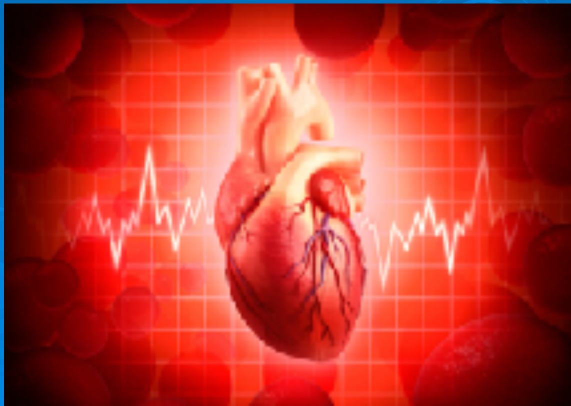
Introduction to Electrocardiography

Outline

1. Review of the conduction system
2. ECG leads and recording
3. ECG waveforms and intervals
4. Normal ECG and its variants
5. Interpretation and reporting of an ECG



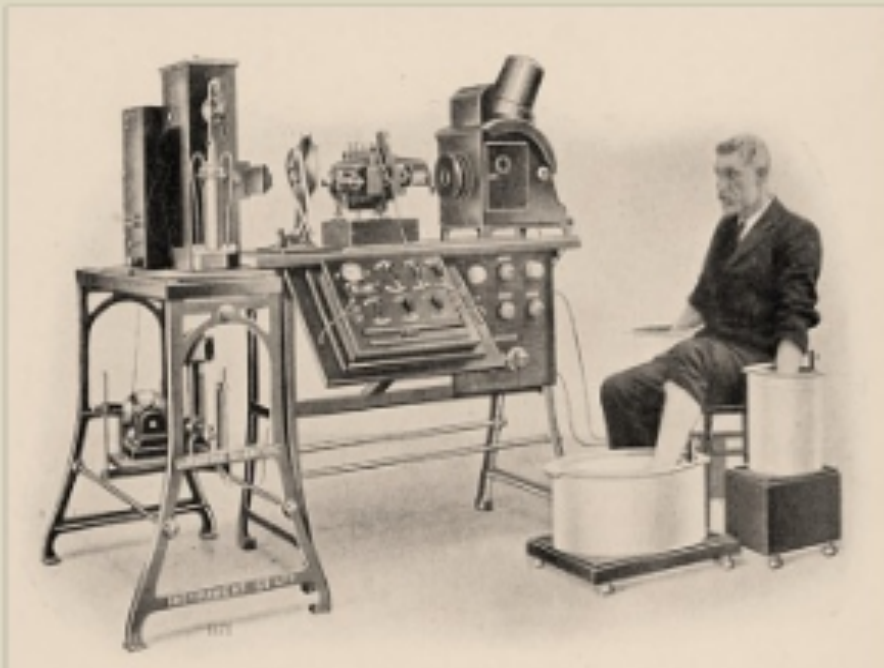
History

- 1842- Italian scientist Carlo Matteucci realizes that electricity is associated with the heart beat
- 1876 – Irish scientist Marey analyzes the electric pattern of frog`s heart
- 1895- Wiliam Einthoven, credited for the invention of EKG
- 1906- using the string electrometer, Wiliam Einthoven, diagnoses some heart problem
- 1924 - the noble prize for physiology or medicine is given to William Einthoven for his work on EKG
- 1938 -AHA and Cardiac society of great Britain defined and position of chest leads
- 1942- Goldberger increased Wilson's Unipolar lead voltage by 50% and made augmented leads.

1903

Willem Einthoven

A Dutch doctor and physiologist.
He invented the first practical electrocardiogram and received the Nobel Prize in Medicine in 1924 for it



Photograph of a Complete Electrocardiograph, Showing the Manner in which the Electrodes are Attached to the Patient, In this Case the Hands and One Foot Being Immersed in Jars of Salt Solution

NOW

Modern ECG machine

has evolved into compact electronic systems that often include computerized interpretation of the electrocardiogram.

The ECG provides information regarding the electrical activity of the heart and offers:

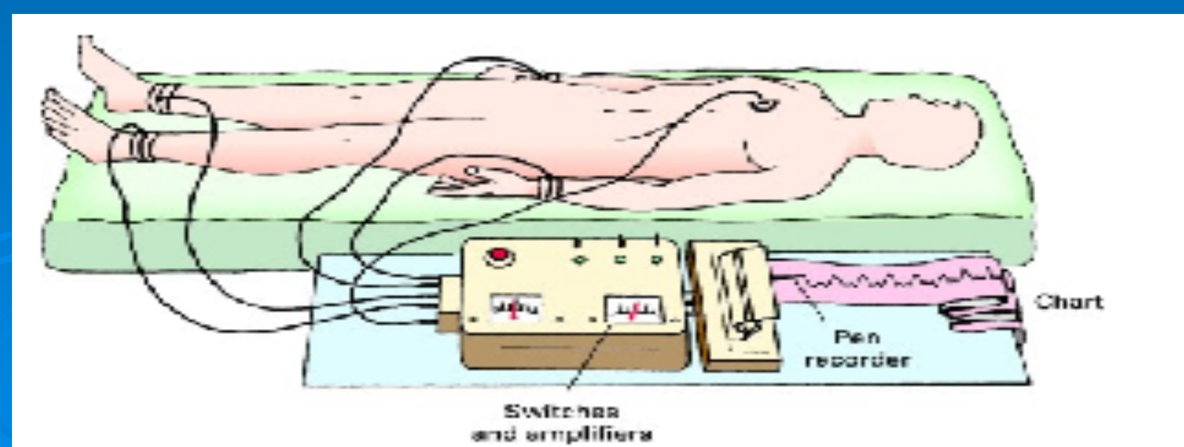
- the possibility to assess the heart‘s ability to generate electrical impulses (***automacity*** or ***chronotropy***);
- to conduct action potentials (***conductivity or drompotropy***);
- the ability of cardiac cells to respond to electrical impulses (***excitability or bathmotropy***);
- but offers no information about contractility (inotropy) or relaxation (lusiotropy).

The genesis of the electrocardiogram

The electrocardiogram (ECG or EKG)- provides a general picture regarding the electrical activity of the heart, recording the electrical changes that take place at the surface of cardiac myocytes at different moments of the cardiac cycles.

The device used for recording the ECG is called electrocardiograph. The main components of an electrocardiograph are:

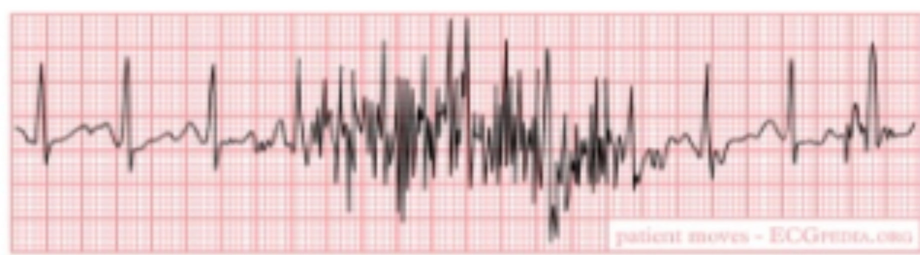
- the signal acquisition system- includes the electrodes and the cables;
- the amplification and signal filtering system, used to amplify the relatively small potentials collected by the electrodes (in the order of mV) and to limit the artifacts.
- the signal charting system, displays the ECG trace either on millimeter paper or an a screen.



HOW TO DO ELECTROCARDIOGRAPHY

1. Place the patient in a supine or semi-Fowler's position. If the patient cannot tolerate being flat, you can do the ECG in a more upright position.
2. Instruct the patient to place their arms down by their side and to relax their shoulders.
3. Make sure the patient's legs are uncrossed.
4. Remove any electrical devices, such as cell phones, away from the patient as they may interfere with the machine.
5. If you're getting artifact in the limb leads, try having the patient sit on top of their hands.
6. Causes of artifact: patient movement, loose/defective electrodes/apparatus, improper grounding.

Patient, supine position

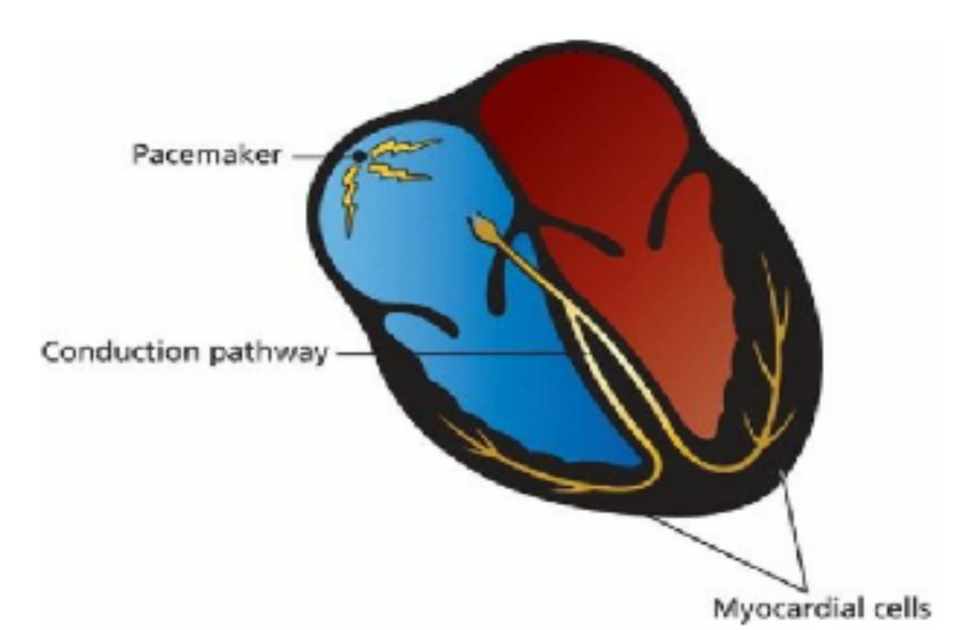


An ECG with artifacts.

The cells of the heart

The heart consists of three types of cells:

- Pacemaker cells- under normal circumstances, the electrical power source of the heart
- Electrical conducting cells- the hard wiring of the heart
- Myocardial cells- the contractile machinery of the heart



Sinoatrial node (SA) node or sinus node – the dominant pacemaker cell of the heart.

- located high up in the right atrium:
  - a branch from SA node is sent to left atria
  - it initiates all heart beat and determine heart rate
  - the wave front travels through the right and left atria in a centrifugal manner.

***Atrioventricular node (AV)* :**

- located in the wall of the right atrium just next to the opening of the coronary sinus,
- serve as electrical gateway to the ventricles.

Bundle of His (AV bundle) divided:

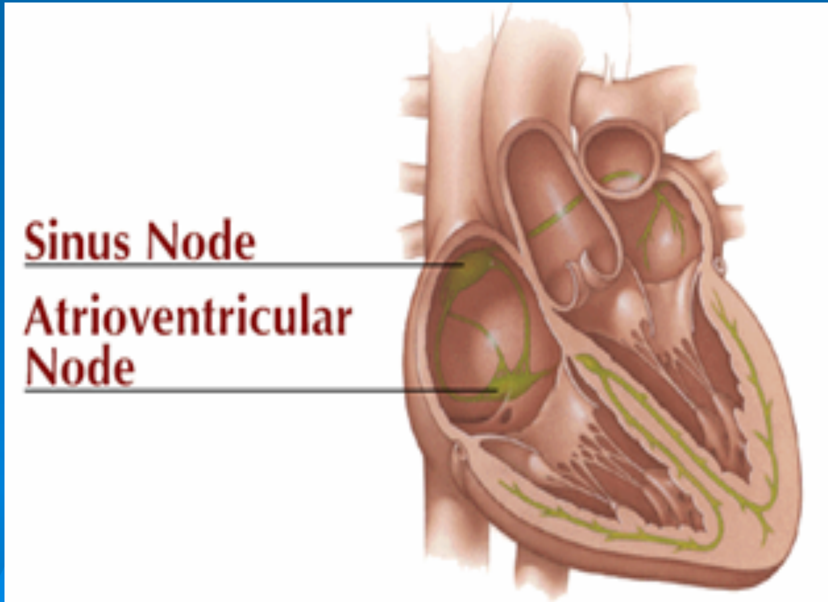
- LBB and RBB

The LBB divides:

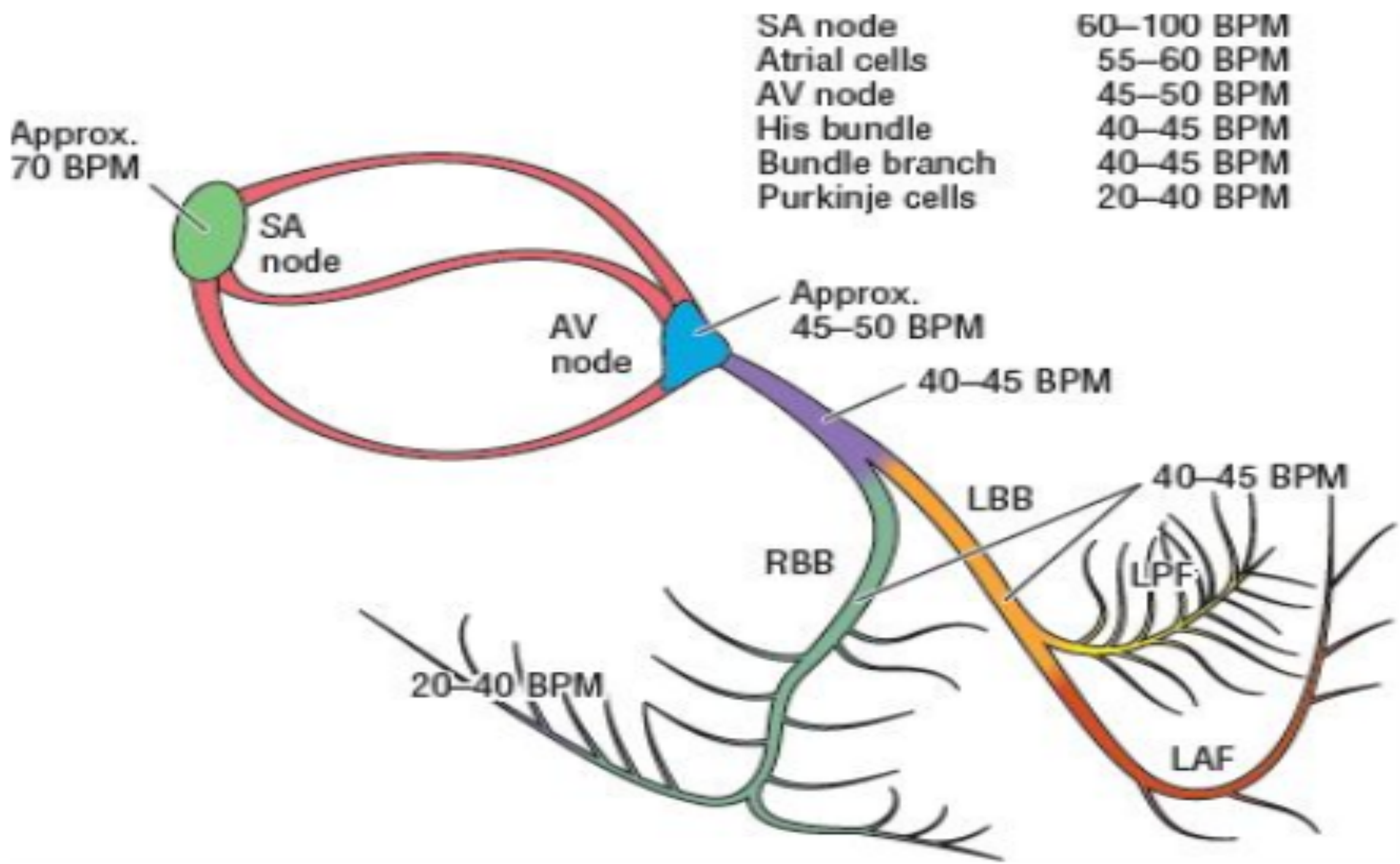
- anterior and posterior branch.

More distally the bundles ramify into Purkinje fibers.

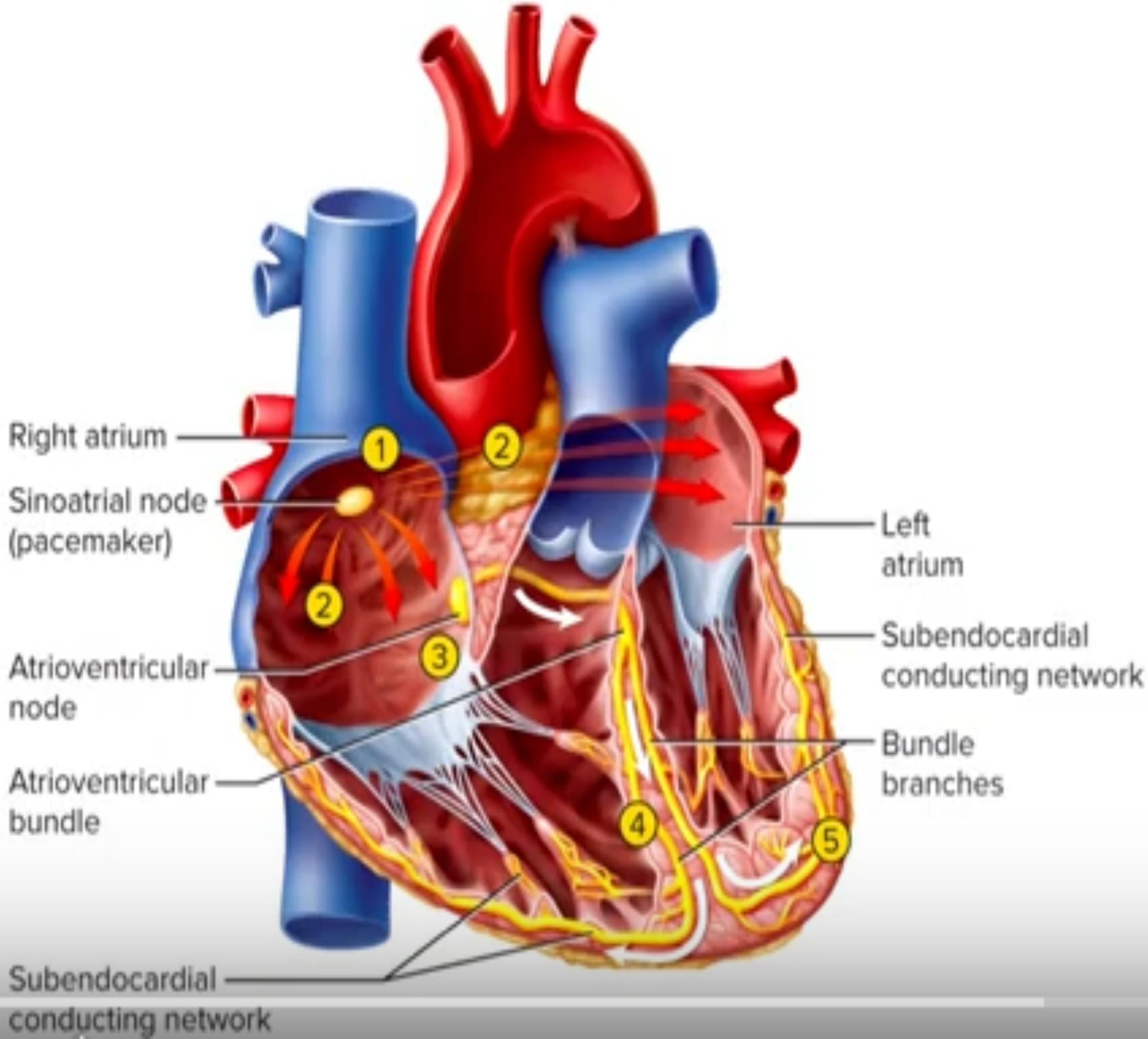
- Bachman's bundle - fibers at the top of the intraatrial septum that allow rapid activation of the left atrium from the right.



Intrinsic rates of pacing cells



The electrical conduction system of the heart



1. SA node fires.
2. Excitation spreads through atrial myocardium.
3. AV node fires.
4. Excitation spreads down AV bundle.
5. Subendocardial conducting network distributes excitation through ventricular myocardium.

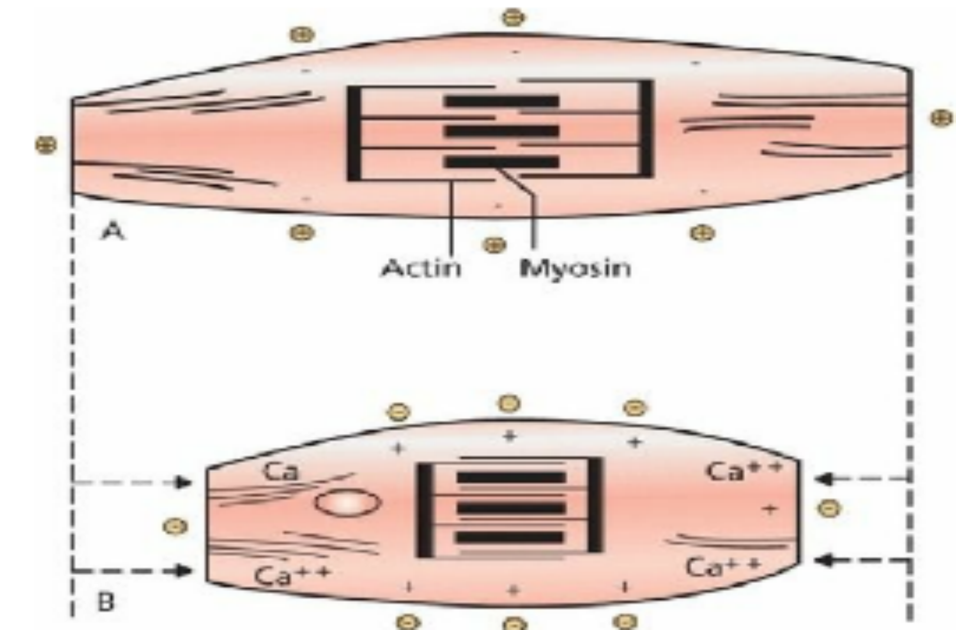
Myocardial cells

- the largest part of the heart tissue;
- are responsible for the heavy labour of repeatedly contracting and relaxing, delivering blood to the rest of the body;
- contain an abundance of the contractile proteins and myosin.

When a wave of depolarization reaches a myocardial cell, calcium is released within the cell, causing the cell to contract (this process- excitation- contraction coupling).

A- resting myocardial cell

B- a depolarized, contracted myocardial cell

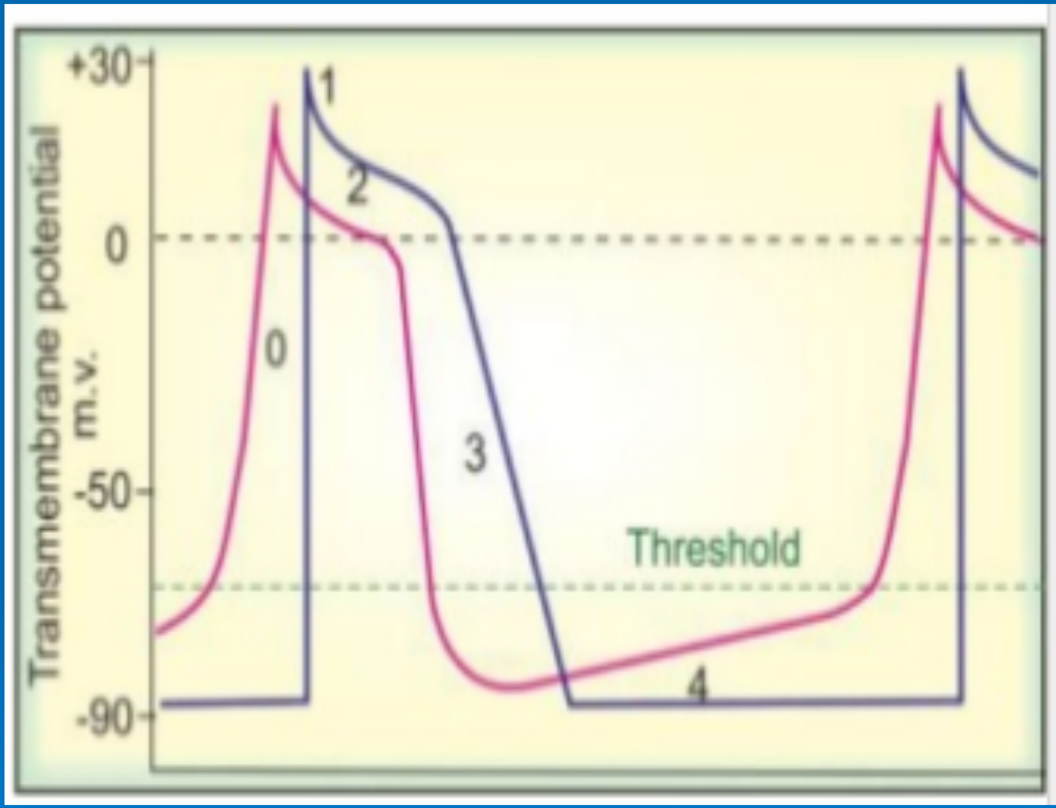


Cardiac Electrophysiology

Impulse generation

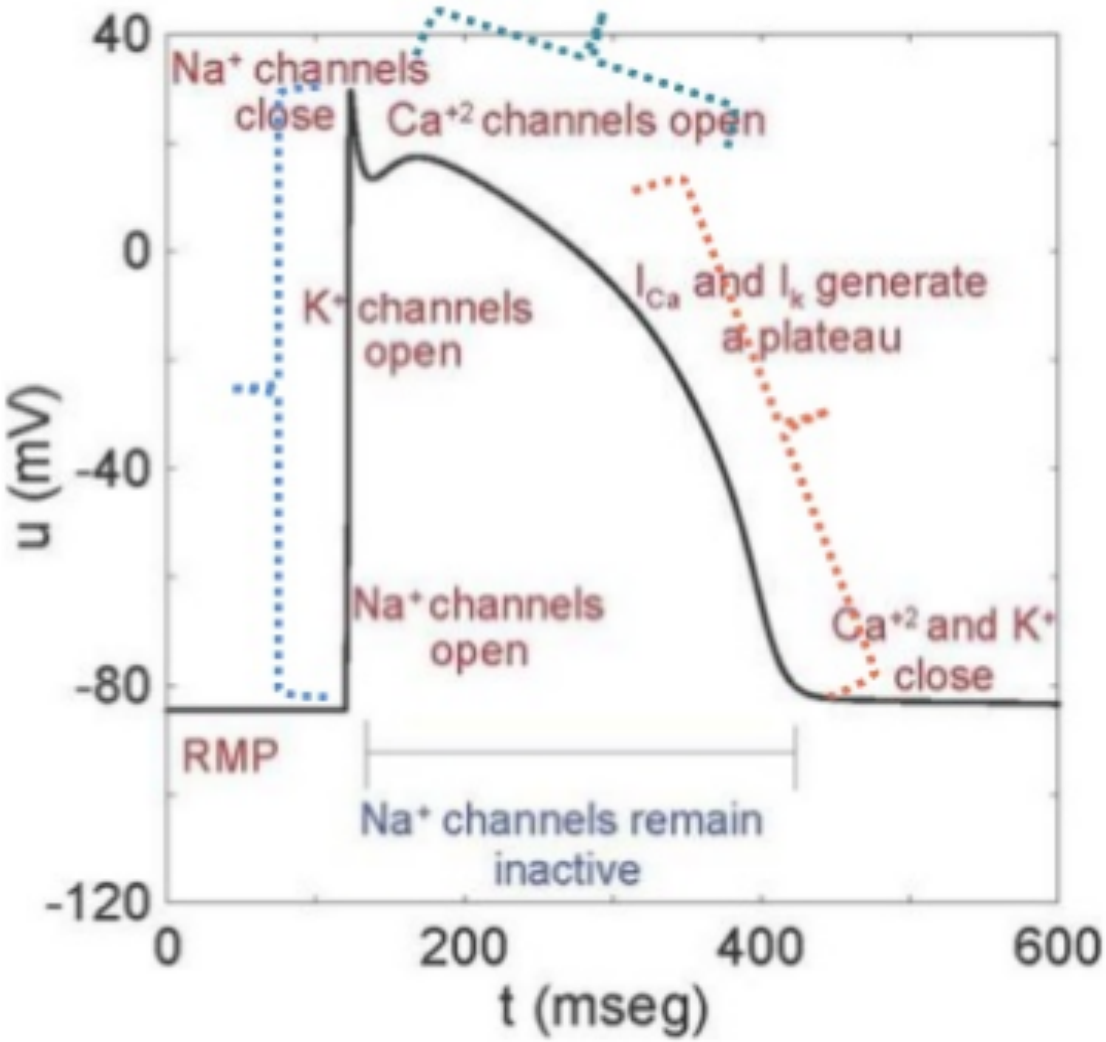
- ***Nonautomatic fibres***: Ordinary working myocardial fibers and cannot generate impulse of their own

- ***Automatic fibres***: SA node, AV node, His- Purkinje system.



