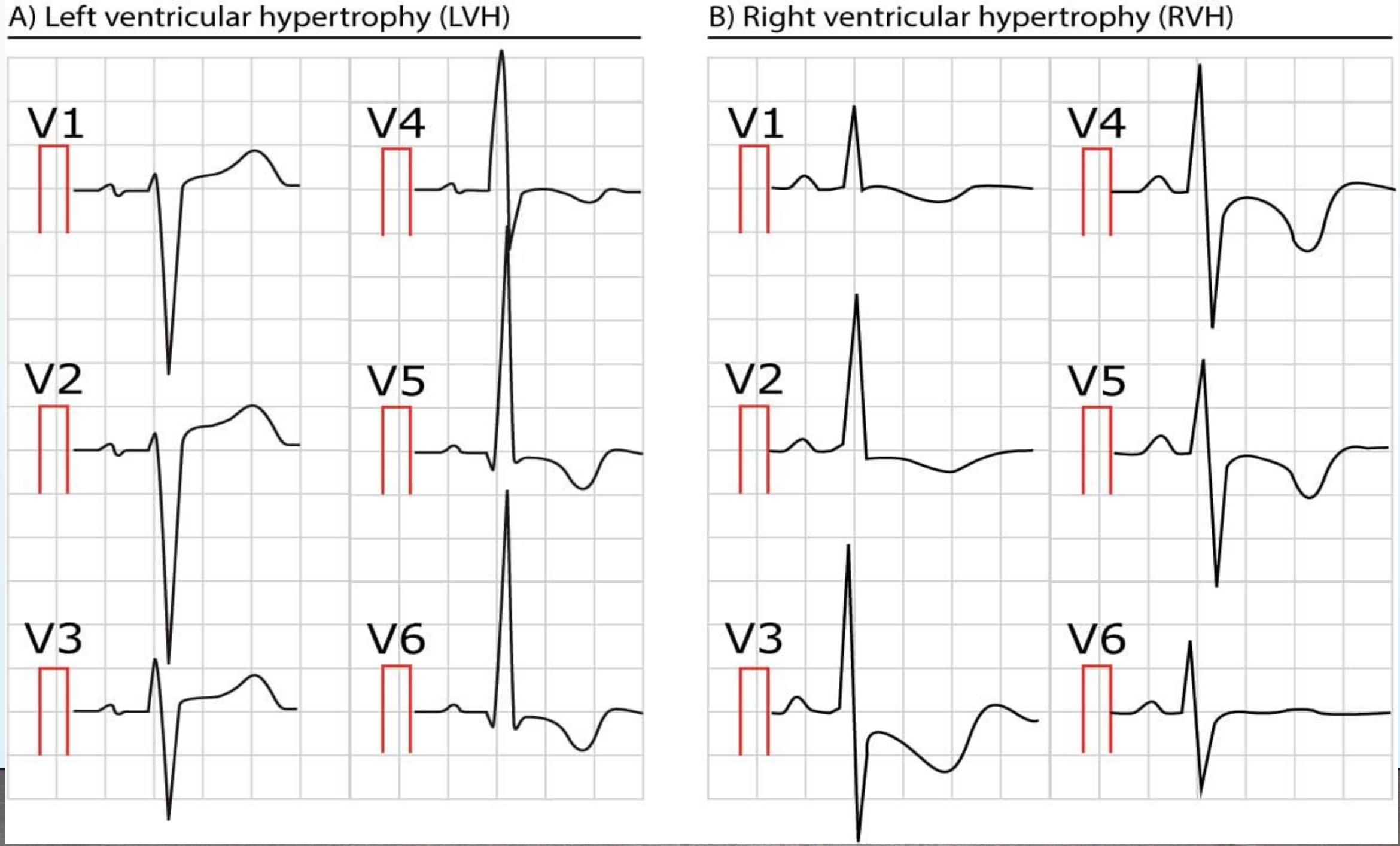
ECG manifestation in ventricular hypertrophy

Lt ventricular hypertrophy

1. High R wave in V5 &V6.
2. Deep S in V1 &V2.
3. Inversion of T wave in V5 & V6.
4. Lt axis deviation.

Rt ventricular hypertrophy

1. High R in V1 & V2.
2. Deep S in V5 & V6.
3. Inversion of T wave in V1 & V2.
4. Rt axis deviation.


A) Left ventricular hypertrophy (LVH)
V1
V4
V2
V5
V3
V6
B) Right ventricular hypertrophy (RVH)
V1
V4
V2
V5
V3
V6

Thank you

To be completed