Cardiac Electrophysiology

- Impulse generation



Rapid depolarization due to opening of voltage-dated fast Na+ channels

Plateau (maintained depolarization) due to opening of voltage-gated slow Ca+ channels and closing of some K+ channels

Repolarization due to opening of voltage-dated K+ channels and closing of Ca+ channels

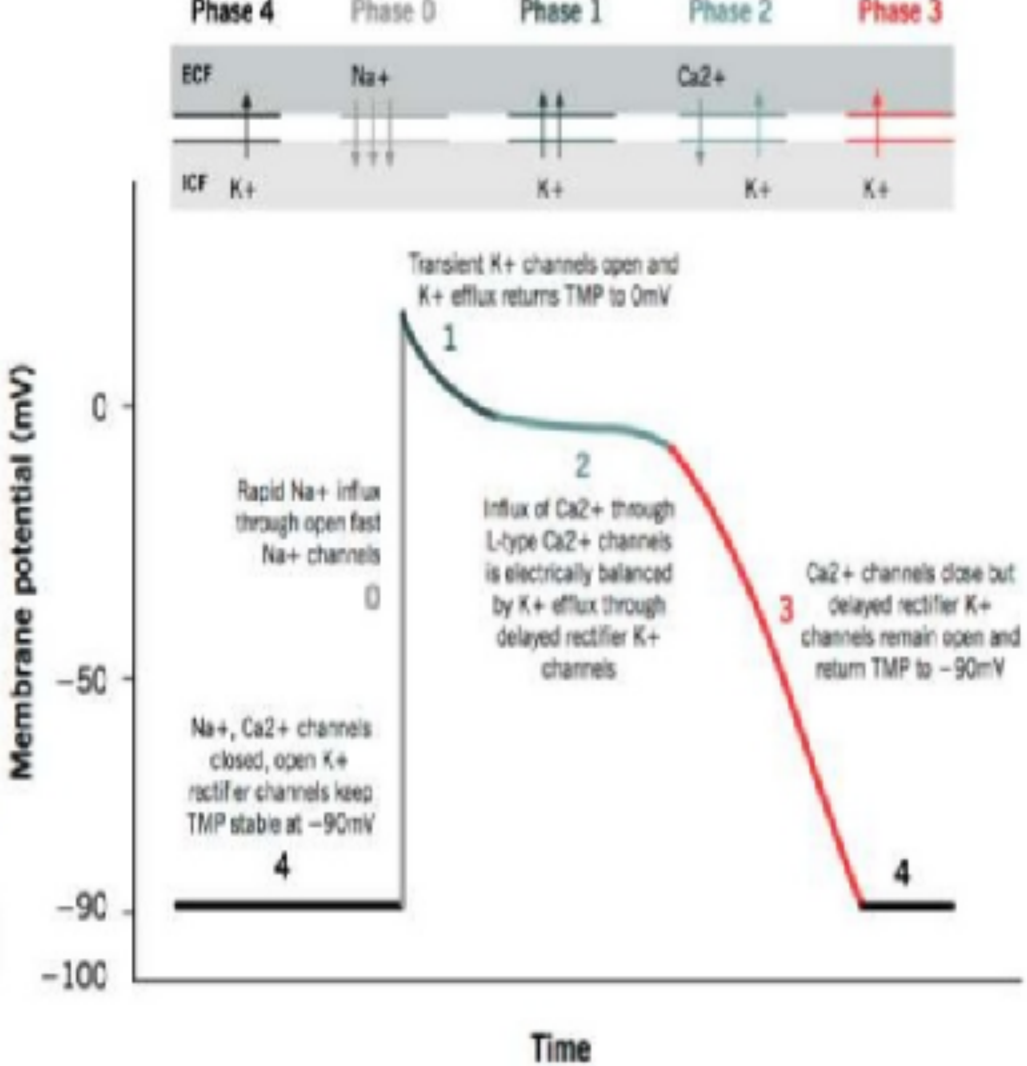
Rapid Na+ entry

Phase 1: Early depolarization
Ca++ slow entry

Phase 2: *Plateau*
continuous repolarization
Slow entry of sodium and calcium

Phase 3: Repolarization
Potassium outflow

Phase 4: Pacemaker potential



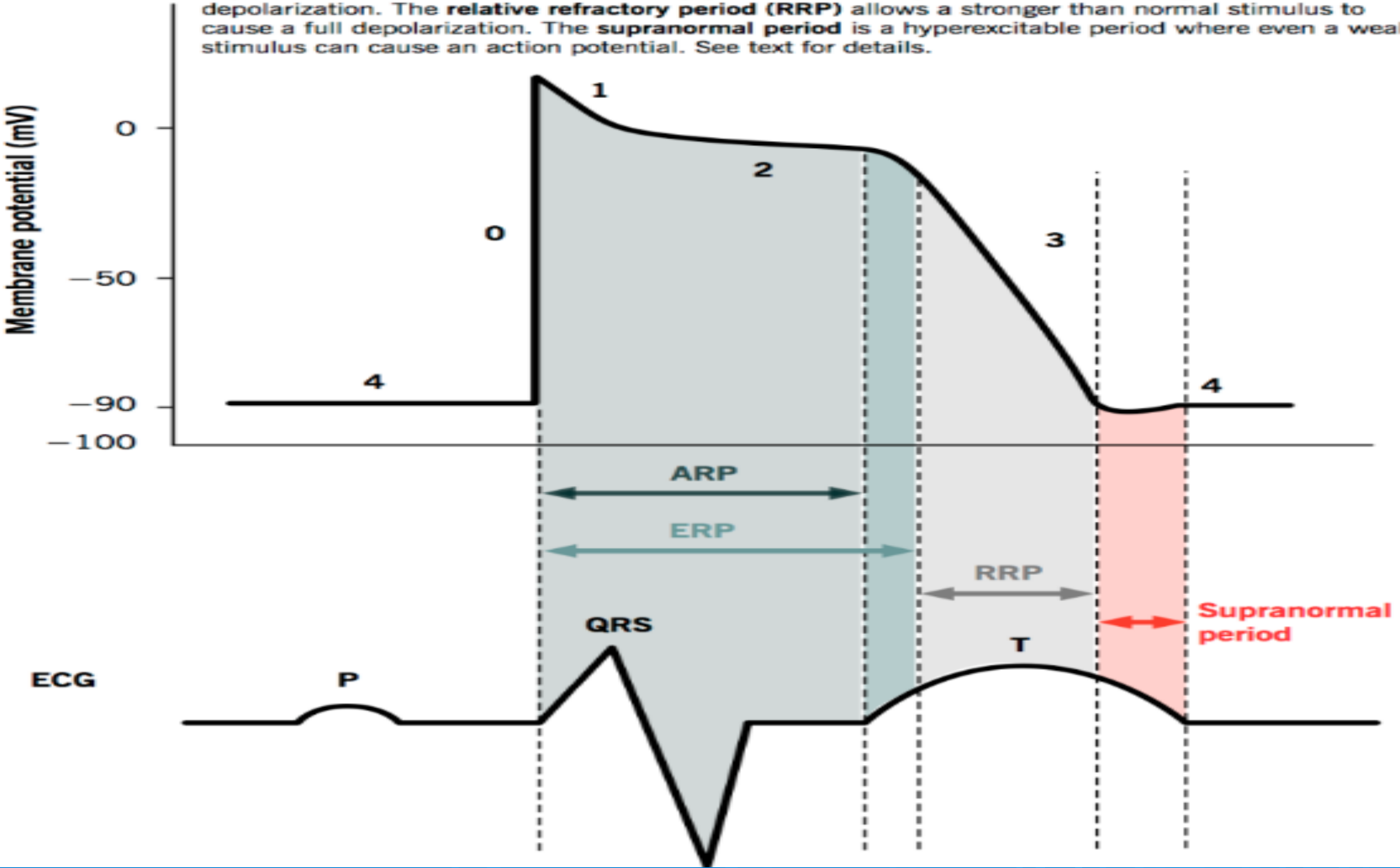
Phase 1 – 3: Refractory period

Ref: Pharmacol Ther. 2005;107(1):59-79.

Refractory periods in cardiac cycle

Grigoriy Ikonnikov and Eric Wong

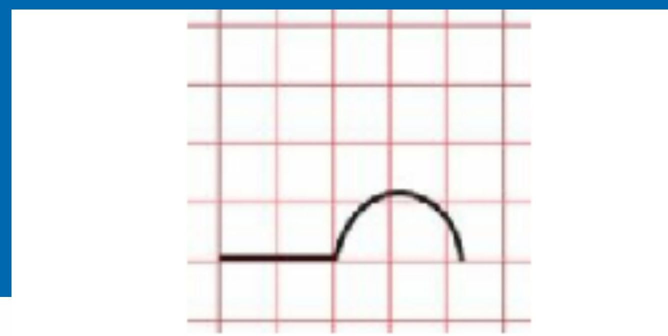
The refractory periods in cardiac muscles allow complete emptying of the ventricles prior to the next contraction. Refractoriness of each phase of the action potential is governed by the number of sodium channels ready to activate. The **absolute refractory period (ARP)** does not allow for any depolarizations. The **effective refractory period (ERP)** may allow for non-propagated depolarization. The **relative refractory period (RRP)** allows a stronger than normal stimulus to cause a full depolarization. The **supranormal period** is a hyperexcitable period where even a weak stimulus can cause an action potential. See text for details.



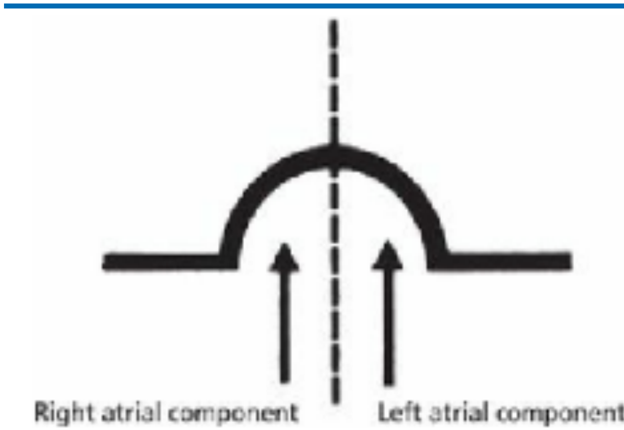
Ikonnikov G, Yelle D. Physiology of cardiac conduction and contractility. Available in http://www.pathophys.org/physiology -of-cardiac-conduction-and- contractility

Each wave or segment of the EKG coresponds to a certain event of the cardiac electrical cycle.

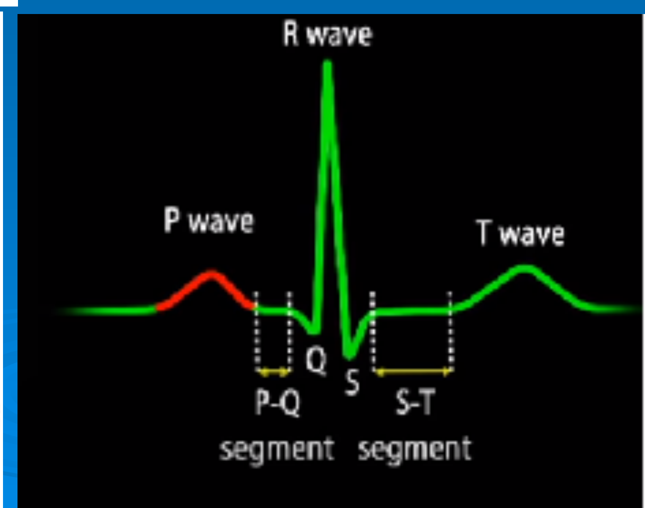
- The sinus nodes fires spontaneously, a wave of depolarization begins to spread outward into the atrial myocardium. During atrial depolarization and contraction, electrodes record a small electrical activity lasting a fraction of second- ***P wave.***



The EKG records a small deflection, the P wave

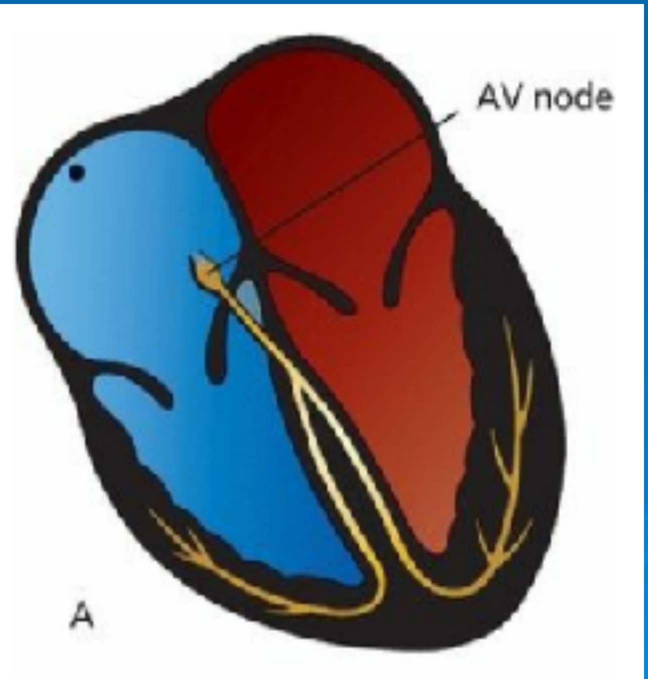


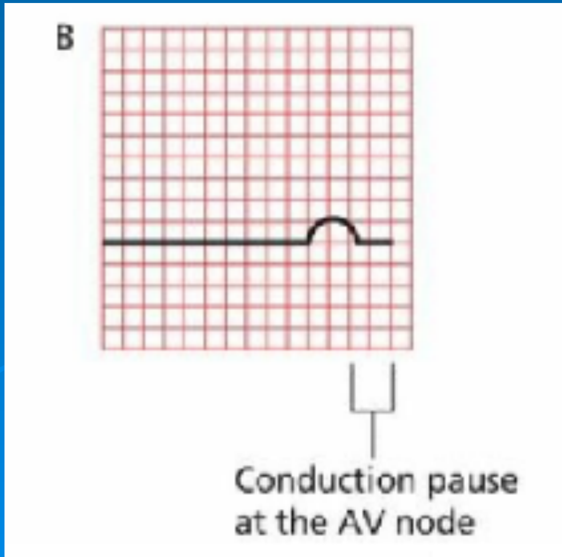
The components of the P wave.



A pause separates conduction from the atria to the ventricles.

- AV node slows conduction to a crawl. This pause lasts only a fraction of second.
- This physiological delay in conduction is essential to allow the atria to finish contracting before the ventricles begin to contract. This electrical wiring of the heart permits the atria to empty their volume of blood completely into the ventricles before the ventricles contract.





A- The wave of depolarization is briefly held up at the AV node

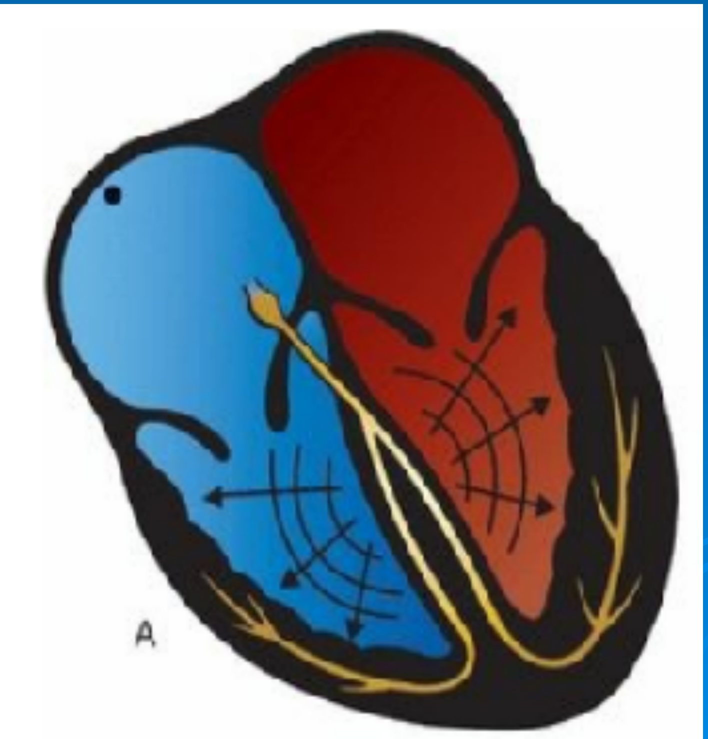
B-During this pause, the EKG falls silent; there is no detectable electrical activity.

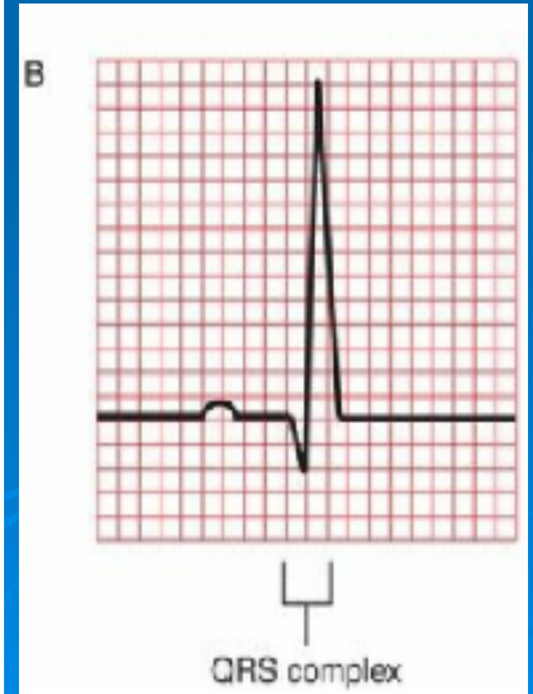
The QRS complex marks the firing of AV node and represent ventricular depolarization.

- Impulse travels to the bundle His, causing the depolarization of the interventricular septum, results in a small downward (negativ)

deflection- ***Q wave***

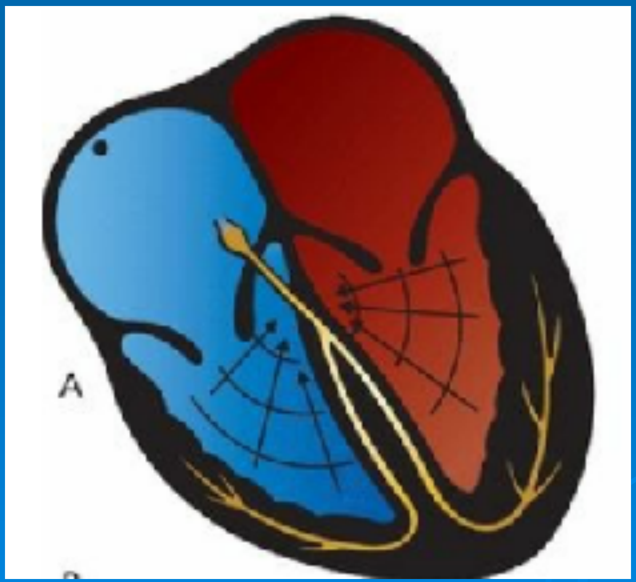
- R wave- the first upward deflection, produced by depolarization of the main mass of ventricles
- S wave- the first downward deflection following an upward deflection, the last phase of ventricular depolarization at the base of the heart.

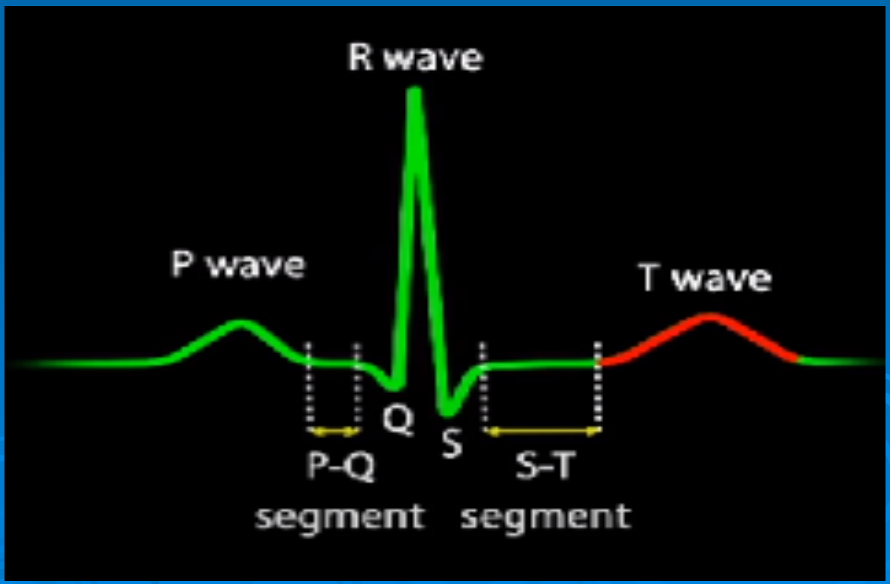


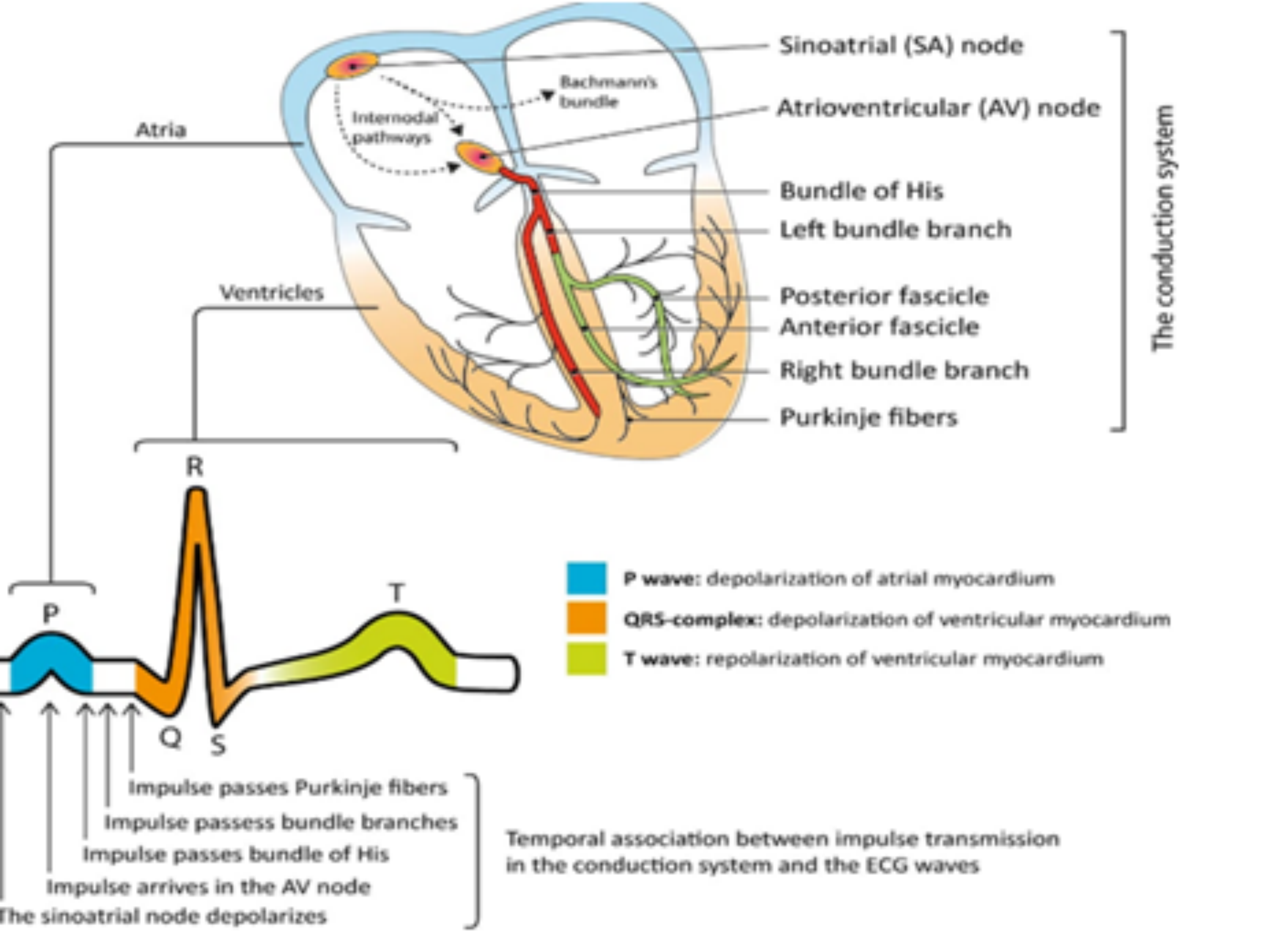


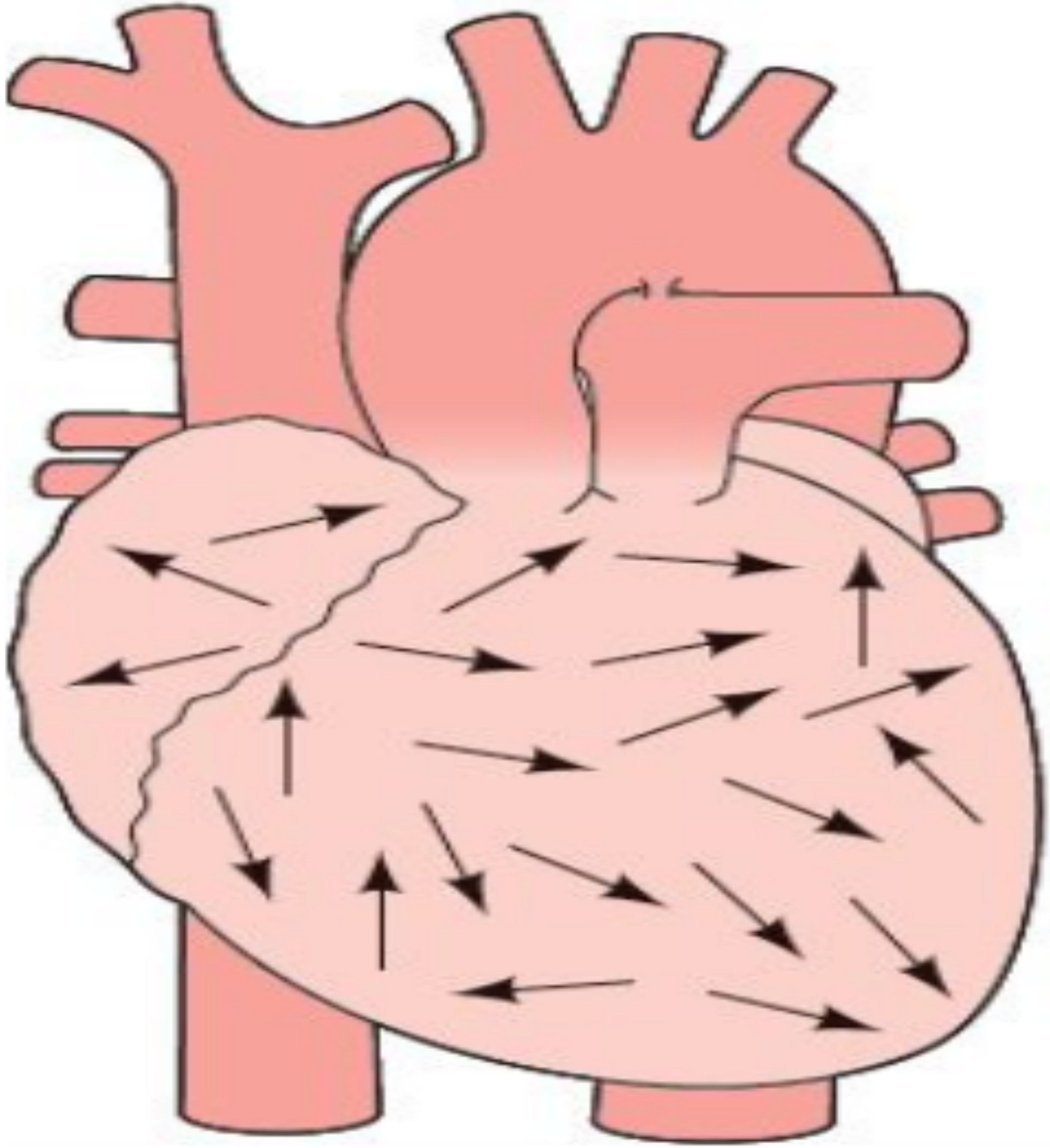
There is a wave of atrial repolarization as well, but it coincides with ventricular depolarization and is hidden by the much more prominent QRS complex.

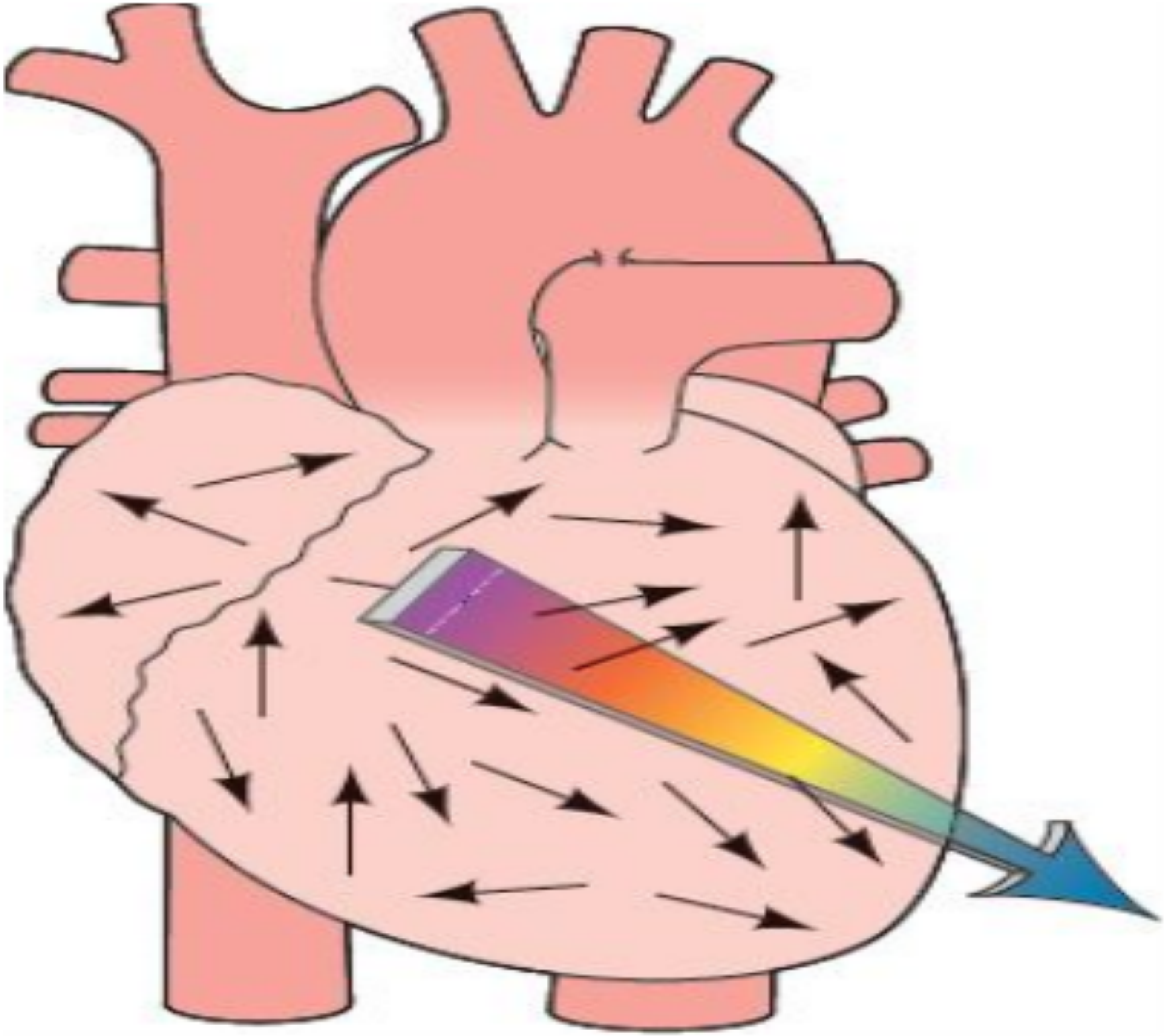
- ST segment reflects the plateau in the myocardial action potential action
- T wave represents ventricular repolarization immediately before the ventricular relaxation or ventricular diastole.
- Ventricular repolarization is a much slower process than ventricular depolarization.






Sinoatrial (SA) node
Bachmann's bundle
Internodal pathways
Atrioventricular (AV) node
Atria
Bundle of His
Left bundle branch
Ventricles
Posterior fascicle
Anterior fascicle
Right bundle branch
Purkinje fibers
The conduction system
R
P
T
Q
S
P wave: depolarization of atrial myocardium
QRS-complex: depolarization of ventricular myocardium
T wave: repolarization of ventricular myocardium
Impulse passes Purkinje fibers
Impulse passess bundle branches
Impulse passes bundle of His
Impulse arrives in the AV node
The sinoatrial node depolarizes
Temporal association between impulse transmission in the conduction system and the ECG waves



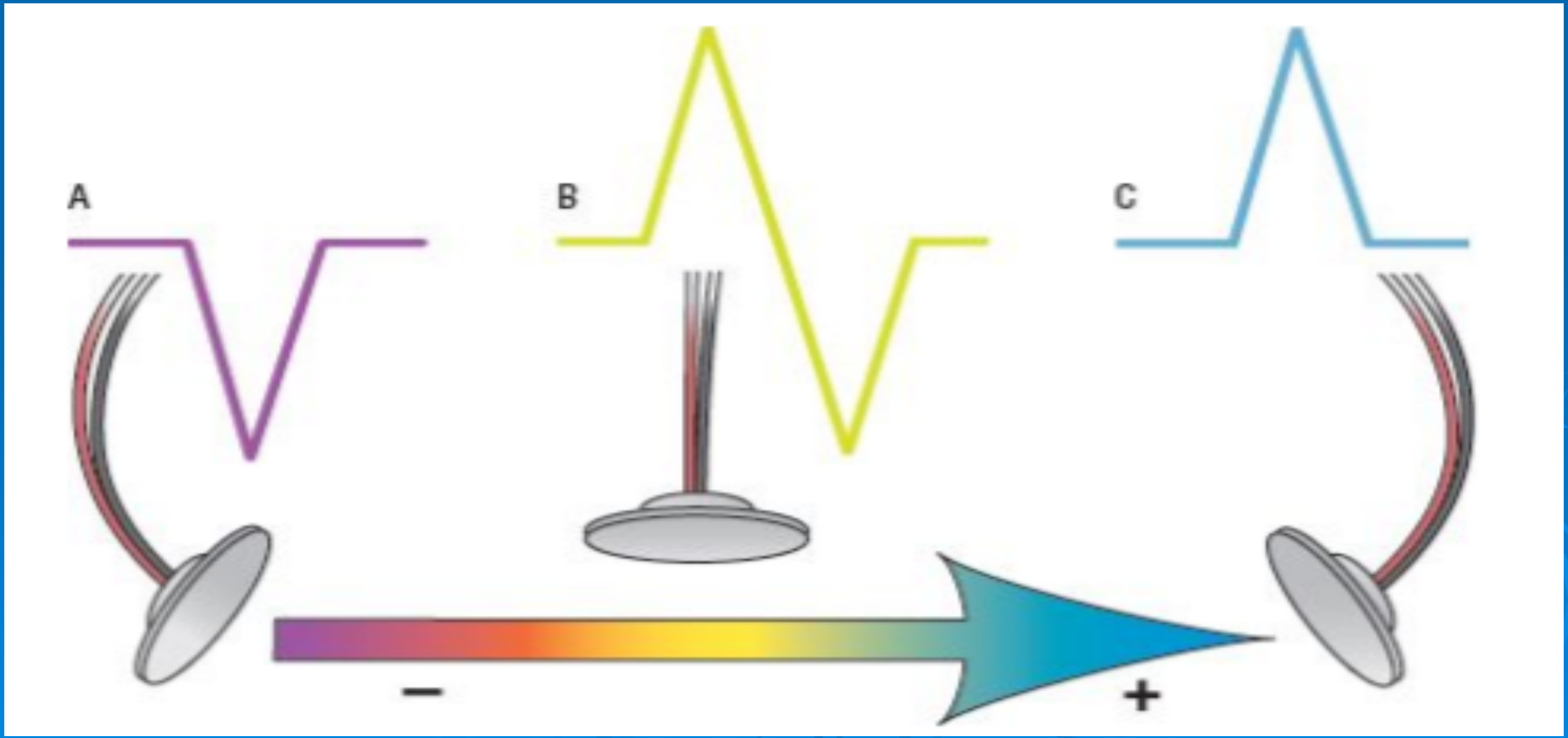


Sum of all ventricular vectors = electrical axis.

Electrodes and wave

- The electrodes are sensing devices that pick up the electrical activity occurring beneath them.

- Three different ECGs resulting from the same vector, due to different lead placements.



Electrocardiographic leads

- In order to collect the potentials generated by electrical activity of the heart, electrodes are placed at the surface of the body.
- Graphically, each lead has a coresponding axis, each axis has an orientation.

There are three lead systems that make up the standard ECG:

- Standard Limb Leads (Bipolar): I, III & III
- Augmented Limb Leads (Unipolar): aVR, aVL & aVF
- Precordial Leads: V1- V6

Standard limb leads

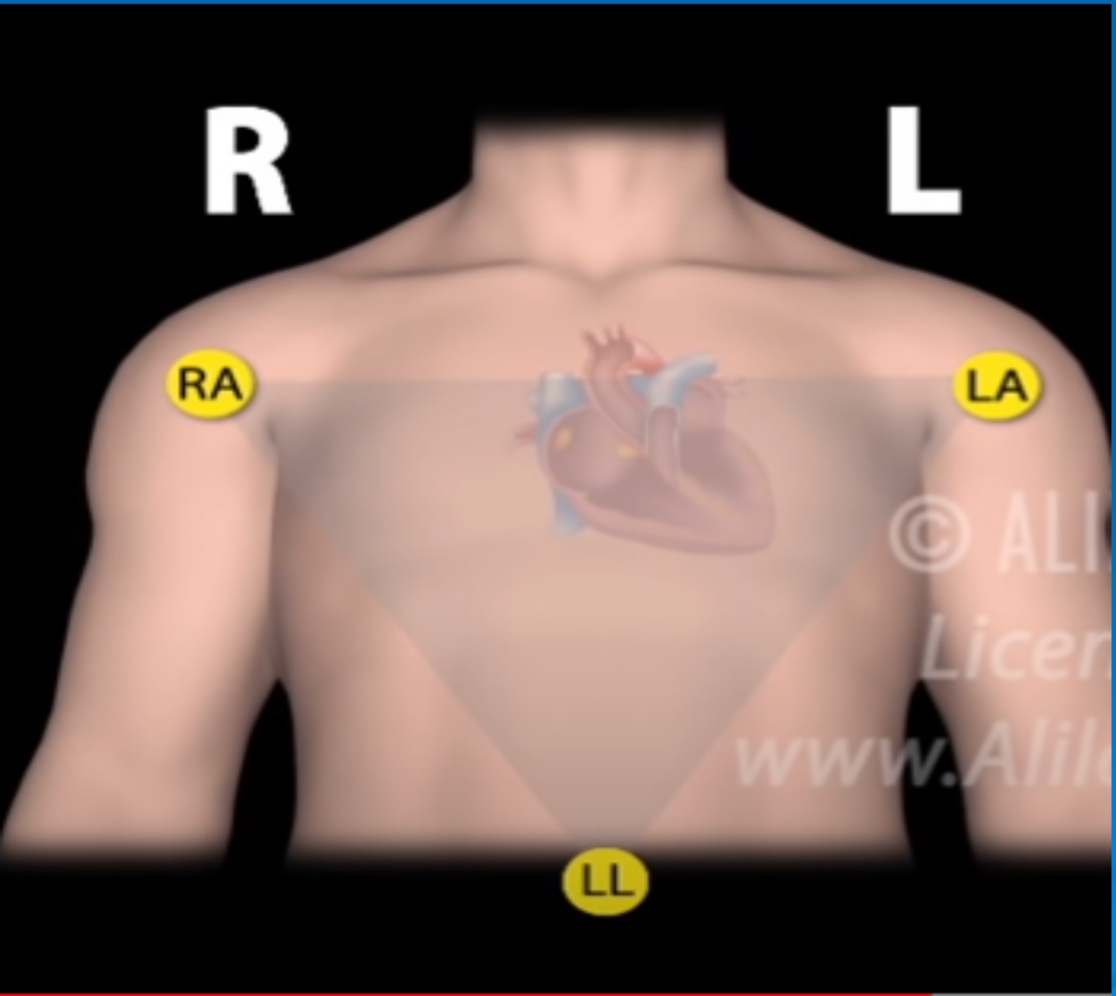
- are bipolar leads, exploring the activity of the heart in frontal plane.
- It is used three active electrodes and a grounding electrode.

The electrodes are named with the initiales of the words indicating their positions and are usually color- coded:

- Right upper limb –R (right)- red
- Left upper limb- L (left)-yellow
- Left lower limb- F(foot)- green

The ground limb- on the right lower limb and is usually black.

The standard (limb) leads



The measurements of a voltage require 2 poles: negative and positive.

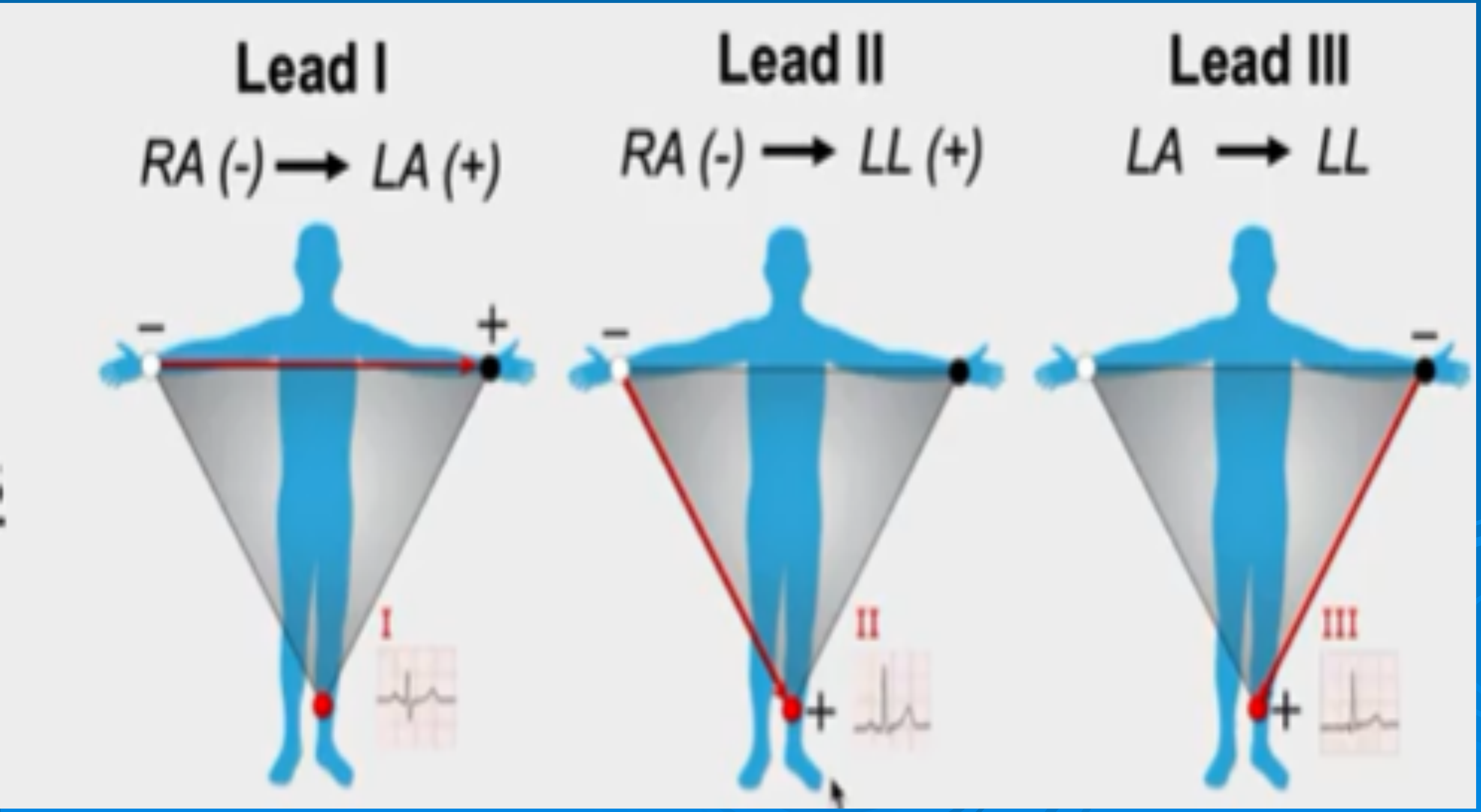
The standard (limb) leads

The electrodes are located on the limbs – one on each arm and one on the left leg.

I = LA - RA

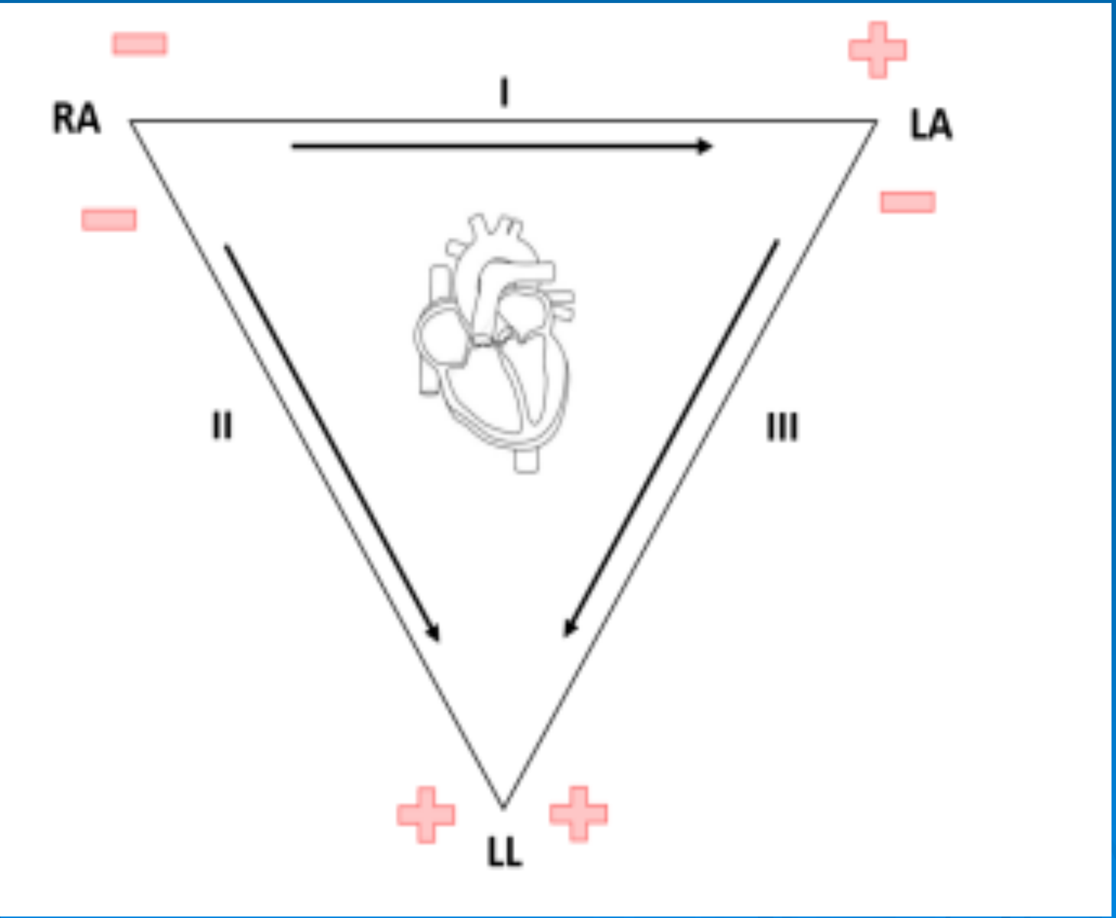
II = LL - RA

III = LL- LA



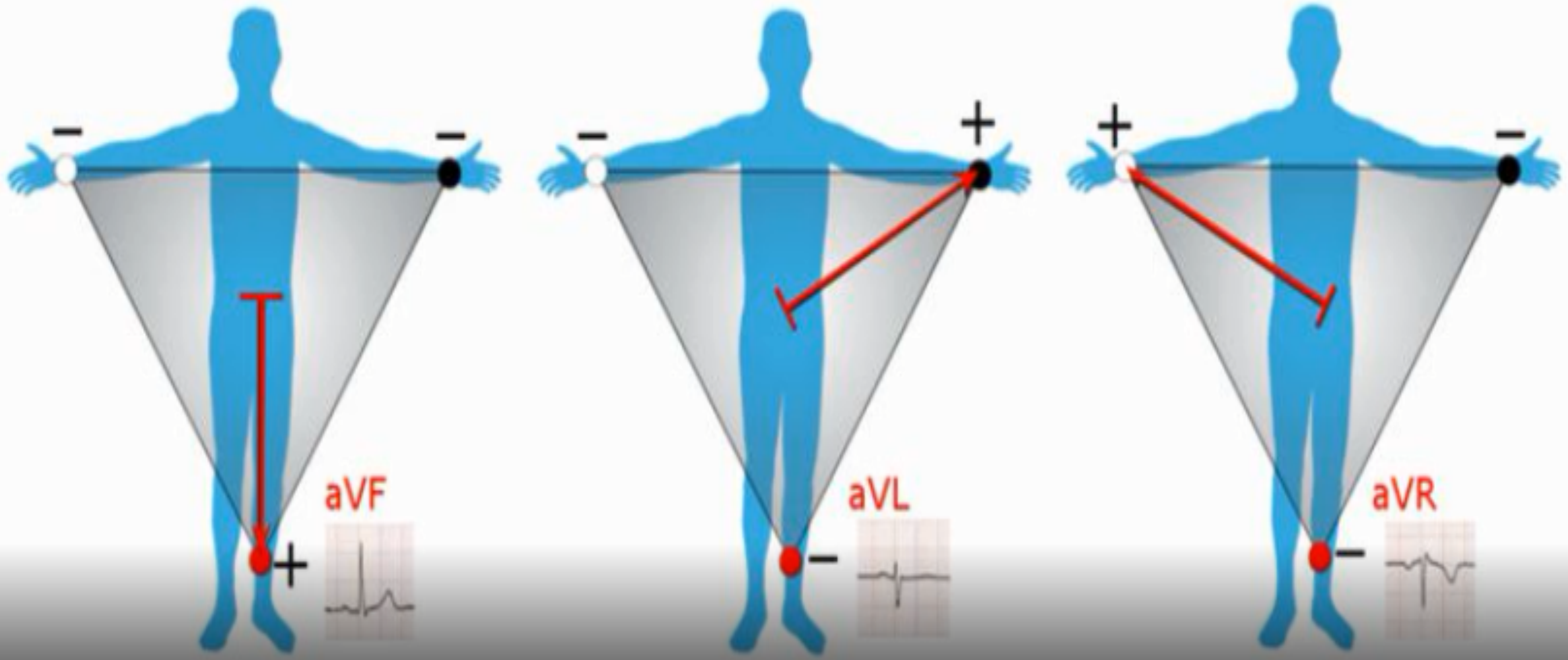
The three limb electrodes I, II and III form a triangle (**Einthoven's Equilateral Triangle**), at the right arm (RA), left arm (LA) and left leg (LL).

Einthoven's Law explains that Lead II's complex is equal to the sum of the corresponding complexes in Leads I and III and is given as **II = I + III.**



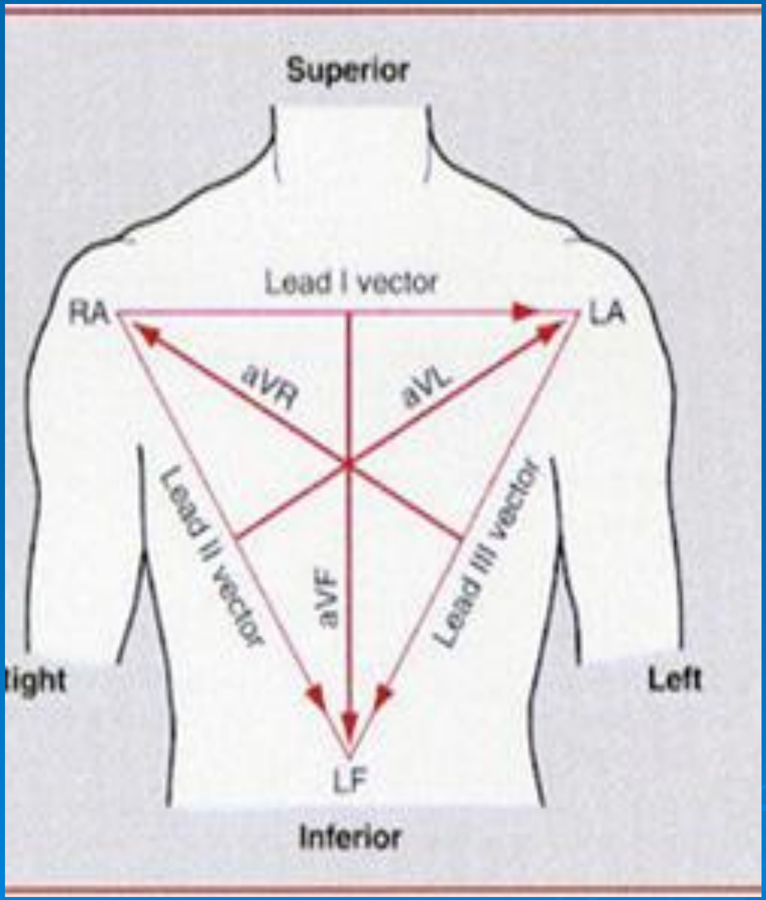
The augmented limb leads

- To obtain the augmented limb leads, the same electrodes are placed in the same as for limb leads position (R, L, F). These are unipolar leads, exploring the activity of the heart in the frontal plane.



The augmented limb leads

The axes of the unipolar limb leads are perpendicular to the axes of the limb leads, poining towards the exploring electrodes.



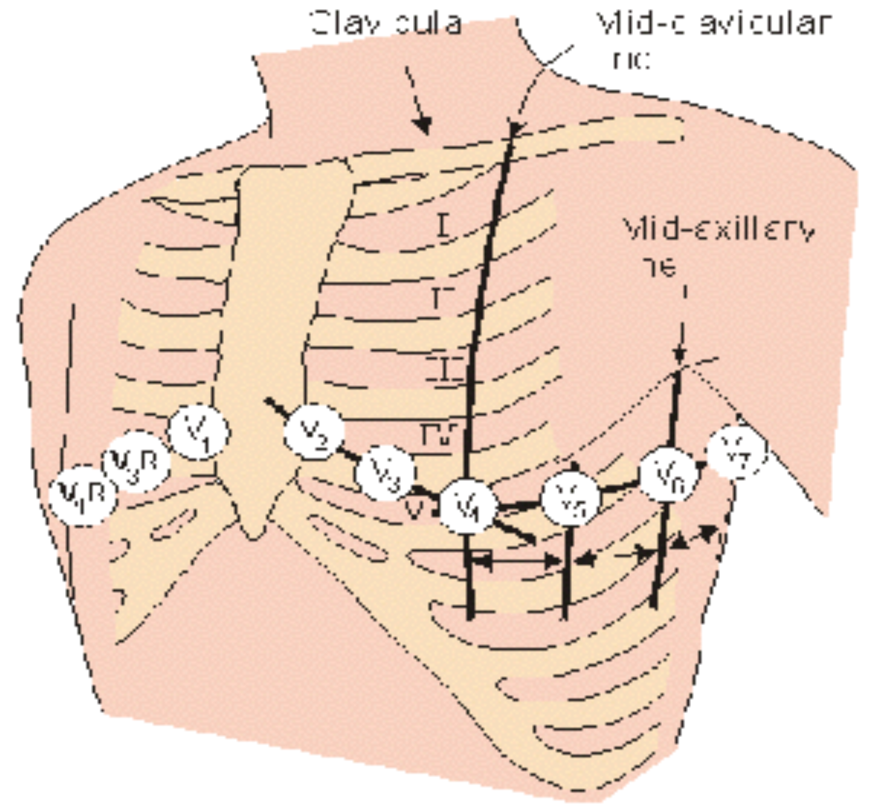
Applying Kirchhoff's second law to this electrical circuit the fundamental law of the augmented limb leas can be writtten:

VR+VL+VF=0

The chest (precordial) leads

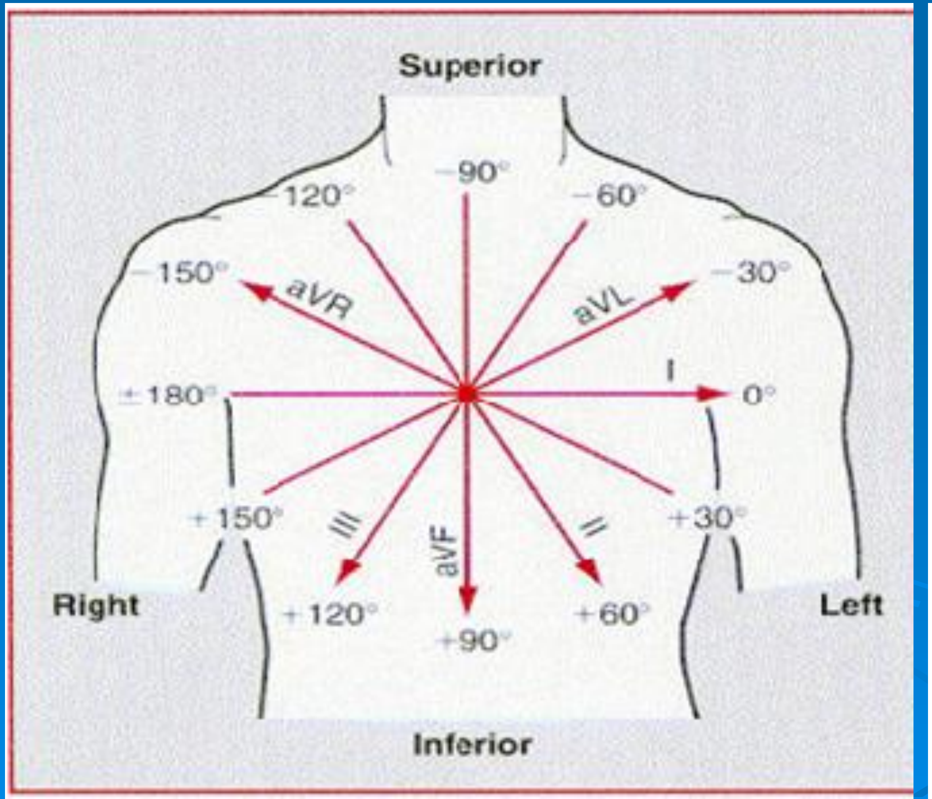
The precordial leads lie in the transverse (horizontal) plane,perpendicular to the other six leads. The exploring electrodes are placed in specific positions at the surface of the thorax, while the indiffernt electrode is obtained by Wilson´s method. The electrodes are placed at the surface of the chest:

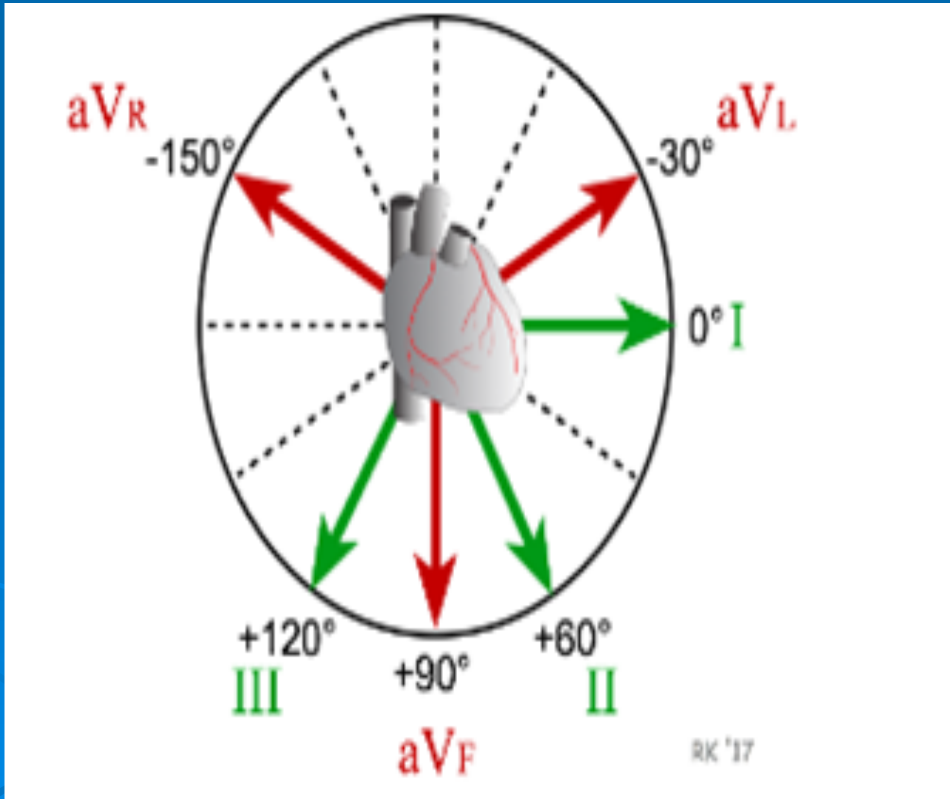
- **V_1- in the 4th intercostal space, right of the sternum;**
- **V_2- in the 4th intercostal space, to the left of the sternum;**
- **V_3- between V_2 and V_4;**
- **V_4- in the 5th intercostal space, on the midclavicular line**
- **V_5- in the 5th intercostal space, on the anterior axillary line,**
- **V_6- in the 5thintercostal space, on the midaxillary line**



The hexaaxial system

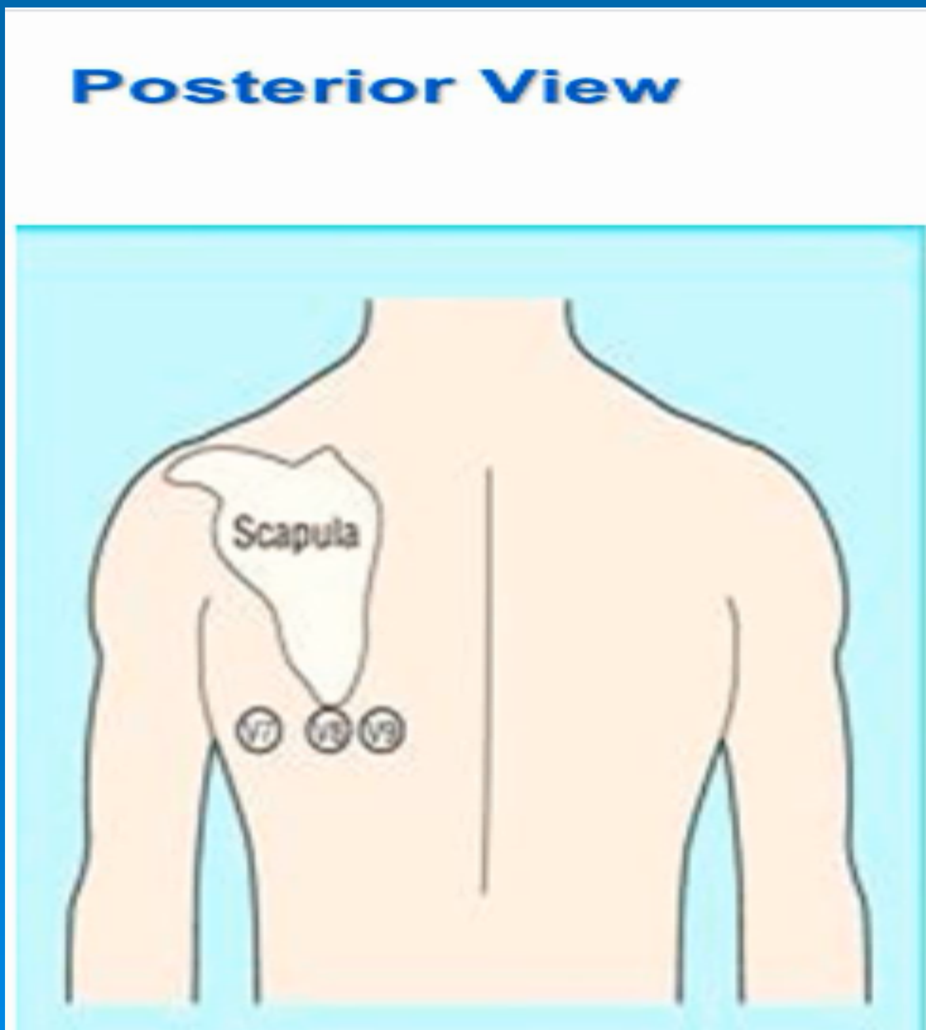
- Since leads I,II, III, aVR, aVL and aVF measure activity in the same plane they are always considered together and represented by a large circle with the negative electrodes for each of the leads aligned in the middle of the chest (hexaaxial system).





The chest (precordial) leads

Additional electrodes may rarely be placed to generate other leads for specific diagnostic purposes. *Right-sided* precordial leads may be used to better study pathology of the right ventricle or for dextrocardia (V3R to V6R). *Posterior leads* (V7 to V9) may be used to demonstrate the presence of a posterior myocardial infarction.



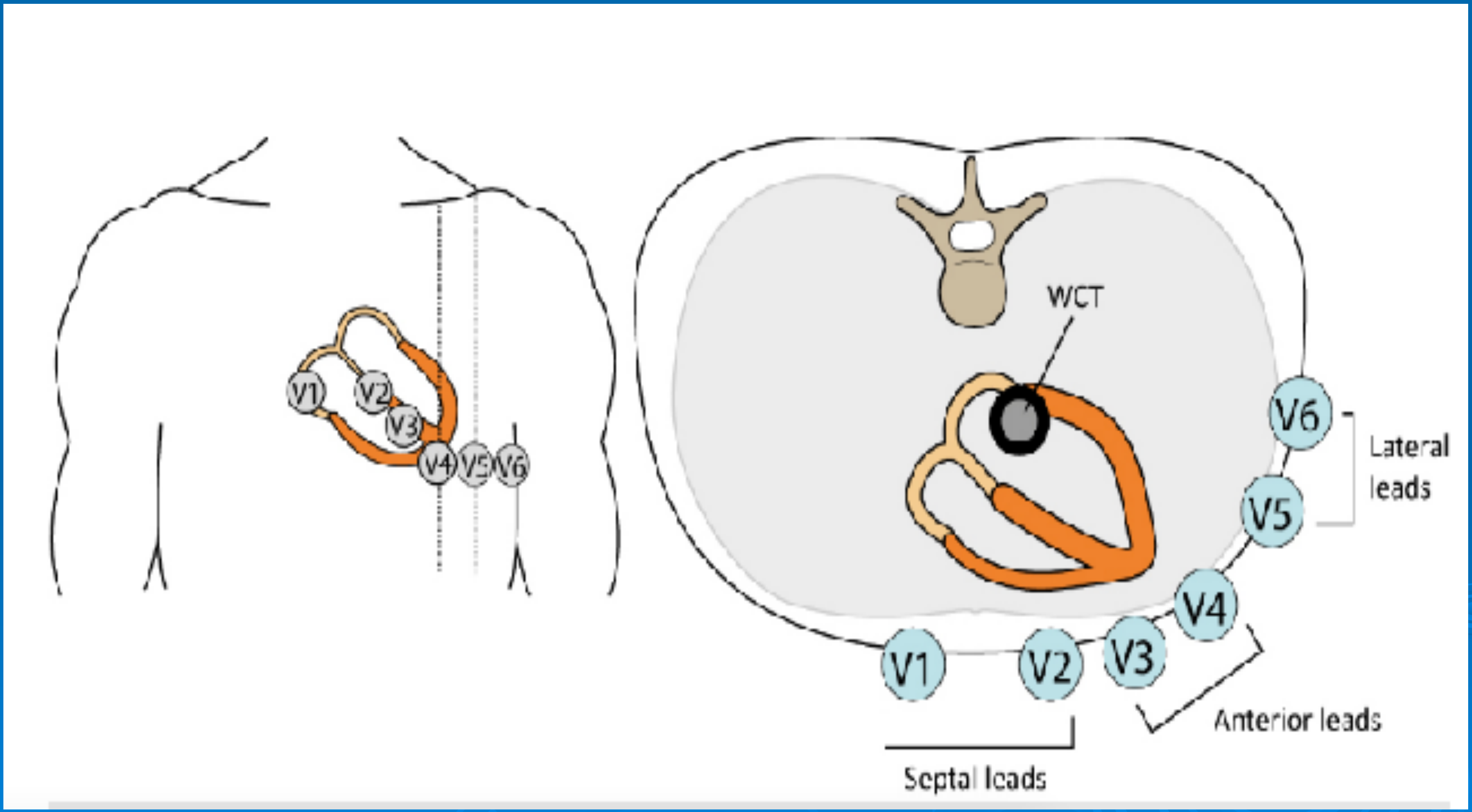
Posterior leads:

V7 – lateral to V6 at posterior axillary line

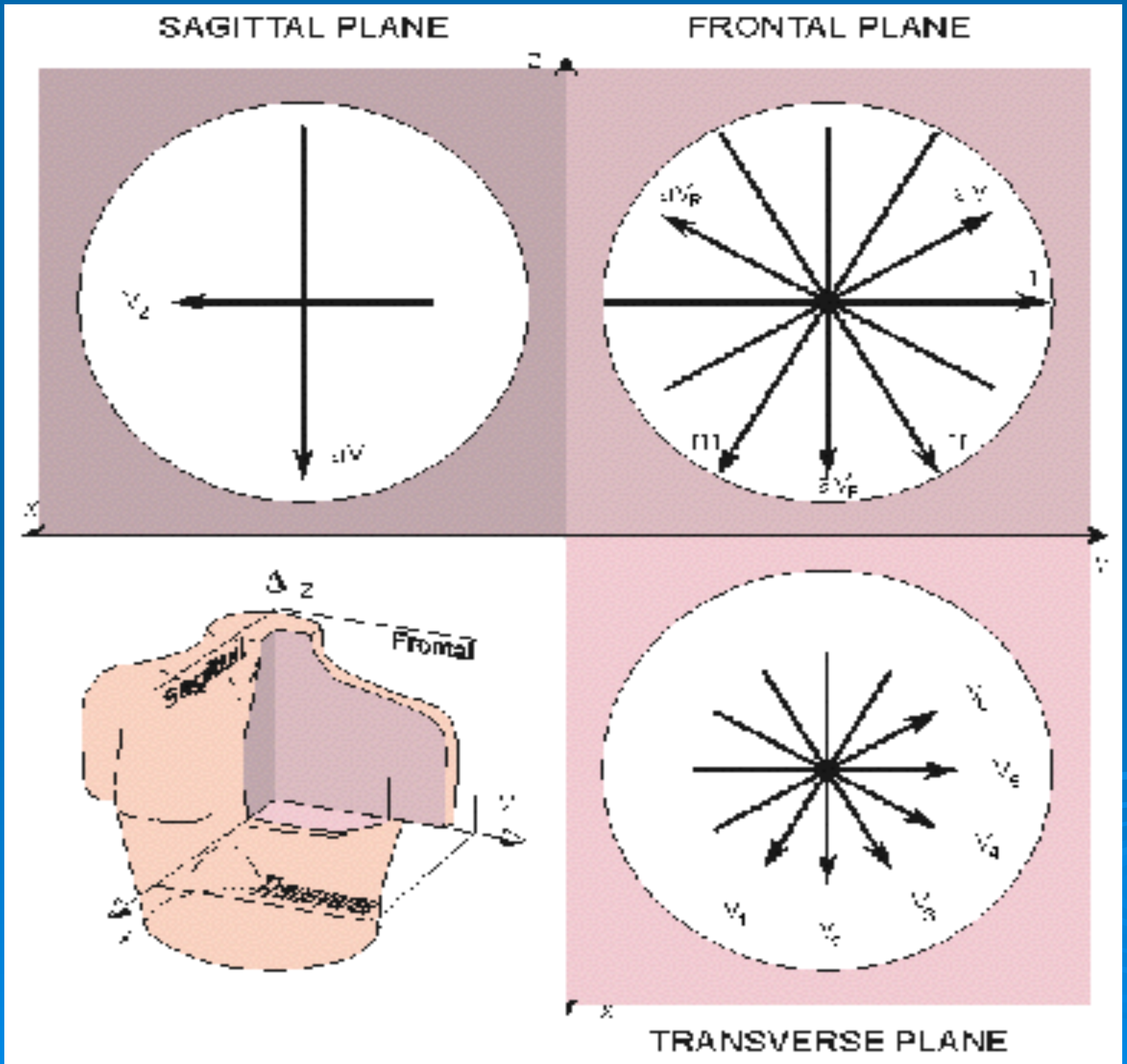
V8 – level of V7 at the mid-scapular line

V9 – level of V8 at the paravertebral line
(left posterior thorax midway from spine to V8)

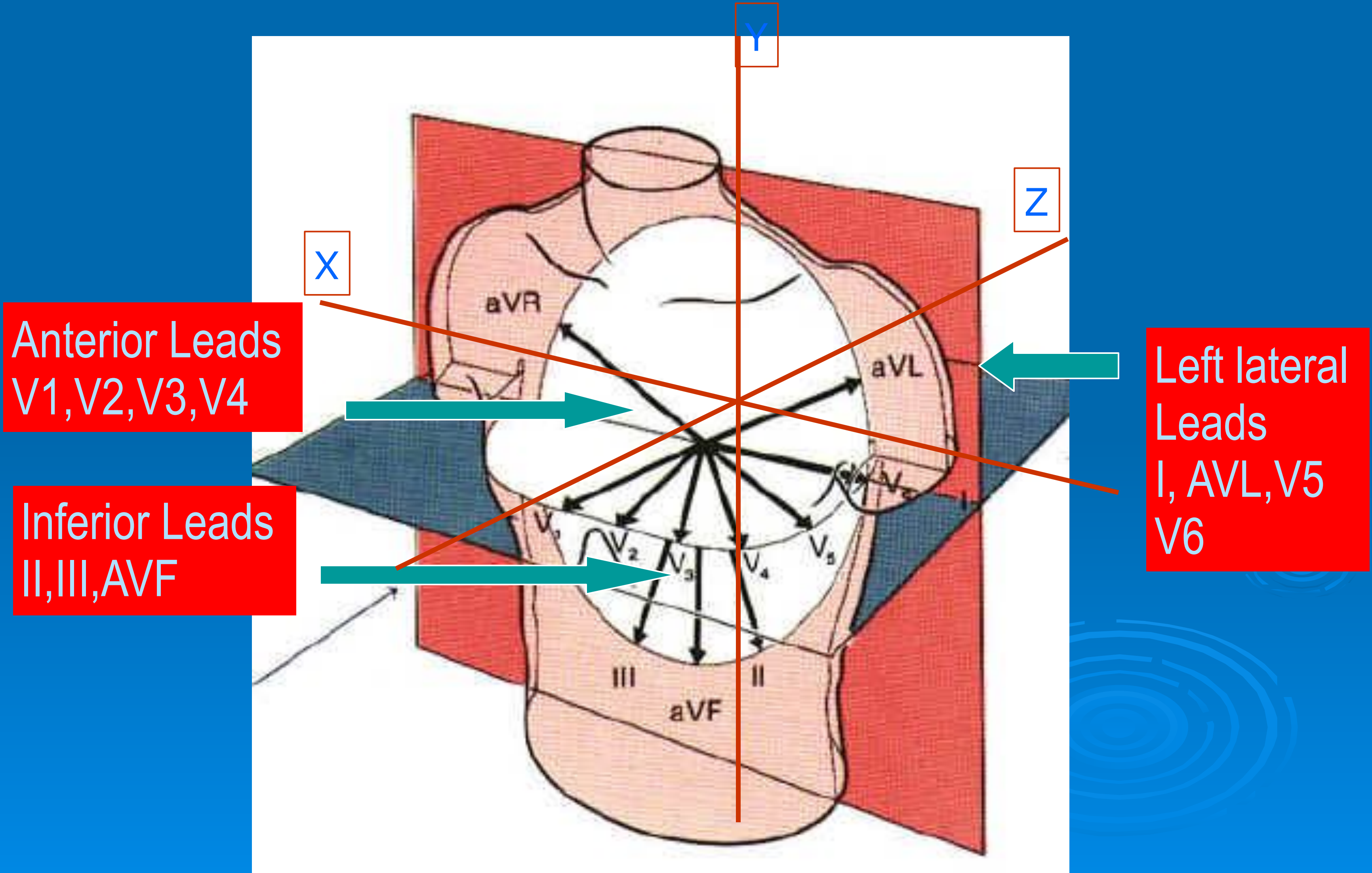
The chest (precordial) leads



Projections of the 12-lead EKG vectors in three orthogonal planes



Review of what each EKG lead looks at



Incorrect electrode placement

Limb lead reversal:

1. Reversal of right and left arm leads

- Resultant ECG mimics dextrocardia in limb leads with inversion of the P-QRS-T in leads I and aVL
- Leads II and III transposed
- Leads aVR and aVL transposed

2. Reversal of left arm and left leg leads

- Leads I and II transposed
- Leads aVF and aVL transposed
- Lead III inverted

3. Reversal of right arm and left leg leads

- Leads I, II, and III inverted

Arrangement of Leads on the EKG

Each twelve leads records has its own particular line of sight and region of the heart that it views best .

I	aVR	V_1	V_4
II	aVL	V_2	V_5
III	aVF	V_3	V_6

Anatomic Groups (Septum)

I Lateral	aVR None	V_1 Septal	V_4 Anterior
II Inferior	aVL Lateral	V_2 Septal	V_5 Lateral
III Inferior	aVF Inferior	V_3 Anterior	V_6 Lateral

I Lateral	aVR None	V_1 Septal	V_4 Anterior
II Inferior	aVL Lateral	V_2 Septal	V_5 Lateral
III Inferior	aVF Inferior	V_3 Anterior	V_6 Lateral

Anatomic Groups (Lateral Wall)

I Lateral	aVR None	V_1 Septal	V_4 Anterior
II Inferior	aVL Lateral	V_2 Septal	V_5 Lateral
III Inferior	aVF Inferior	V_3 Anterior	V_6 Lateral

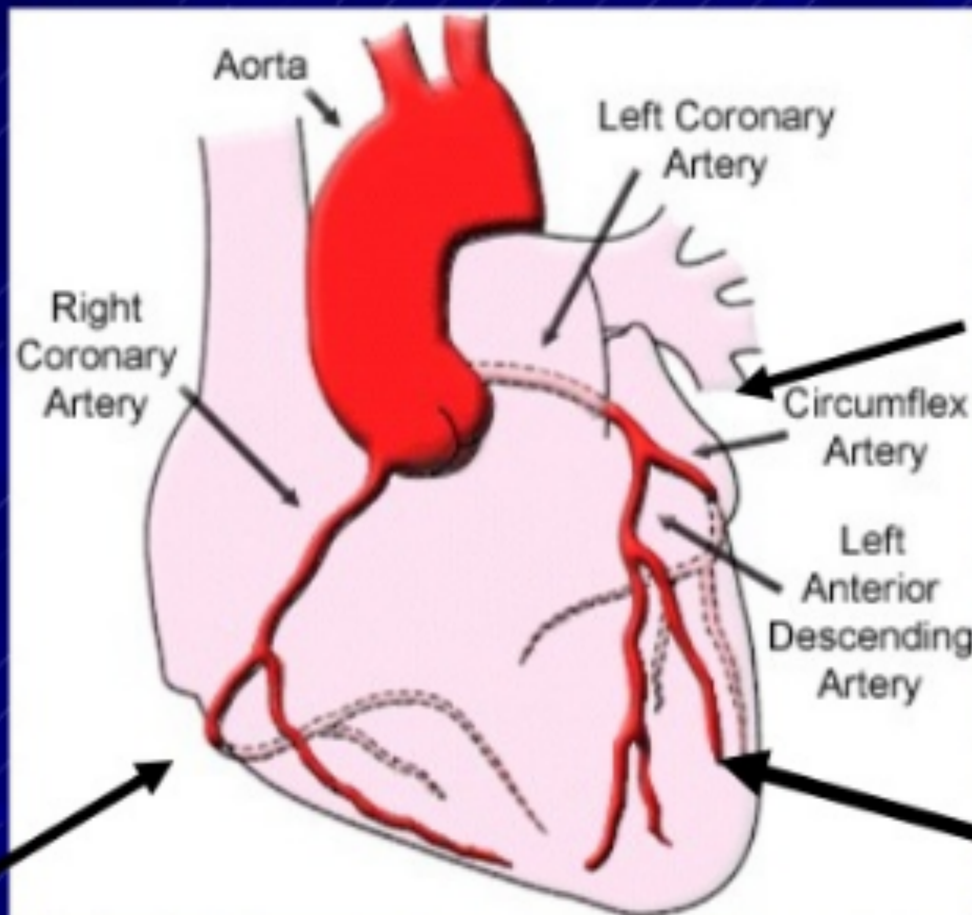
Anatomic Groups (Inferior Wall)

I Lateral	aVR None	V_1 Septal	V_4 Anterior
II Inferior	aVL Lateral	V_2 Septal	V_5 Lateral
III Inferior	aVF Inferior	V_3 Anterior	V_6 Lateral

Summary

I Lateral	aVR None	V_1 Septal	V_4 Anterior
II Inferior	aVL Lateral	V_2 Septal	V_5 Lateral
III Inferior	aVF Inferior	V_3 Anterior	V_6 Lateral

Localising the arterial territory



Lateral

I, AVL, V5-V6

Anterior / Septal

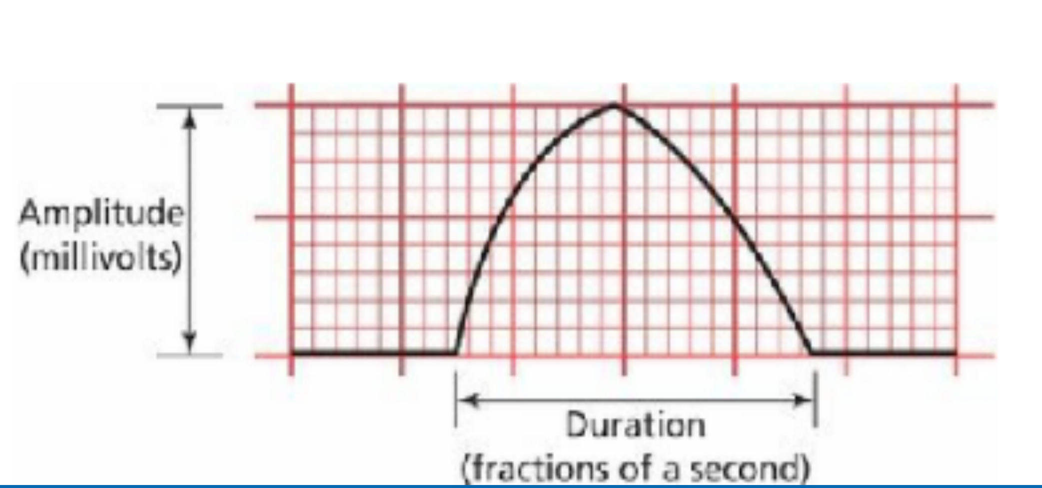
V1-V4

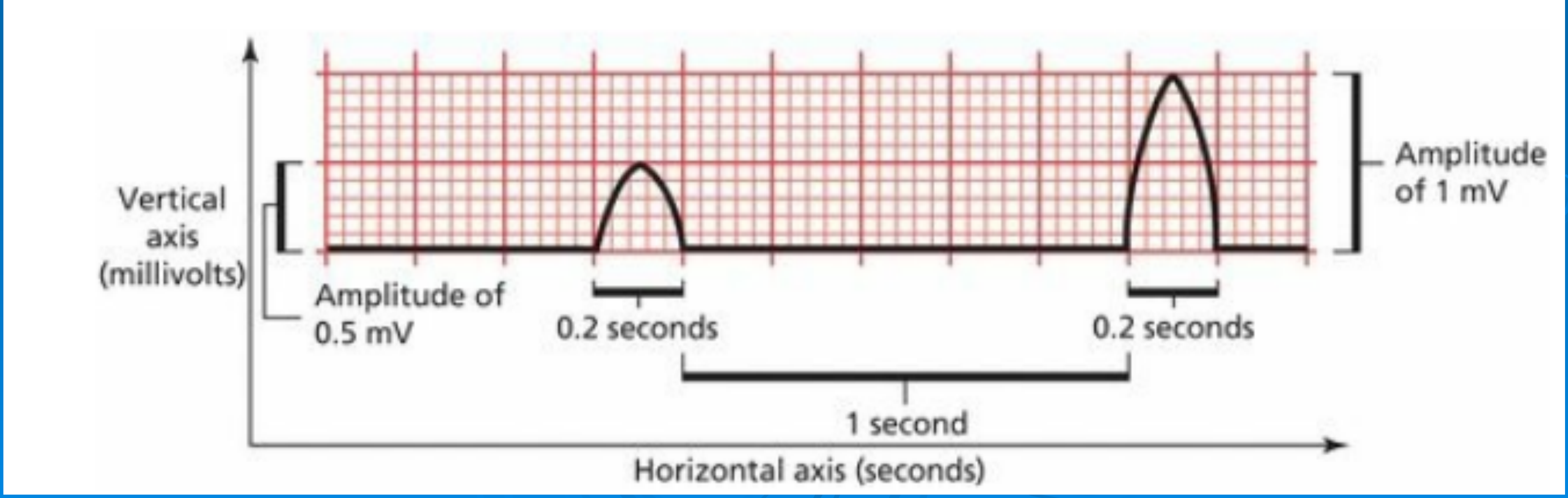
Inferior

II, III, aVF

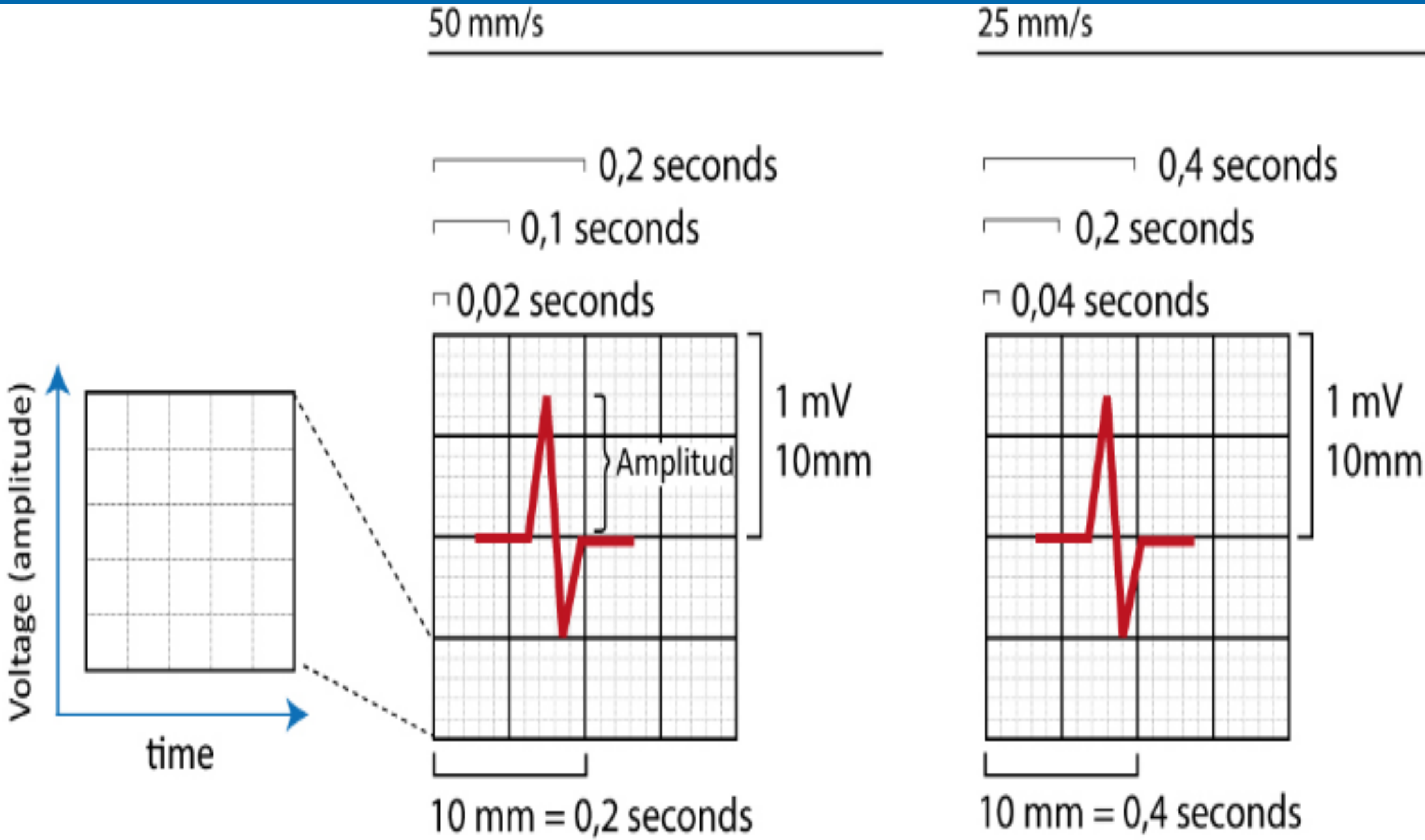
From electrode to paper

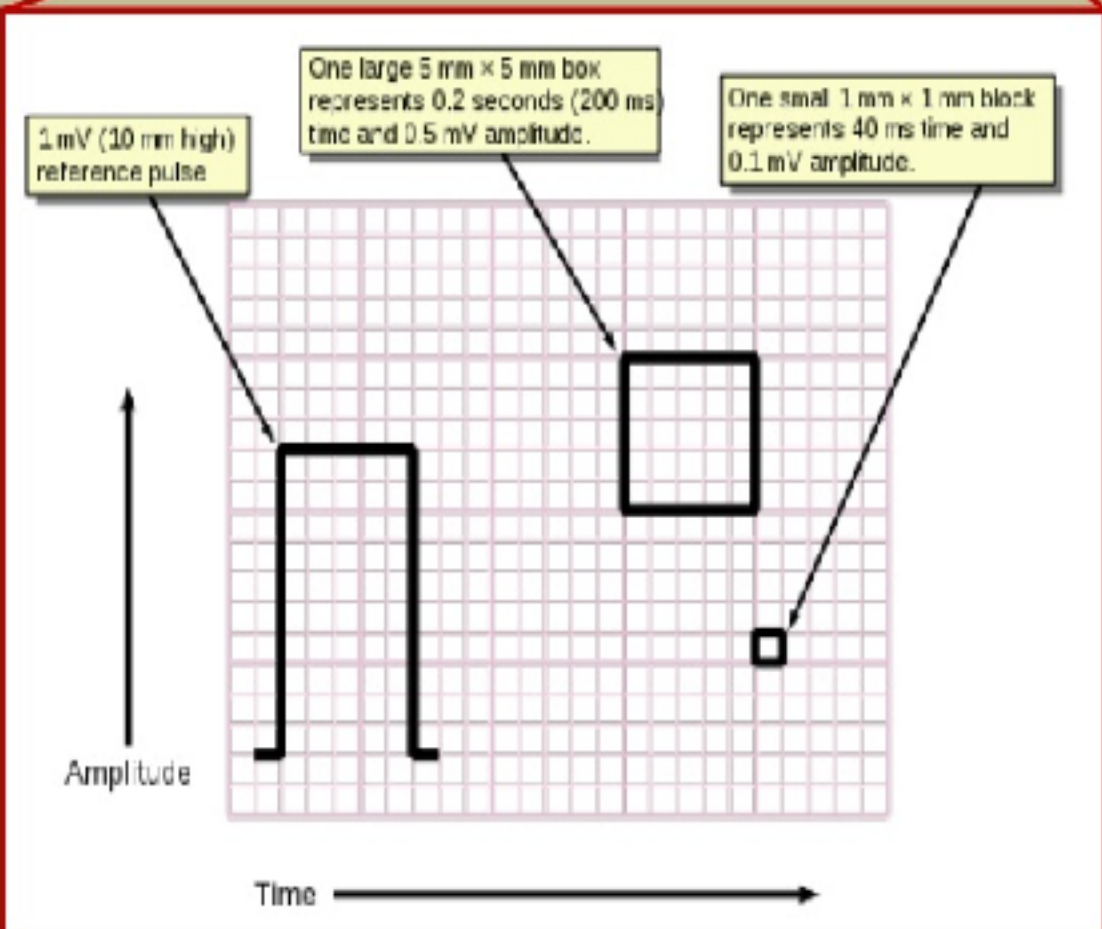
- The waves that appear on the ECG reflect the electrical activity of the myocardial cells.





EKG paper speed





STANDARD CALLIBRATION

Speed = **25mm/s**

Amplitude = **0.1mV/mm**

1mV → 10mm high

1 large square → 0.2s(200ms)

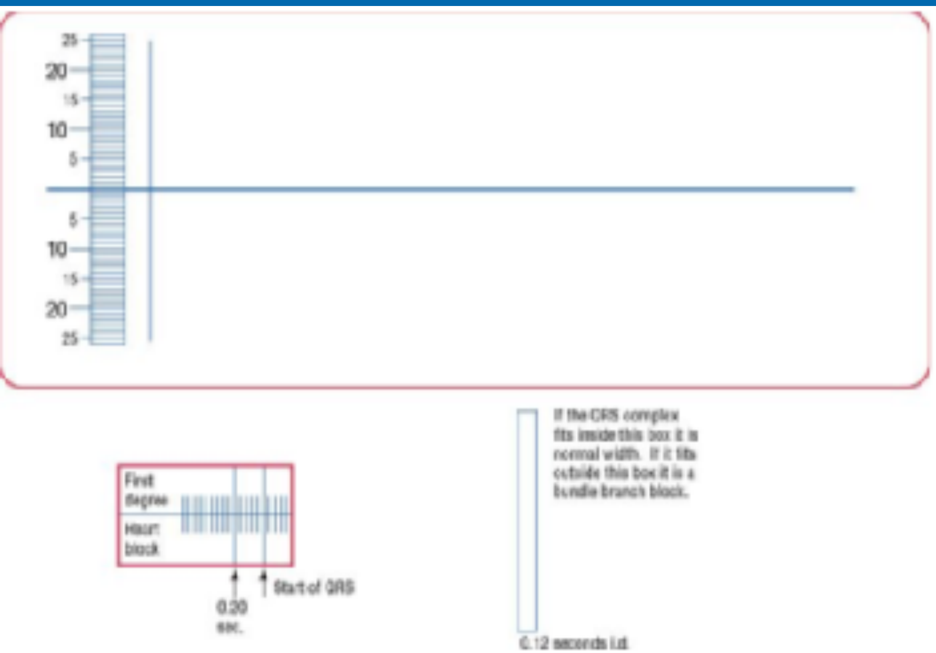
1 small square→ 0.04s (40ms) or

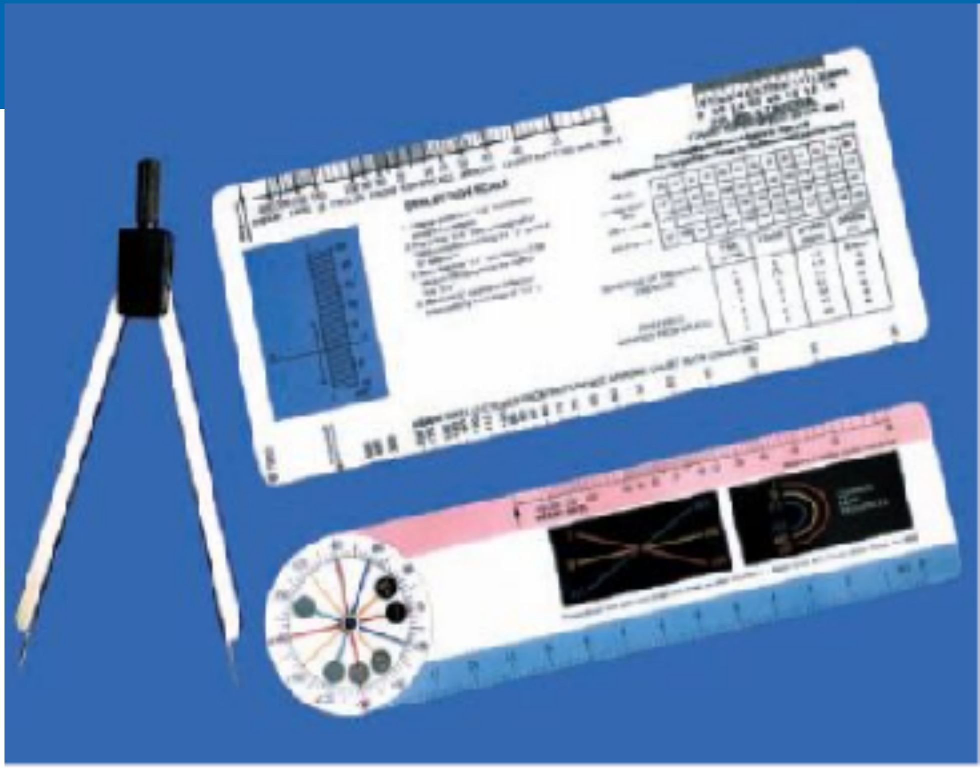
1 mV amplitude

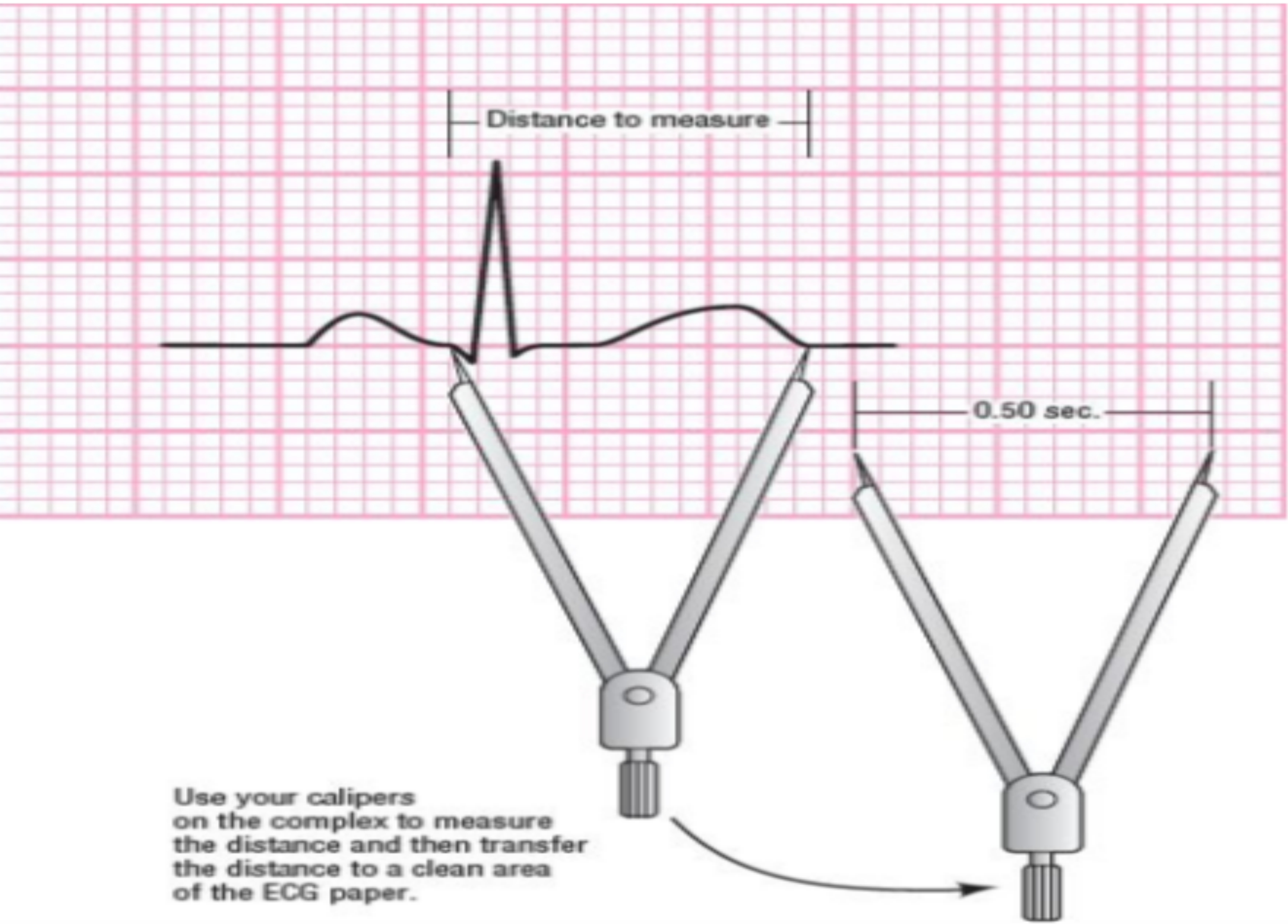
ECG Tools

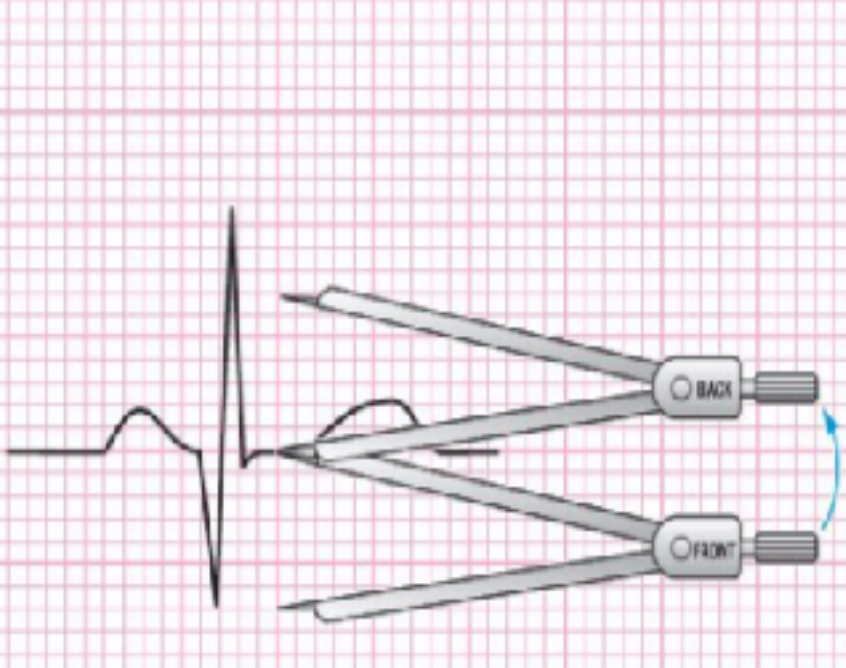
There are various tools that make reading and interpreting the ECG much easier.

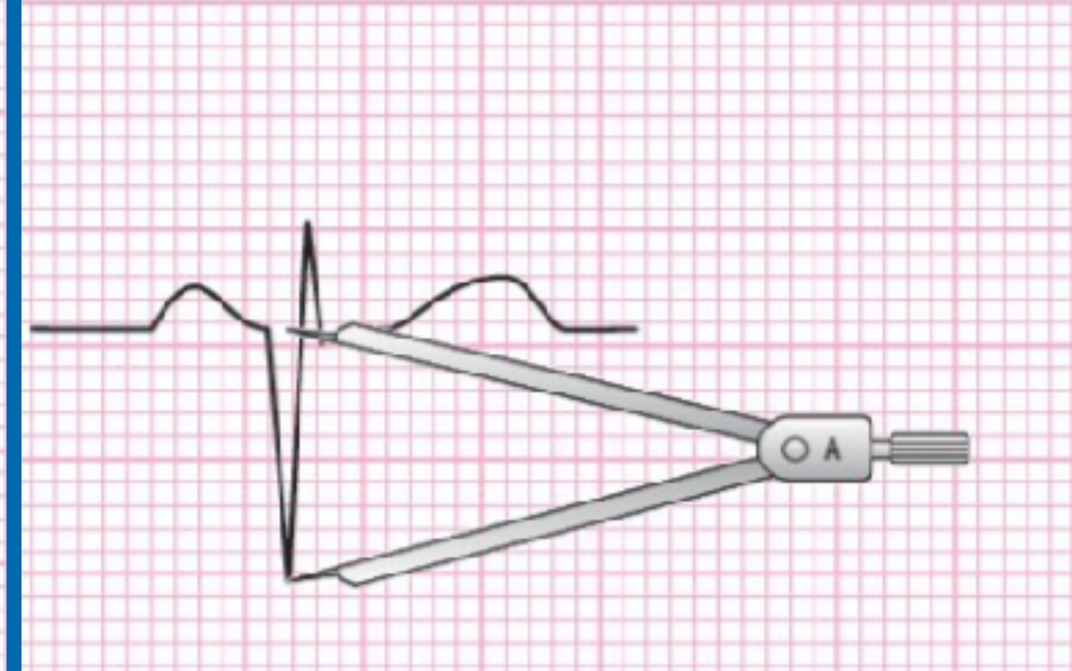
1. Calipers
2. Axis-wheel ruler
3. ECG ruler
4. Straight edge

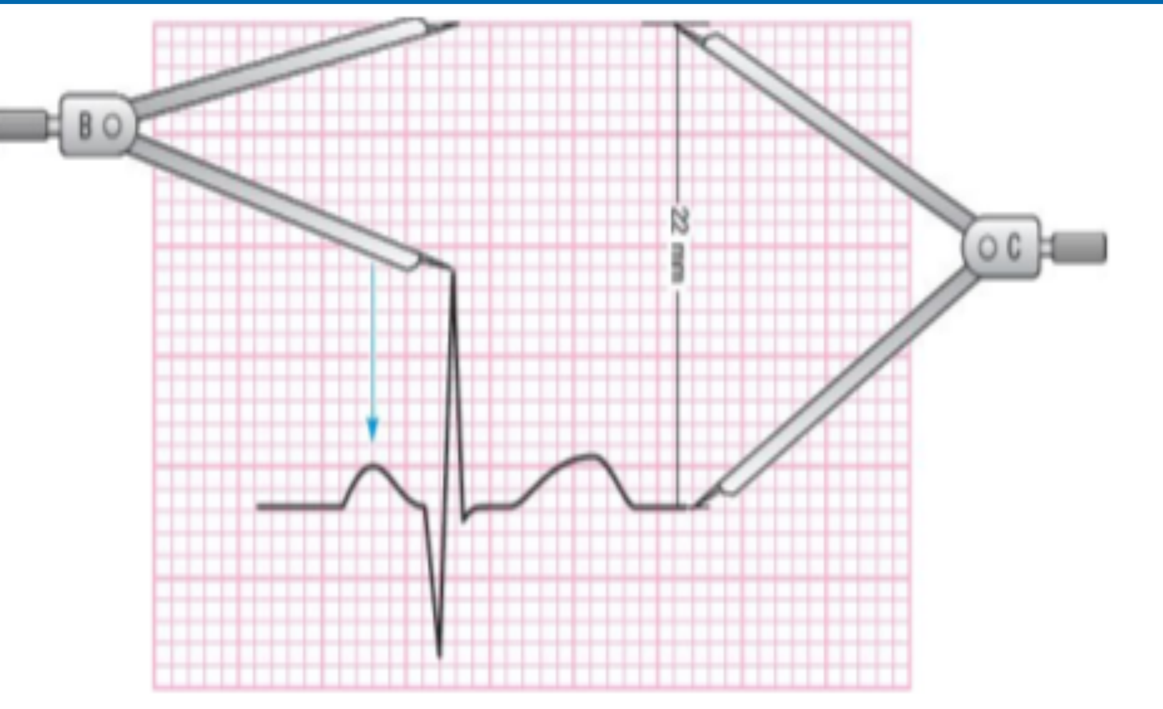





Distance to measure
0.50 sec.
Use your calipers
on the complex to measure
the distance and then transfer
the distance to a clean area
of the ECG paper.


BACK
FRONT

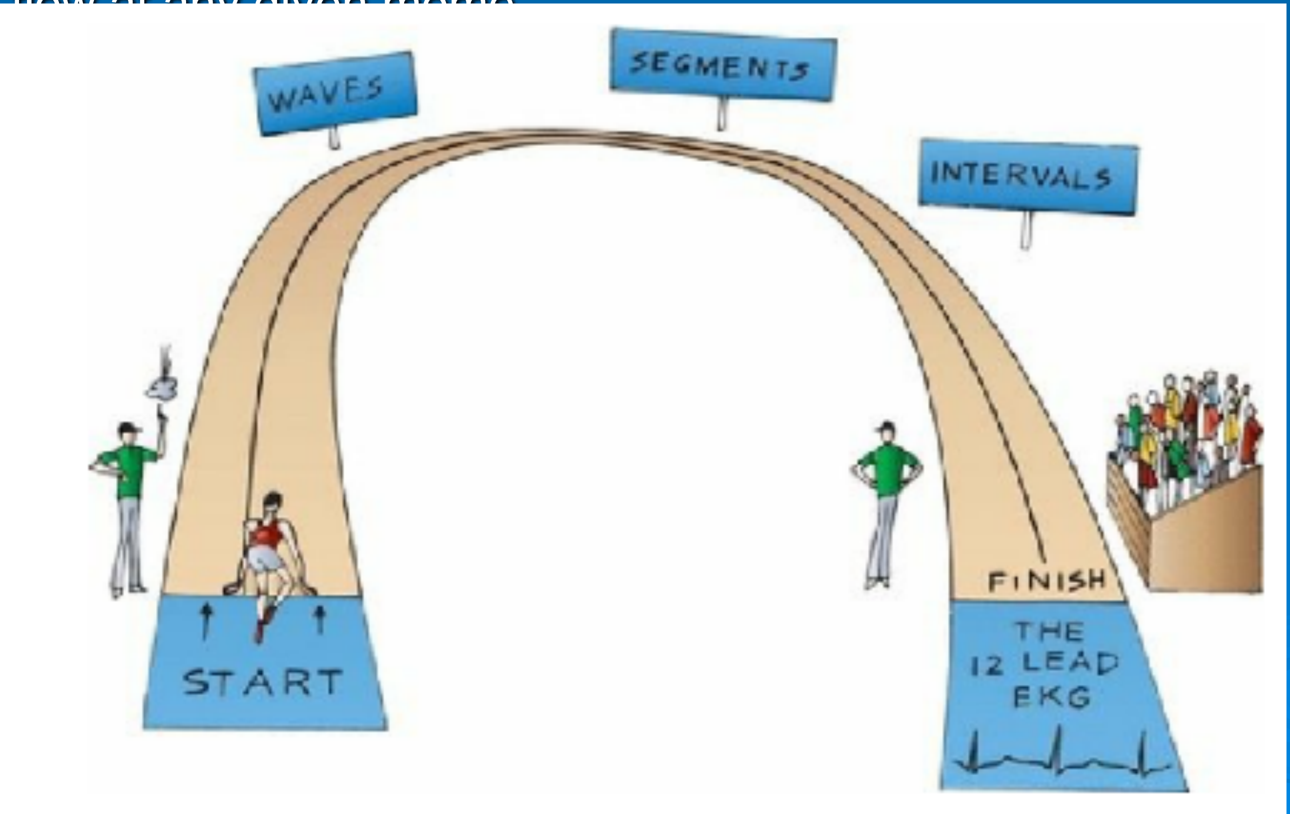

A


B
22 mm
C

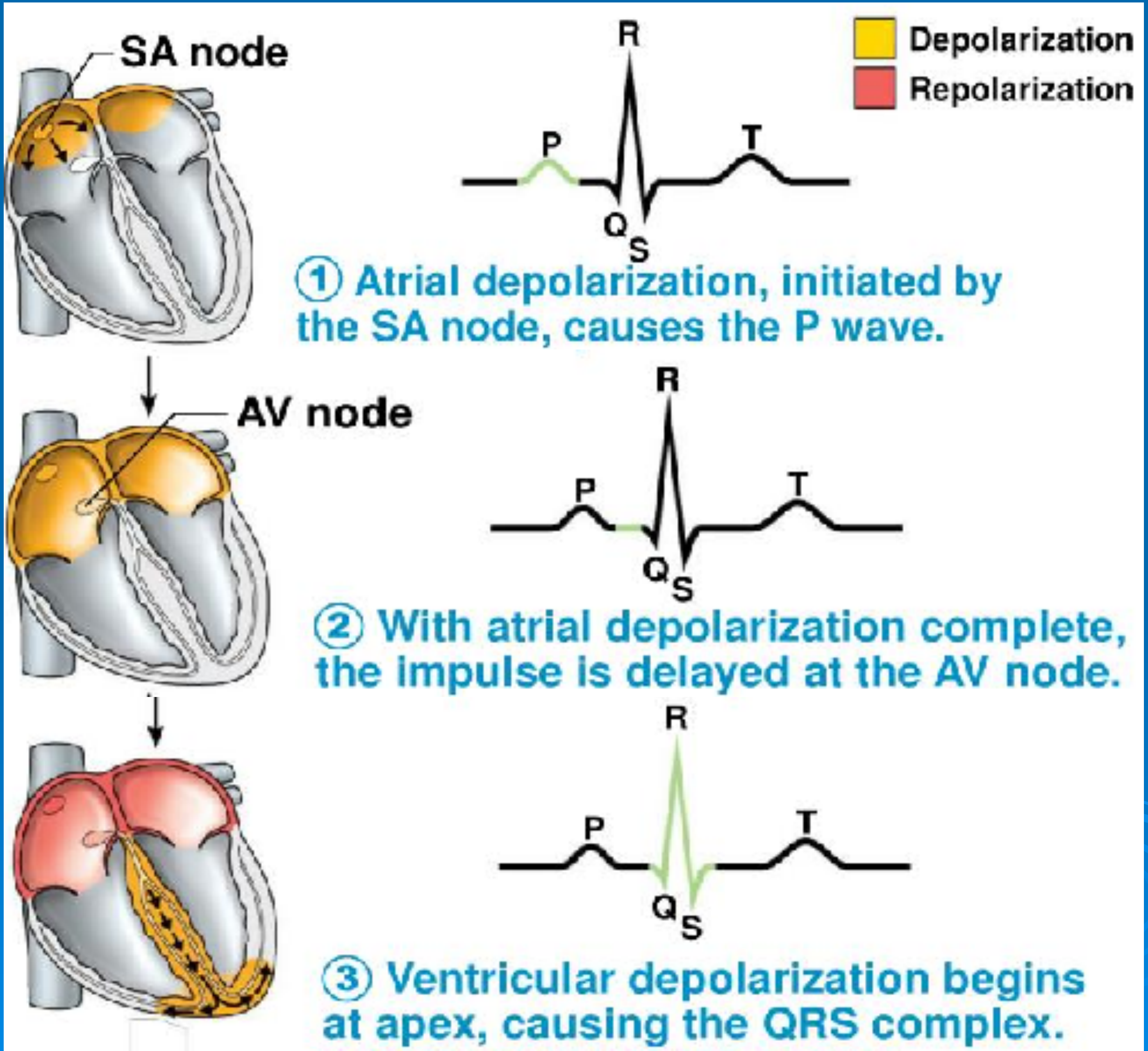
The Normal 12-Lead EKG

The three things necessary to derive the normal 12-lead EKG:

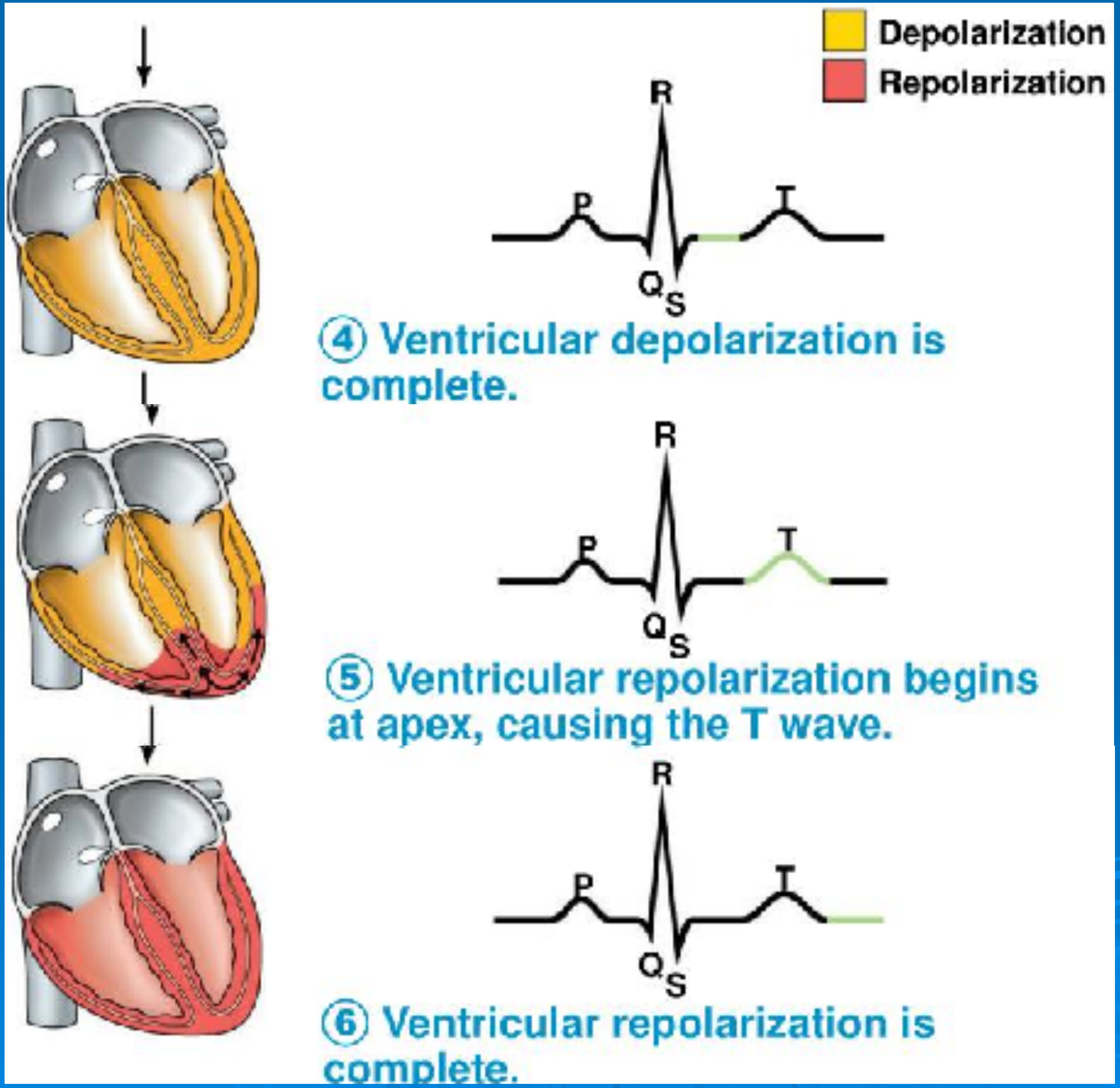
1. The normal pathway of cardiac electrical activation and the names of the segments, waves,and intervals that are generated
2. The orientation of all 12 leads, six in the frontal plane and six in the horizontal plane
3. The simple concept that each lead records the average current. flow at any given mome



Electrical activity of myocardium

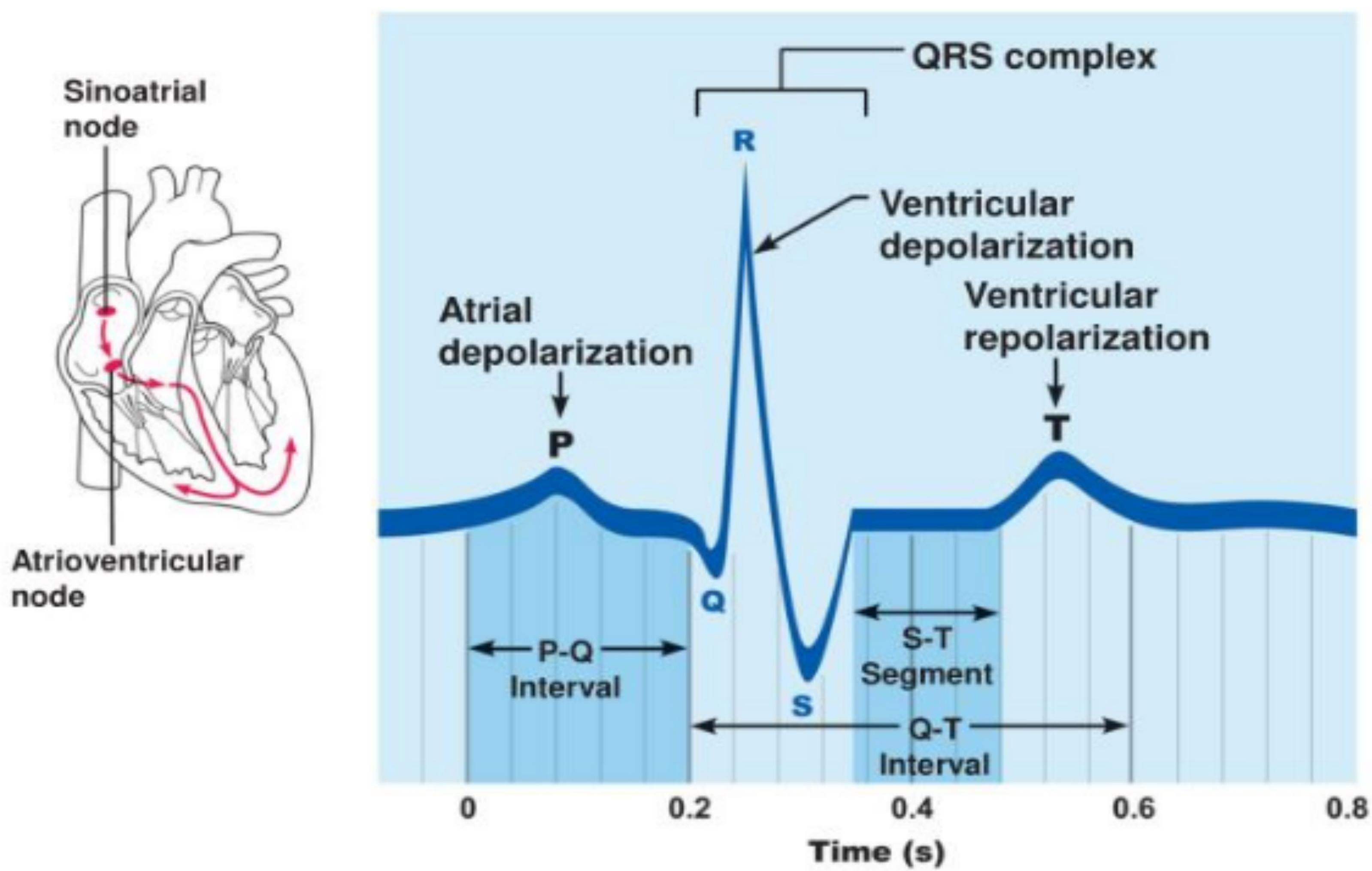


Electrical activity of myocardium



A NORMAL ECG WAVE

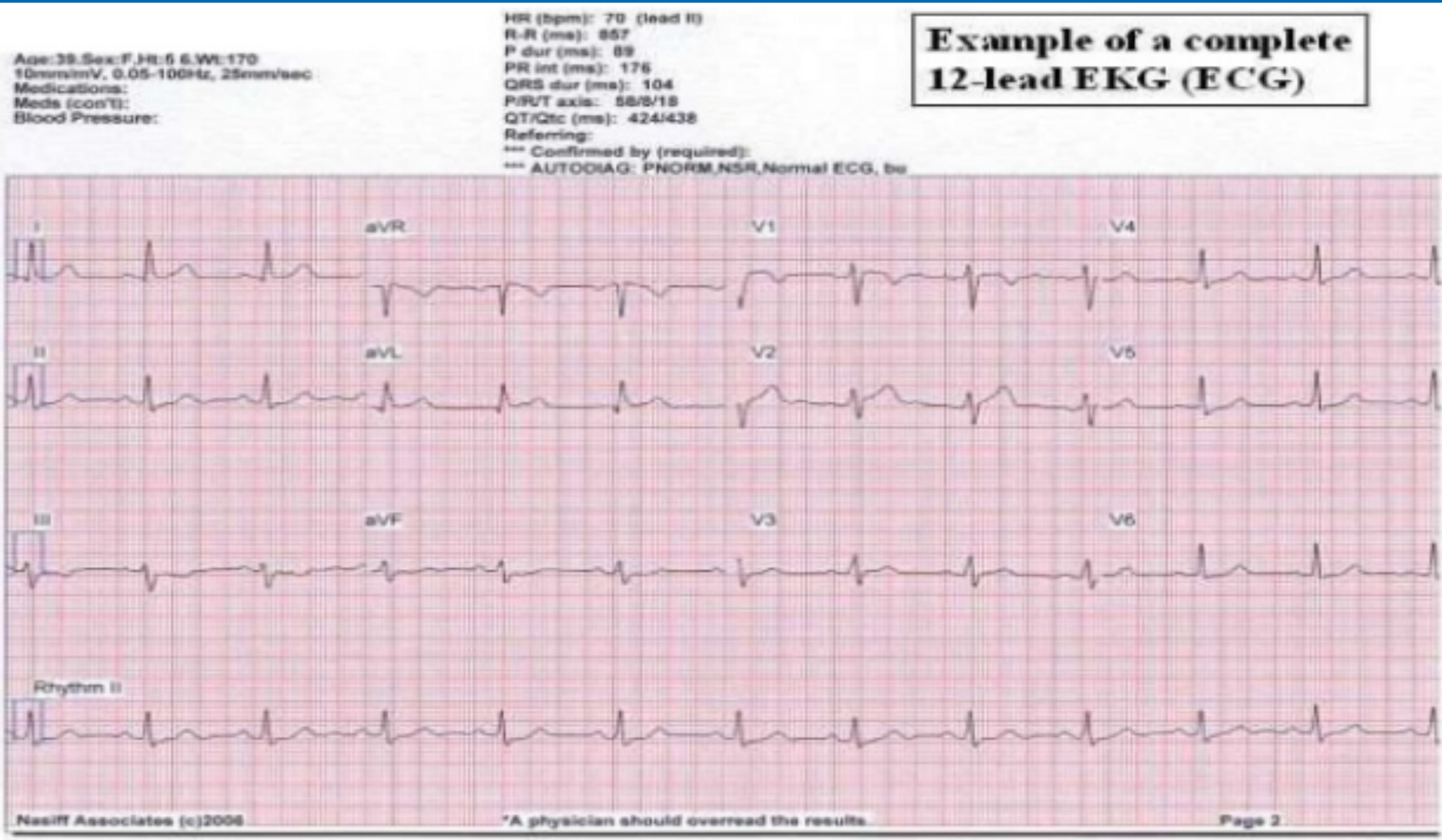
REMEMBER



ECG
INTERPRETATION

The More You See, The More You Know

Obtain an ECG, act confident, read the patient details



Rhythm

- The P waves – can you find them?
- What is the relationship between the P waves and the QRS complexes?

  P wave before every QRS complex= Sinus rhythm
- Is the rhythm regular or irregular?

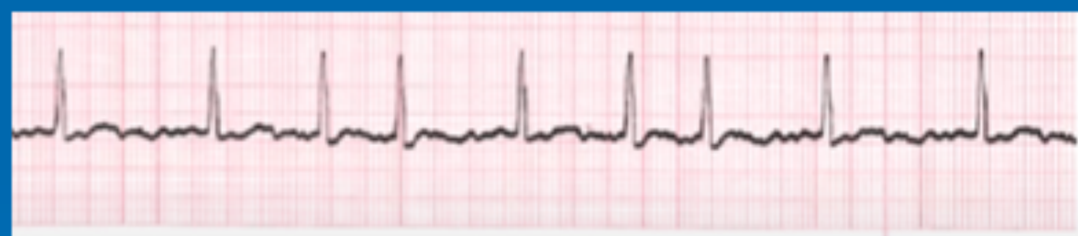
Rhythm

Normal Sinus Rhythm

ECG rhythm characterized by a usual rate of anywhere between 60-99 bpm, every P wave must be followed by a QRS and every QRS is preceded by P wave. Normal duration of PR interval is 3-5 small squares. The P wave is upright in leads I and II

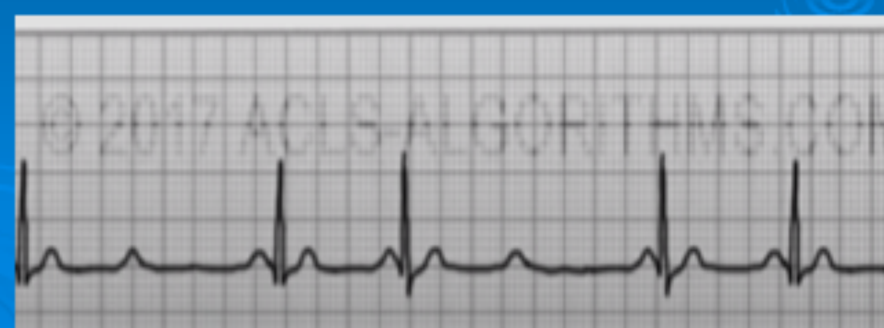
Irregularly Irregular

(atrial fibrilation)



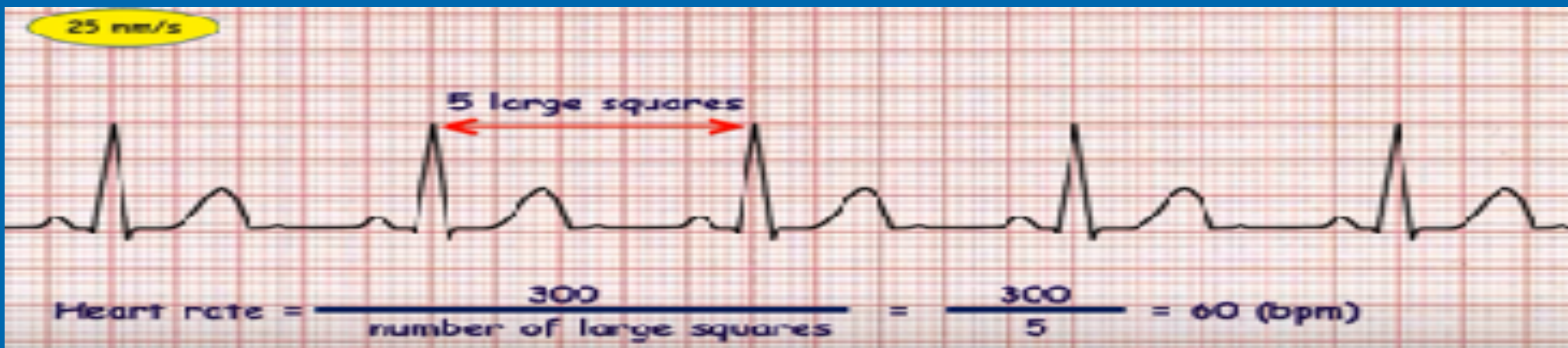
Regularly Irregular

(Second degree heart block type 2)



Calculation rate

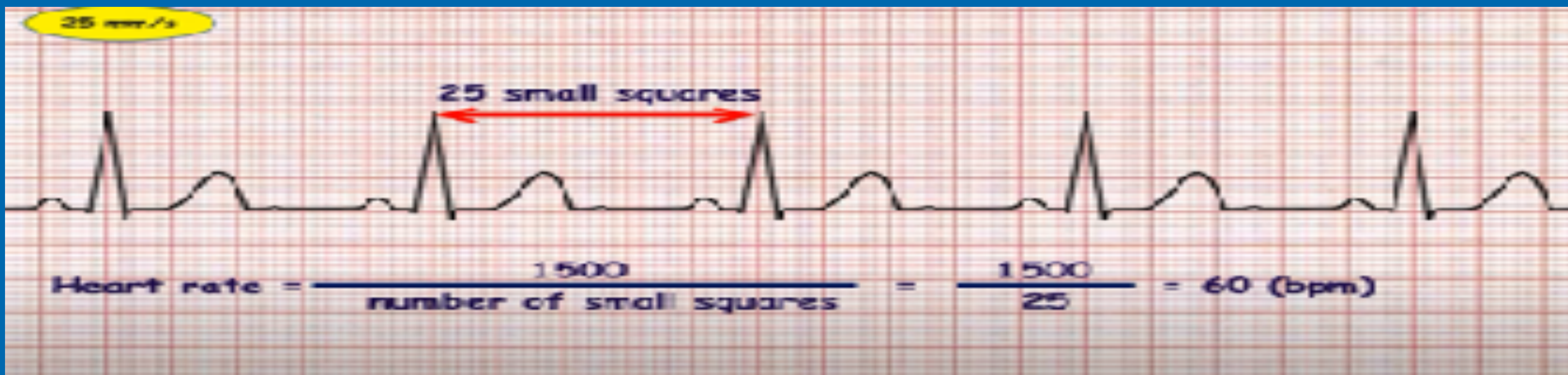
1. *Large box counting method*

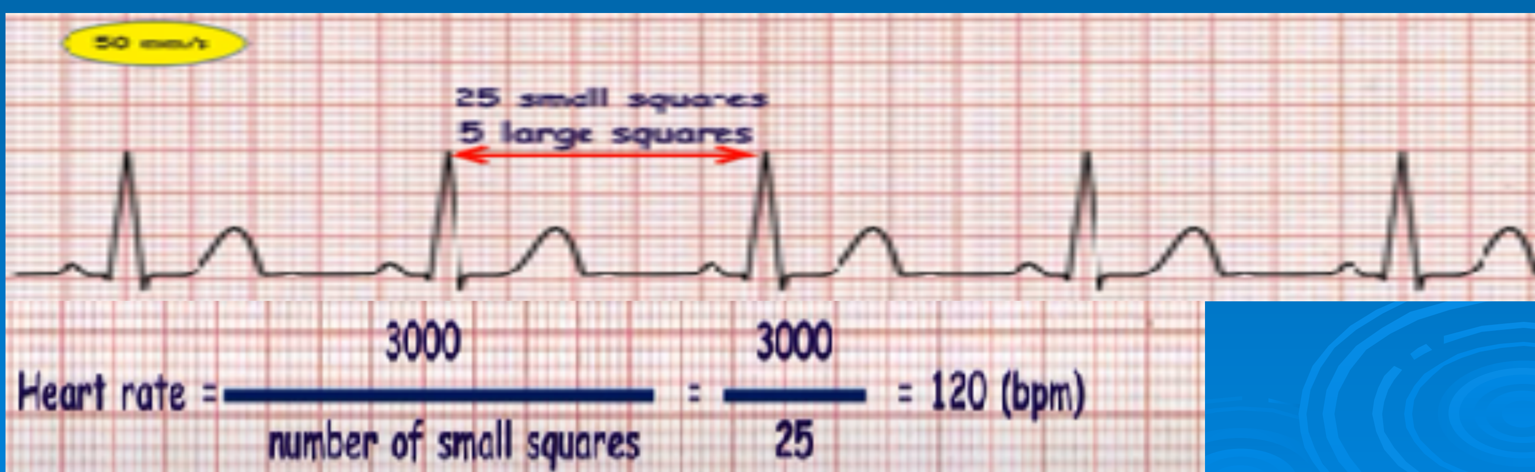


$$\text{Heart rate} = \frac{600}{\text{number of large squares}} = \frac{600}{5} = 120 \text{ (bpm)}$$

Calculation rate

2. Small box counting





The rule of 300

- It may be easiest to memorize the following table

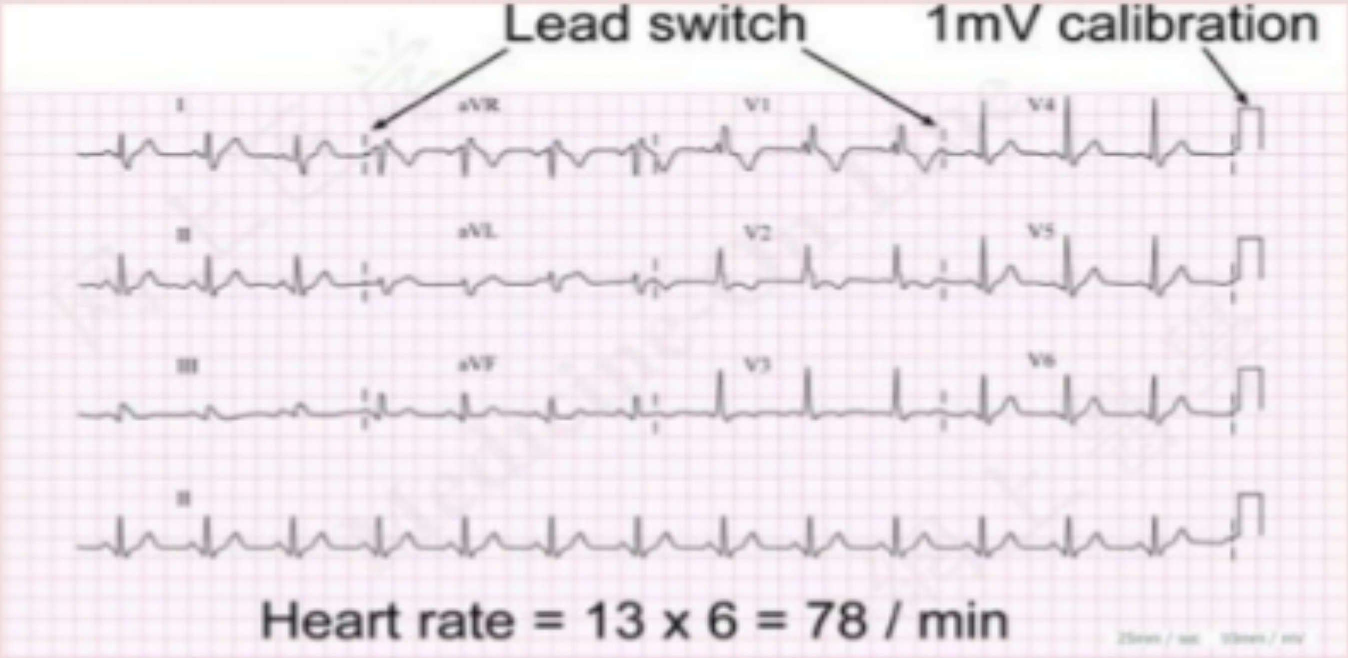
# of big boxes	Rate
1	300
2	150
3	100
4	75
5	60
6	50

IRREGULAR rhythm

There are 8 waves in this 6-seconds strip.

Rate = (Number of waves in 6-second strips) x 10
= 8 x 10
= **80** bpm

IRREGULAR rhythm

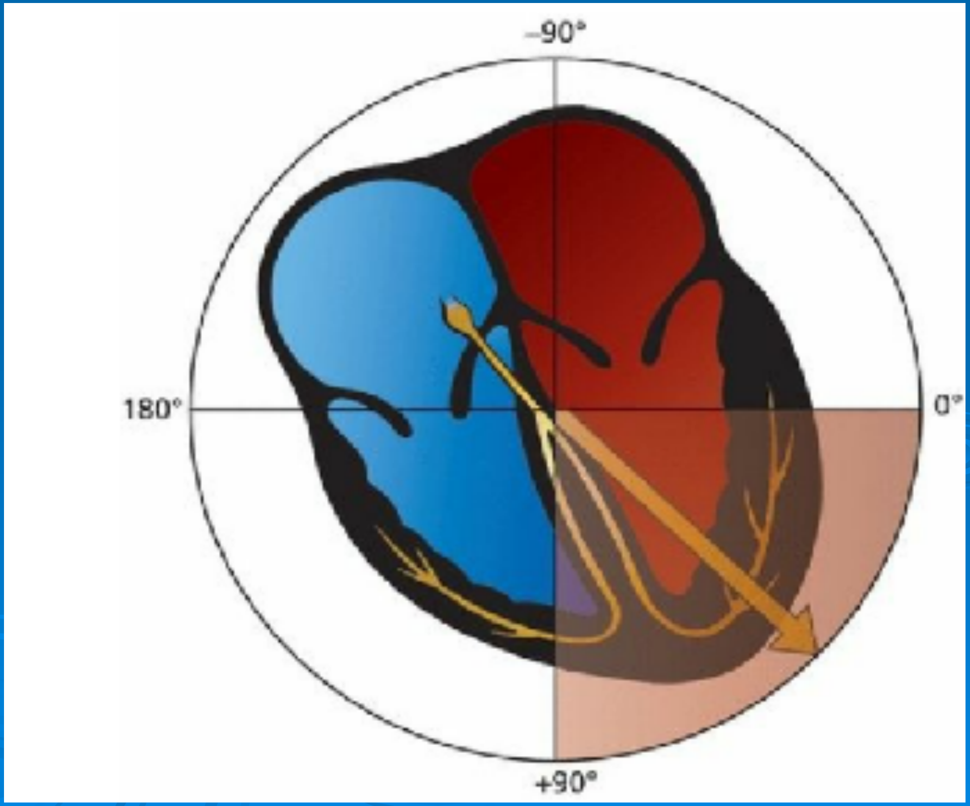


Rate = (Number of waves in 10-second strips) x 6
= 13 x 6
= **78** bpm

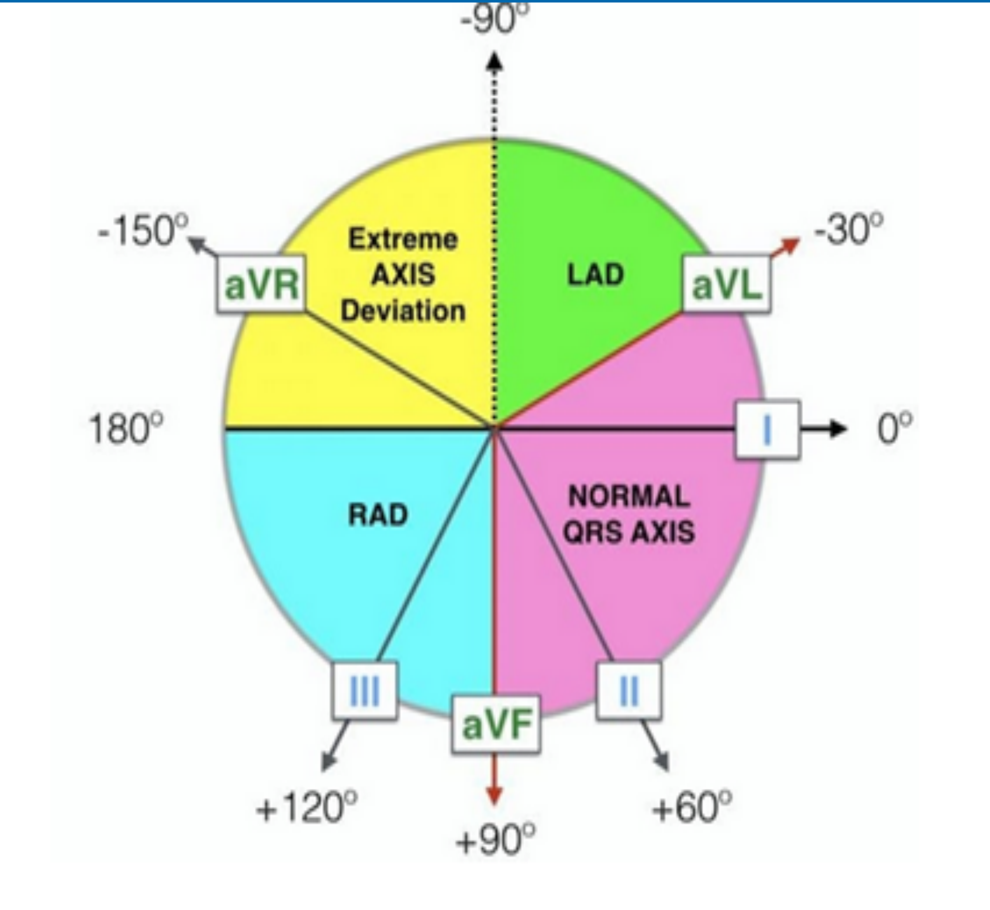
Determining axis

- The term axis refers to the direction of the mean electrical vector, representing the average diretion of current flow. It is defined in the frontal plane only.
- The mean QRS vector points leftward and inferiorly, representing the average direction of current flow during the entirely of ventricular depolarization.

The normal QRS axis- direction of this mean vector- lies between +90° and -30°.

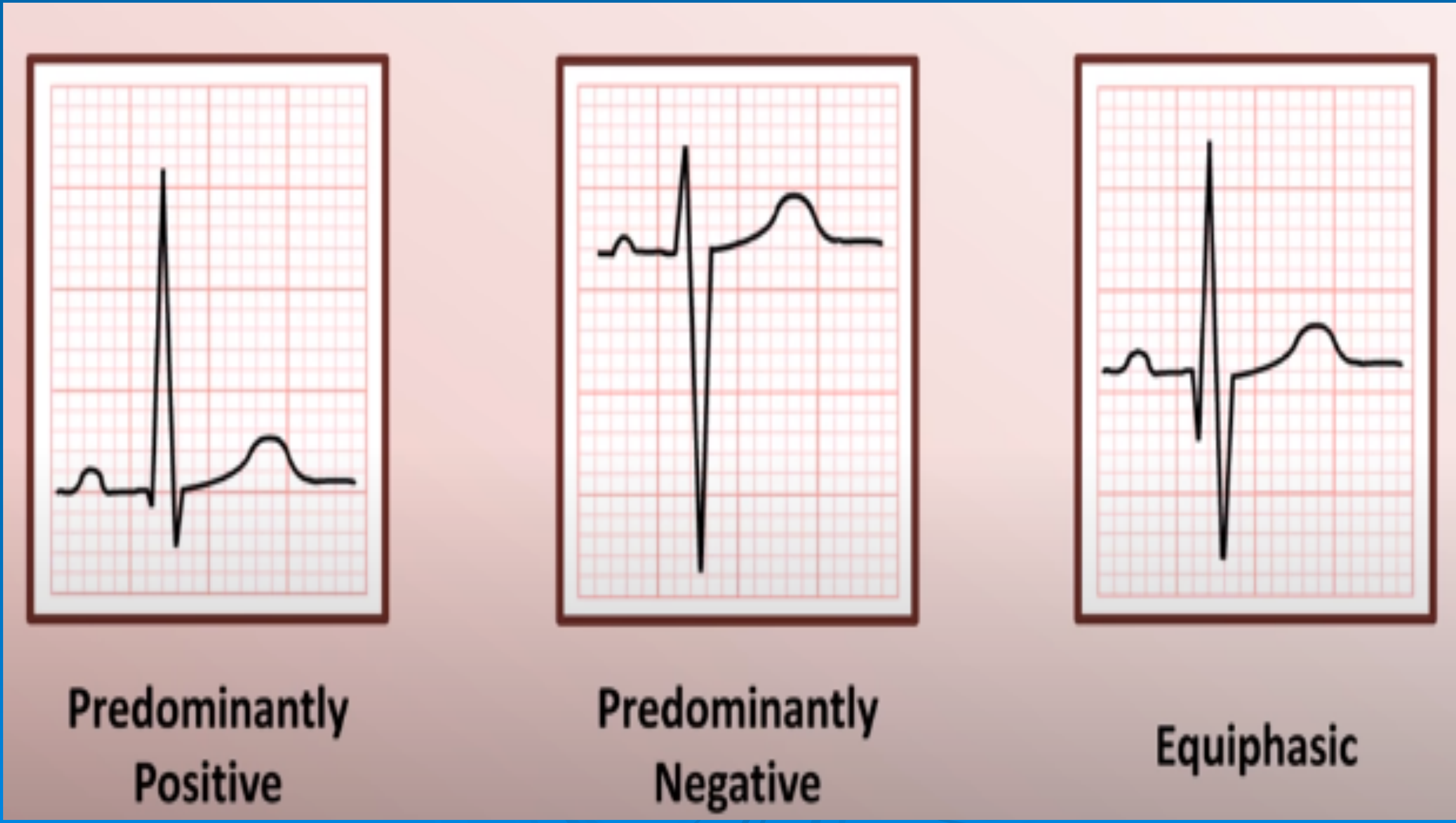


QRS axis



-90°
-150°
-30°
aVR
Extreme AXIS Deviation
LAD
aVL
180°
I
0°
RAD
NORMAL QRS AXIS
III
aVF
II
+120°
+90°
+60°

Determining axis- classifying QRS complexes



Determining Axis- Quadrant Approach

Examine the QRS complex in leads I and aVF.

		Lead aVF	
		Positive	Negative
Lead I	Positive	Normal Axis	LAD?
	Negative	RAD	Extreme

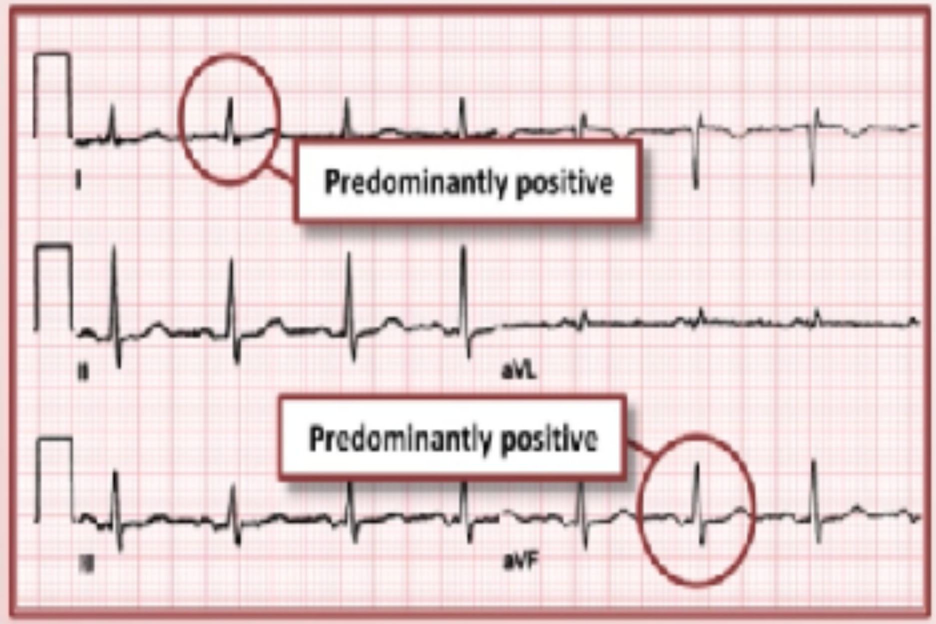
If QRS in I is + and QRS in aVF is -, examine QRS complex in lead II:

Predominantly positive → Normal (-30° to 0°)
Predominantly negative → LAD (-90° to -30°)

Determining Axis- Quadrant Approach

Examine the QRS complex in leads I and aVF.

		Lead aVF	
		Positive	Negative
Lead I	Positive	Normal Axis	LAD?
	Negative	RAD	Extreme

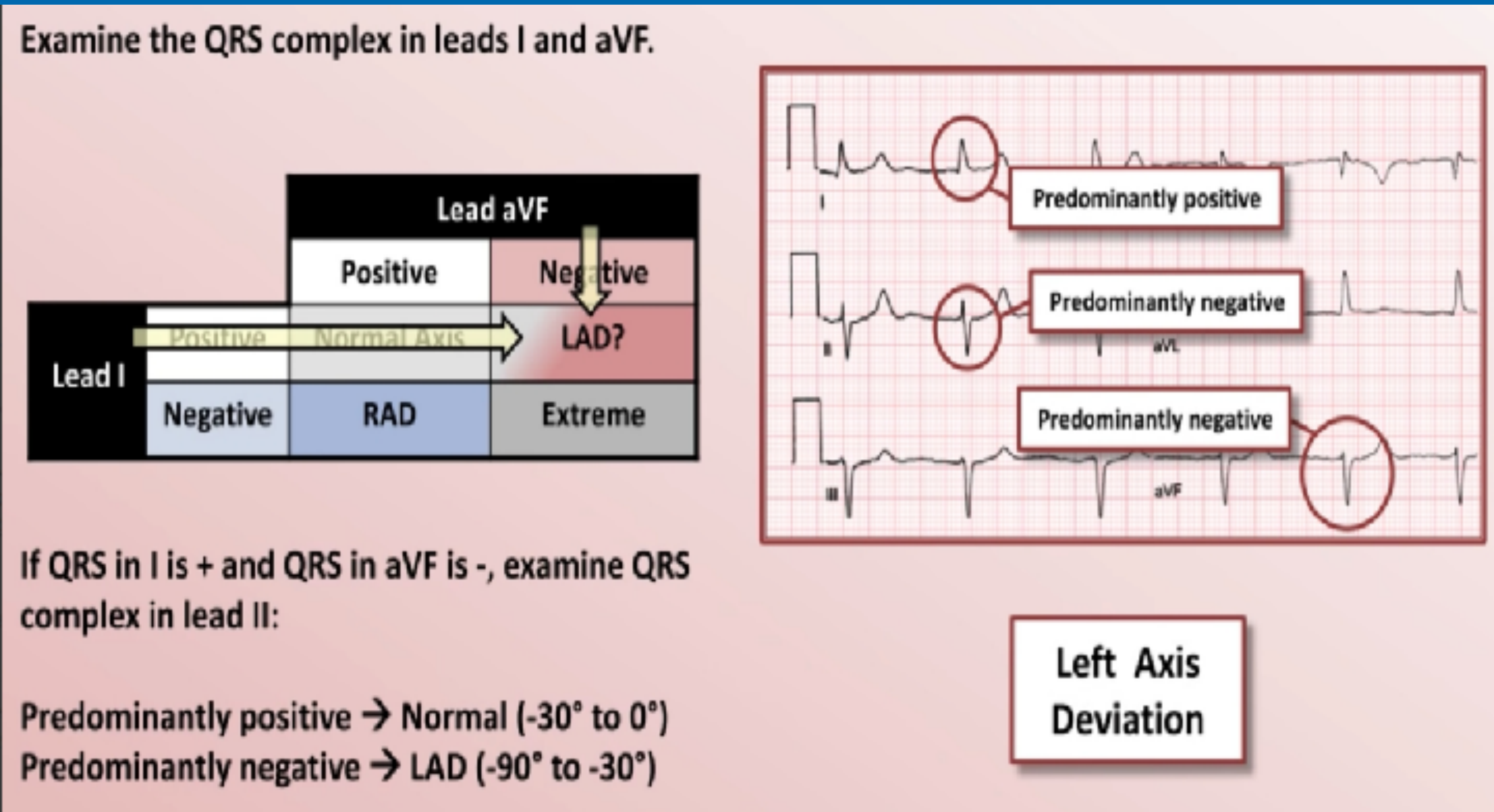


If QRS in I is + and QRS in aVF is -, examine QRS complex in lead II:

Predominantly positive → Normal (-30° to 0°)
Predominantly negative → LAD (-90° to -30°)

Normal Axis

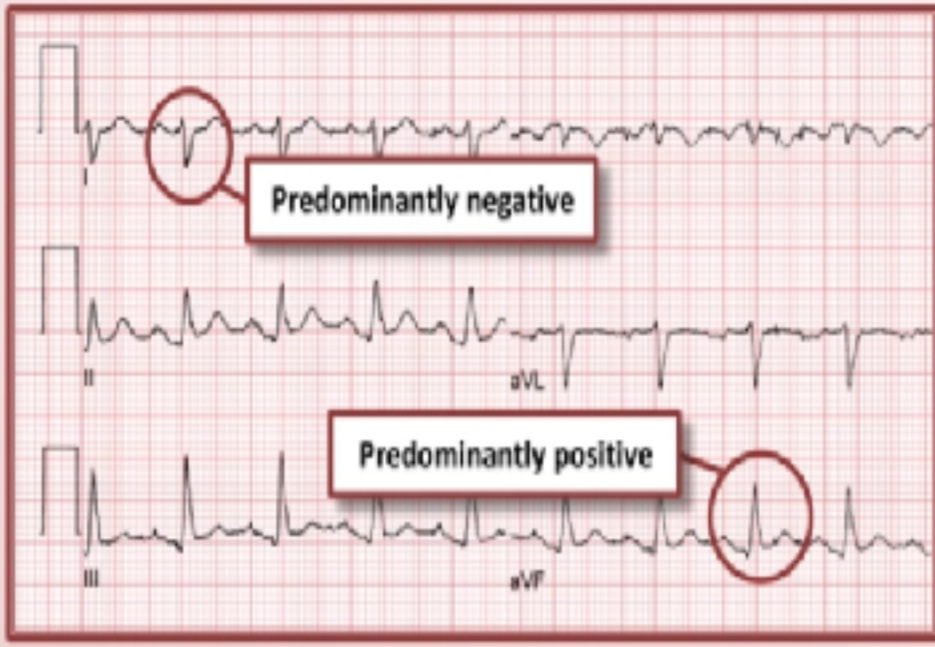
Determining Axis- Quadrant Approach



Determining Axis- Quadrant Approach

Examine the QRS complex in leads I and aVF.

		Lead aVF	
		Positive	Negative
Lead I	Positive	Normal Axis	LAD?
	Negative	RAD	Extreme



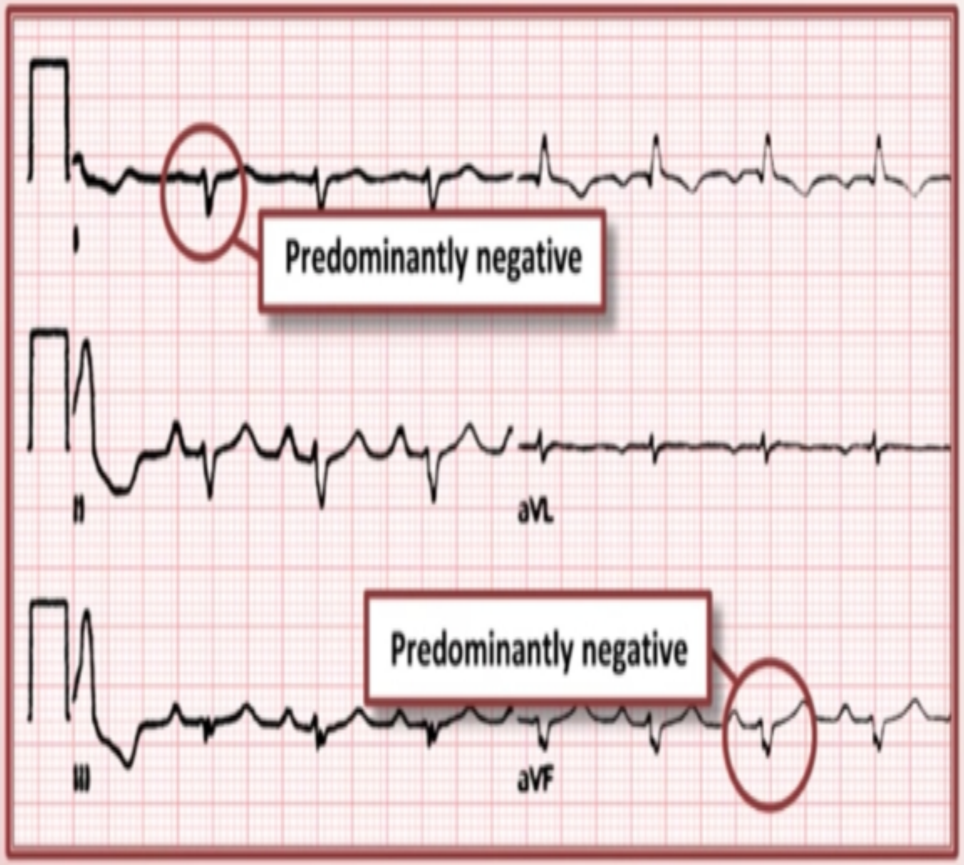
If QRS in I is + and QRS in aVF is -, examine QRS complex in lead II:

Predominantly positive → Normal (-30° to 0°)
Predominantly negative → LAD (-90° to -30°)

Right Axis Deviation

Examine the QRS complex in leads I and aVF.

		Lead aVF	
		Positive	Negative
Lead I	Positive	Normal Axis	LAD?
	Negative	RAD	Extreme



If QRS in I is + and QRS in aVF is -, examine QRS complex in lead II:

Predominantly positive → Normal (-30° to 0°)
Predominantly negative → LAD (-90° to -30°)

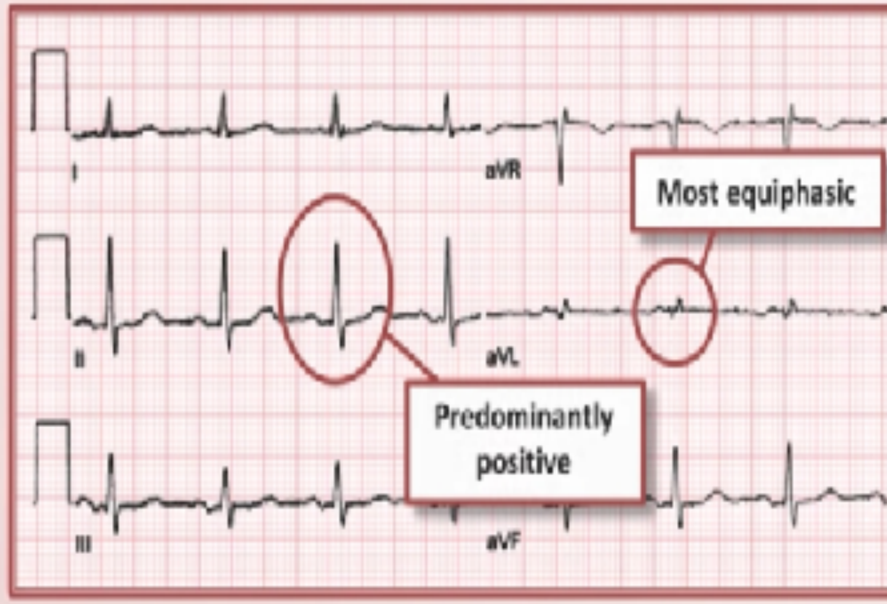
Extreme Axis Deviation

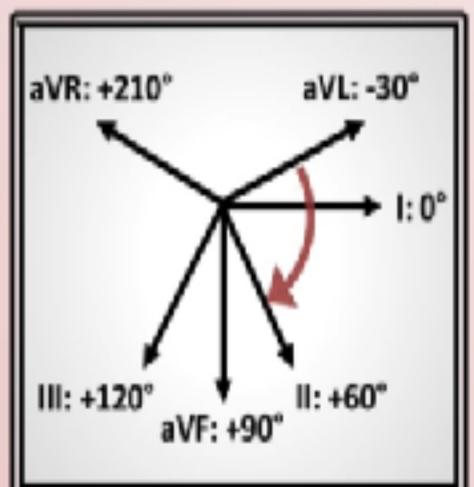
Determining Axis- Equiphasic Approach

1. Determine which lead contains the most equiphasic QRS complex (i.e. the equiphasic lead).

2. Determine which lead lies 90° away from the most equiphasic lead.

3. If the QRS complex in this 2nd lead is predominantly positive, the direction of this lead is approximately the QRS axis. If it is predominantly negative, the QRS axis is 180° away from the direction of this lead.





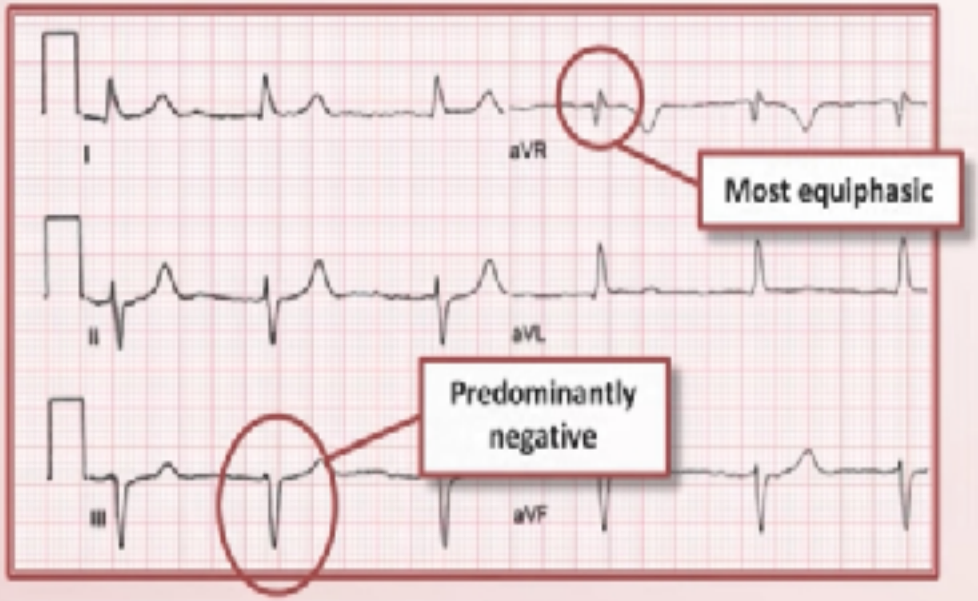
Axis ≈ +60°

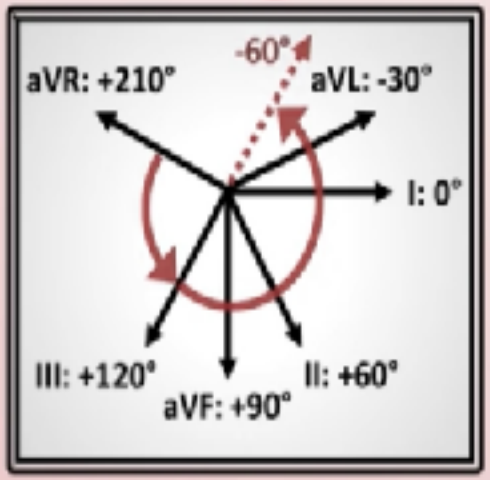
Determining Axis- Equiphasic Approach

1. Determine which lead contains the most equiphasic QRS complex (i.e. the equiphasic lead).

2. Determine which lead lies 90° away from the most equiphasic lead.

3. If the QRS complex in this 2nd lead is predominantly positive, the direction of this lead is approximately the QRS axis. If it is predominantly negative, the QRS axis is 180° away from the direction of this lead.





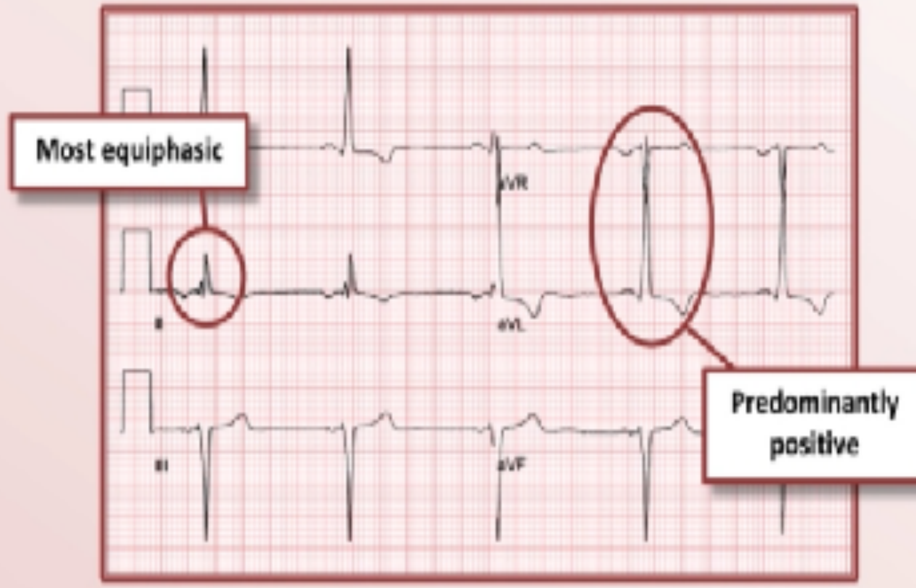
Axis ≈ -60°

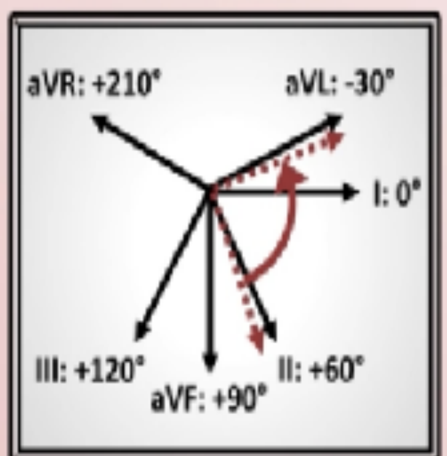
Determining Axis- Equiphasic Approach

1. Determine which lead contains the most equiphasic QRS complex (i.e. the equiphasic lead).

2. Determine which lead lies 90° away from the most equiphasic lead.

3. If the QRS complex in this 2nd lead is predominantly positive, the direction of this lead is approximately the QRS axis. If it is predominantly negative, the QRS axis is 180° away from the direction of this lead.





Axis ≈ Slightly inferior to -30°

Determining Axis- Equiphasic Approach

- Occurs when all of the limb leads have a QRS complex that is equal parts positive and negative.
- Most commonly seen in COPD as a manifestation of the pulmonary disease pattern.

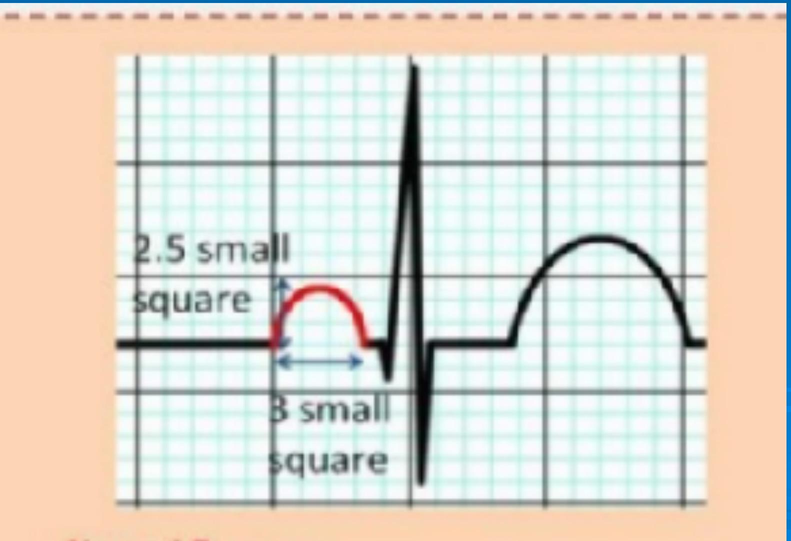
Major Waves of a normal EKG

P wave overview

- Monophasic, most positive in lead II
- often biphasic in lead III and V1
- should be upright in leads I and II, most negative in lead aVR
- duration: < 0.12 s (<120 ms or 3 small squares)

Amplitude

- < 2.5 mm (0.25mV) in the limb leads
- < 1.5 mm (0.15mV) in the precordial leads

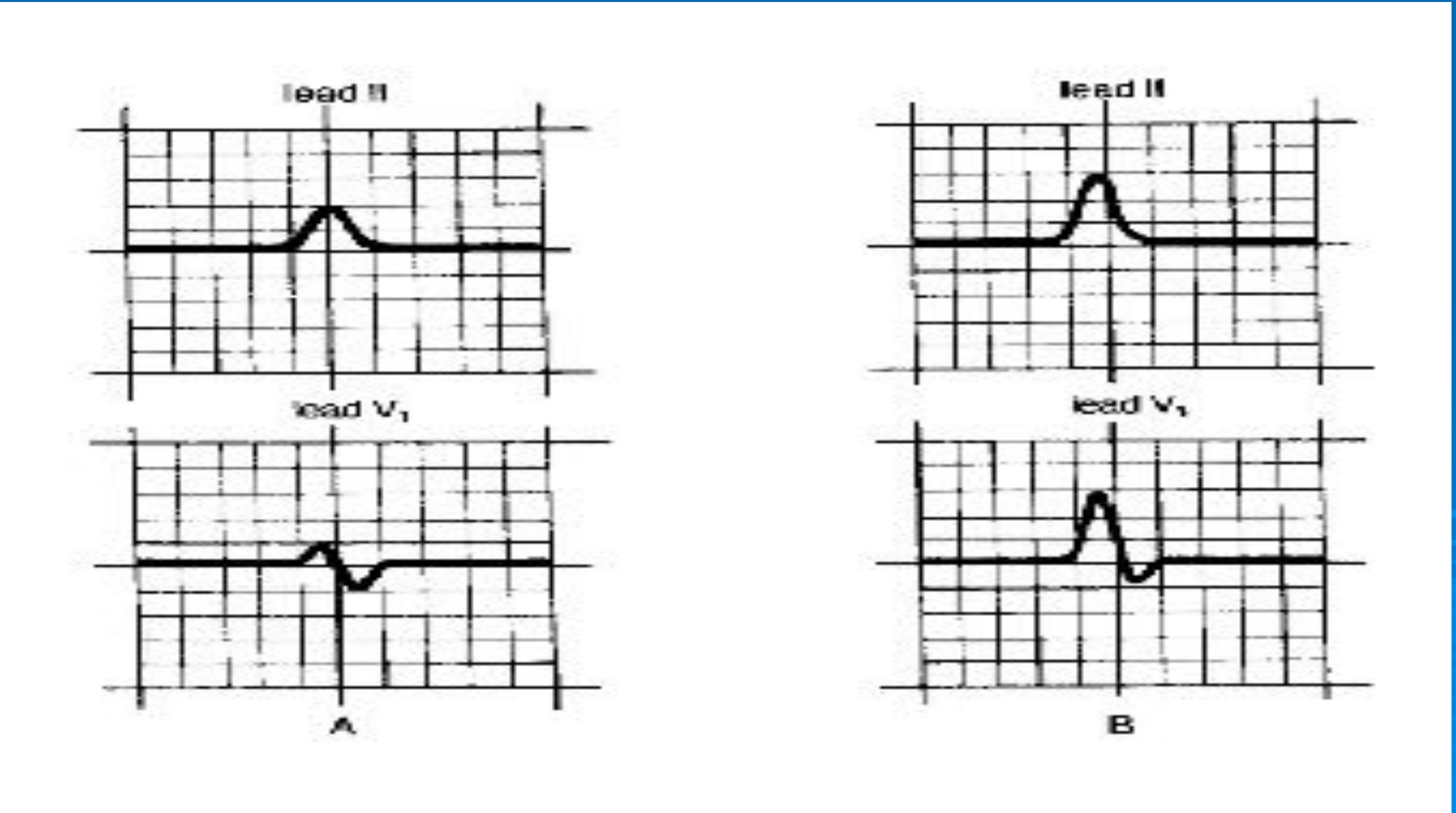


Normal P- wave

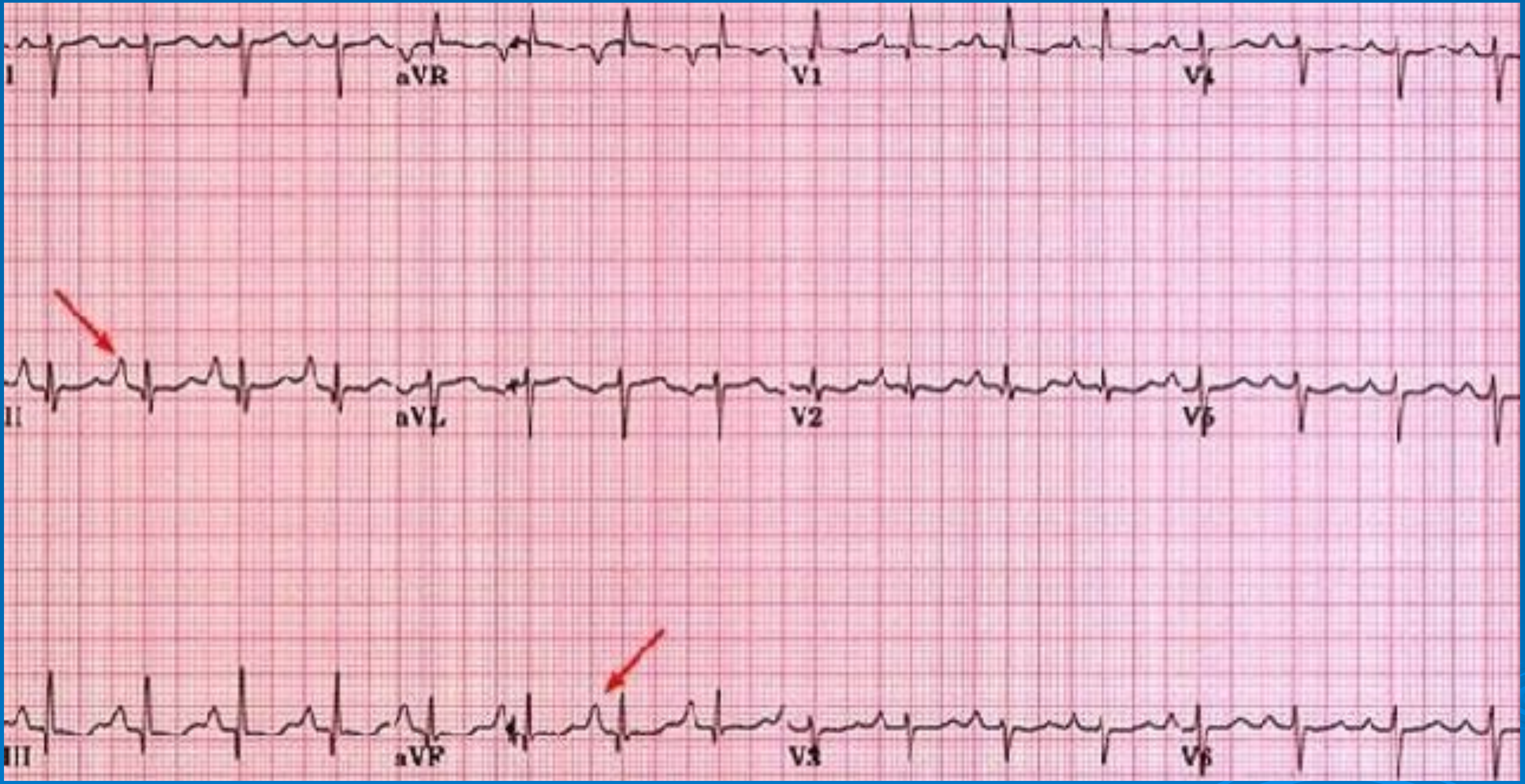
Right atrial enlargement

Tall upright P wave:

- 2.5 mm in leads II, III, and aVF *(P-pulmonale*), or
- 1.5 mm in leads V1 or V2
- It is called “P pulmonale”, because it is often met in cor pulmonare.
- Possible right axis deviation of the P wave

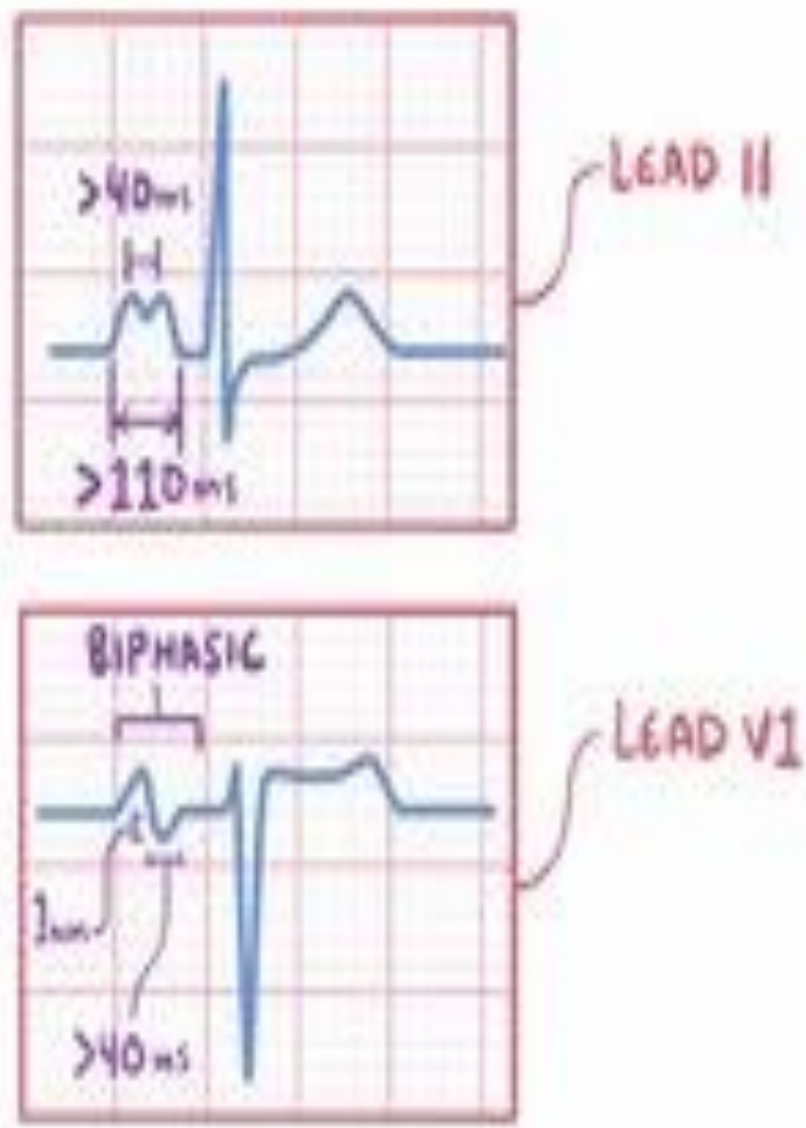


Right atrial enlargement



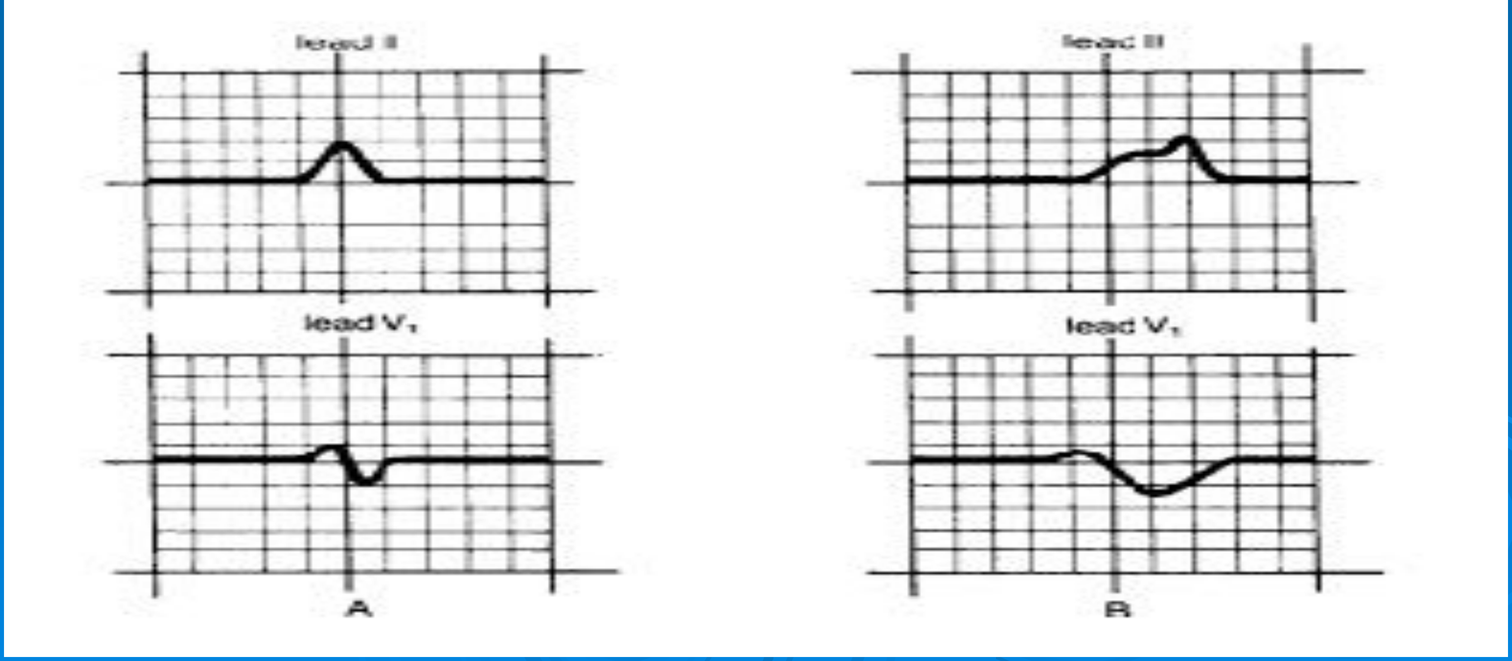
Right atrial enlargement is commonly associated with congenital heart disease, tricuspid valve disease, pulmonary hypertension and diffuse lung disease

LEFT ATRIAL ENLARGEMENT



Left Atrial Enlargement

- The P wave sometimes has a distinctive humped or notched appearance;
- Terminal negative portion of the P wave in lead V1 ≥1mm deep and ≥ 0.04 seconds in duration (one small box deep and one small box wide), or
- Notched P wave with a duration ≥0.12 seconds in leads II, III or aVF (*P-mitrale*)



PR interval

- reflects conduction through the AV node.
- the normal PR interval is between 120 – 200 ms (0.12-0.20s) in duration (three to five small squares).
- if the PR interval is > 200 ms, first degree heart block is said to be present.
- PR interval < 120 ms suggests pre-excitation (the presence of an accessory pathway between the atria and ventricles) or AV nodal (junctional) rhythm.

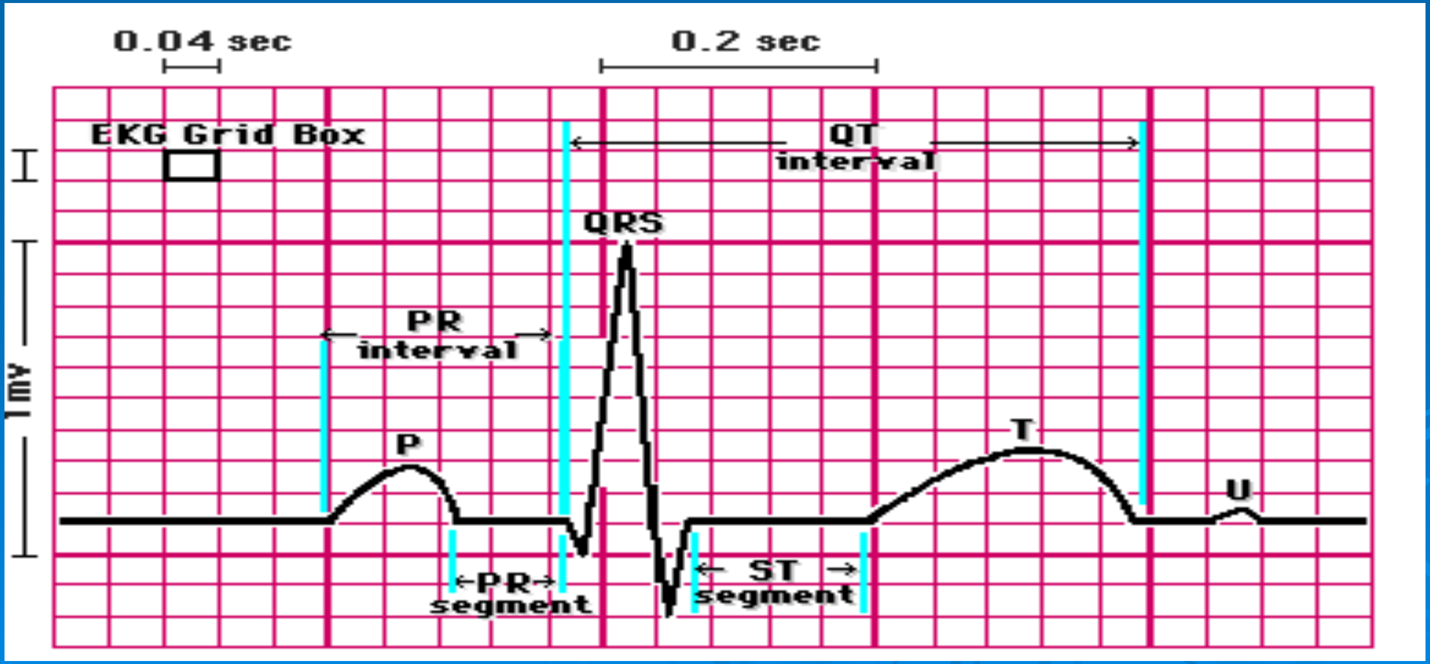
PR INTERVAL = 4 small boxes = 4 x 0.04 = 0.16 sec.

PR segment

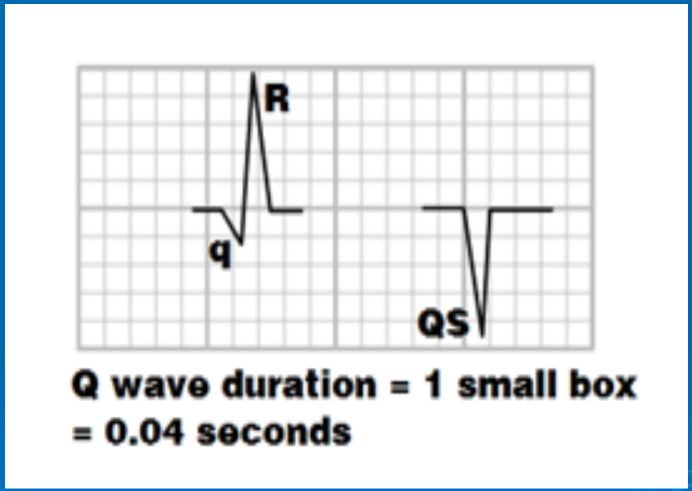
- is the flat, usually isoelectric segment between the end of the P wave and the start of the QRS complex.

PR segment abnormalities can occur in two main conditions:

- Pericarditis
- Atrial ischaemia

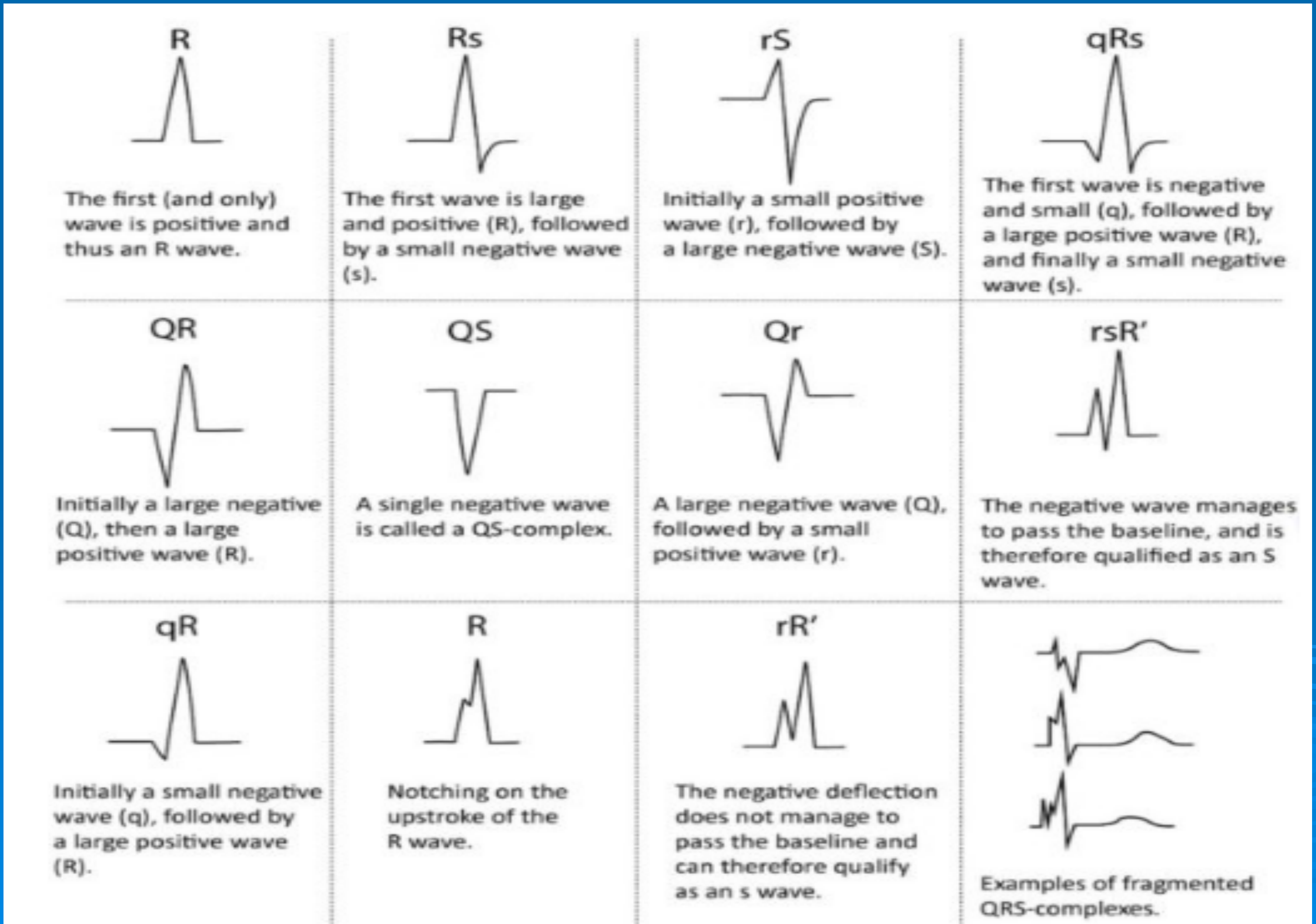


Q wave



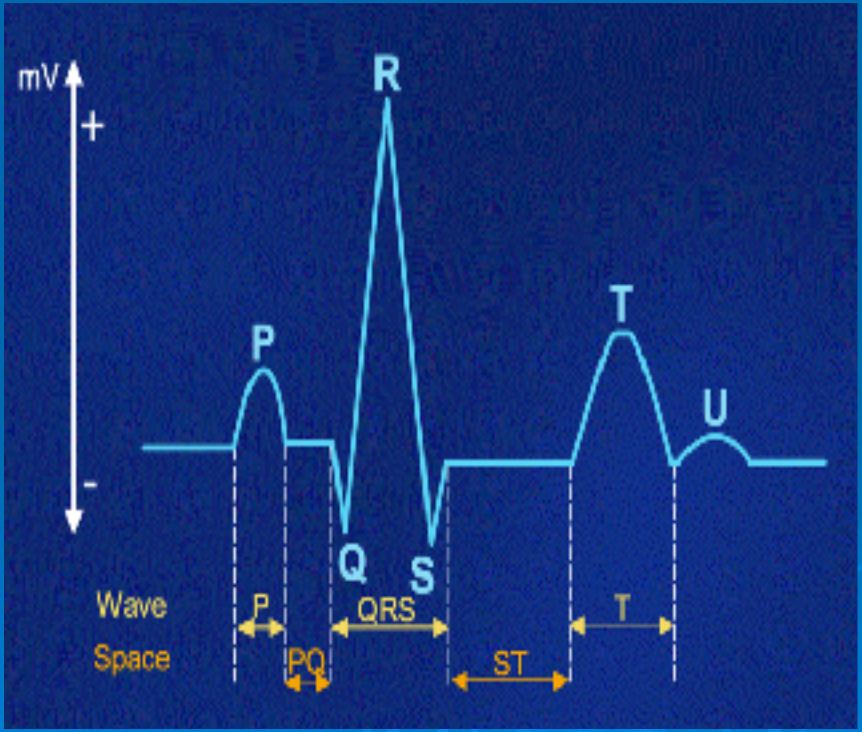
The QRS interval

- The normal QRS duration is about 0.10 sec (or 0.11 sec when measured by computer).
- The QRS duration is slightly longer in males than in females and in large, tall subjects than in small, short subjects.



R wave overview

- The positive wave of the QRS complex is called the R wave, whether or not it is preceded by a Q wave.
- When a second positive deflection occurs, it is termed R’.
- Dominant R wave in V1
- Dominant R wave in aVR
- Poor R wave progression

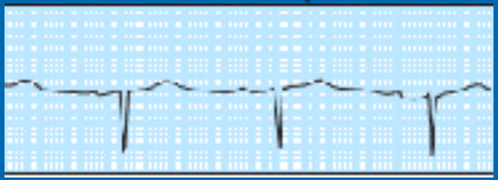


R wave overview

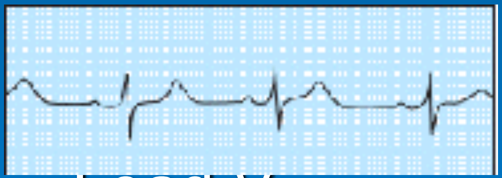
Chest leads - the R wave increases its amplitude and duration from V1 to V4 or V5.

The amplitude of the R wave in leads V5 and V6 varies directly with left ventricular dimension.

- Lead V_1



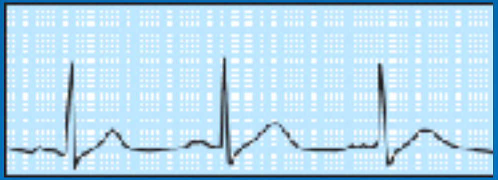
- Lead V_2



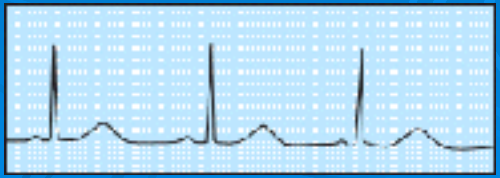
- Lead V_3

Lead V4

Lead V5

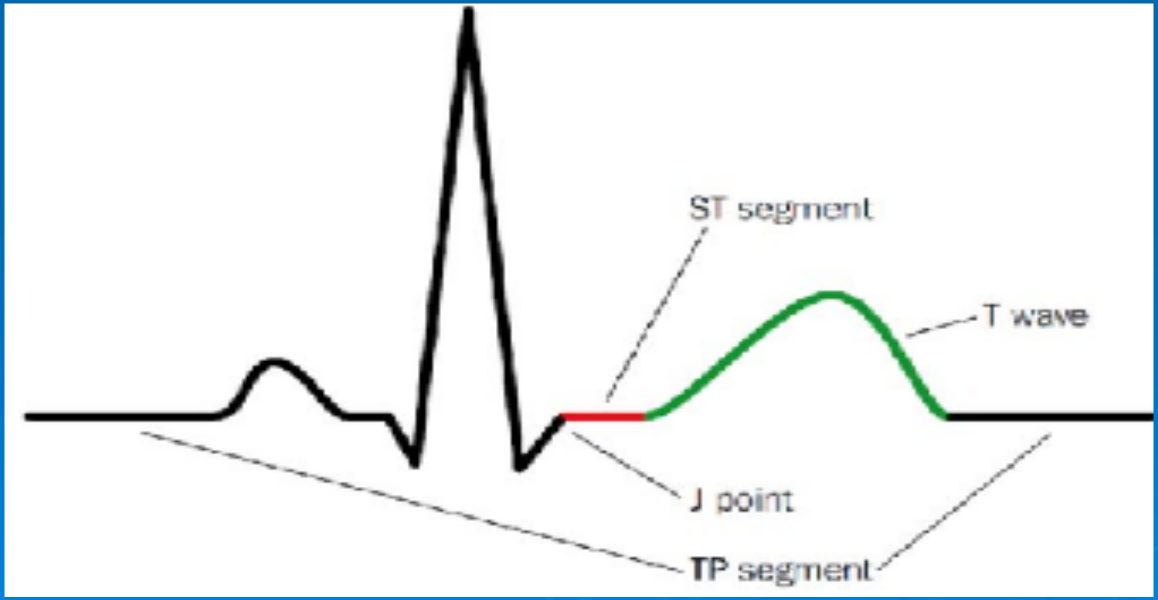


Lead V6



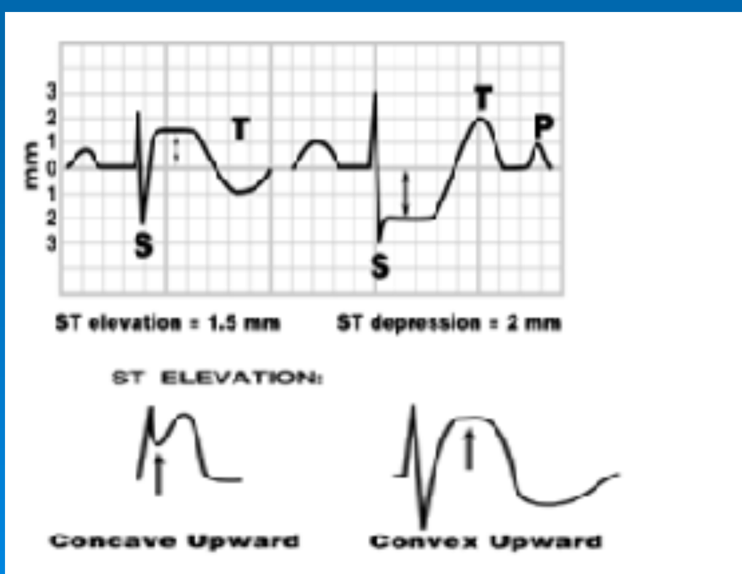
ST segment

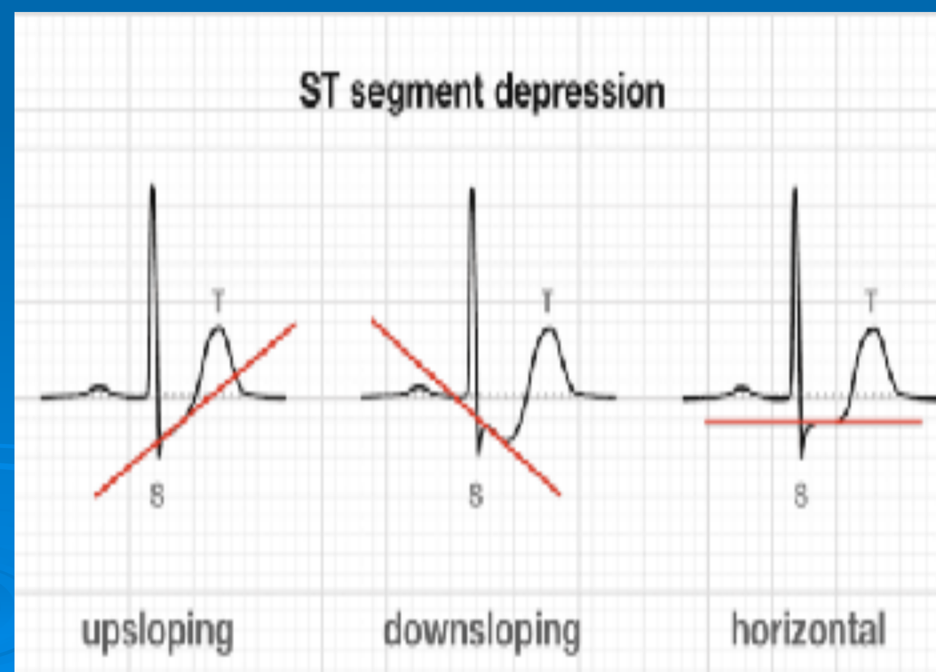
- **The ST segment represents the time from the end of ventricular depolarization to the start of ventricular** repolarization
- is the flat, isoelectric section of the EKG between the end of the S wave (the J point) and the beginning of the T wave**.**
- **The ST segment is normally on the isoelectric line, on the same level with the PR and TP segments**.



ST segment

- The most important cause of ST segment abnormality (elevation or depression) is myocardial ischaemia or infarction.
- ST depression can be either upsloping, downsloping, or horizontal.
- Reciprocal change has a morphology that resembles "upside down" ST elevation and is seen in leads electrically opposite to the site of infarction.



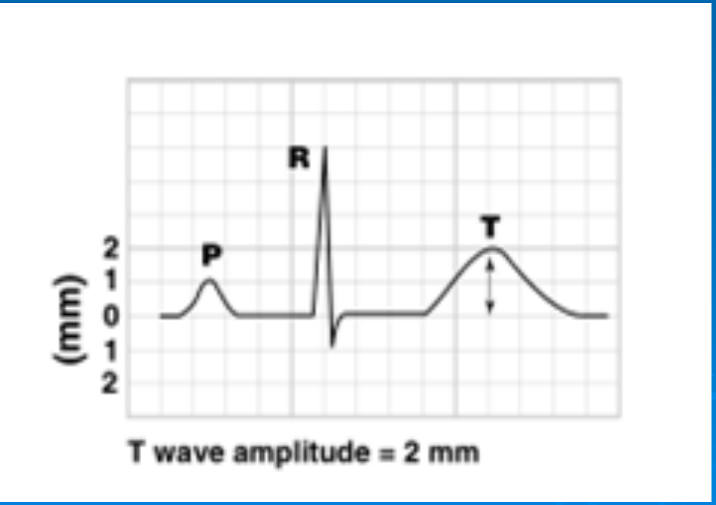


Causes of ST Depression

- Myocardial ischaemia / NSTEMI
- Reciprocal change in STEMI Posterior MI
- Digoxin effect
- Hypokalaemia
- Supraventricular tachycardia
- Right bundle branch block
- Right ventricular hypertrophy
- Left bundle branch block
- Left ventricular hypertrophy
- Ventricular paced rhythm

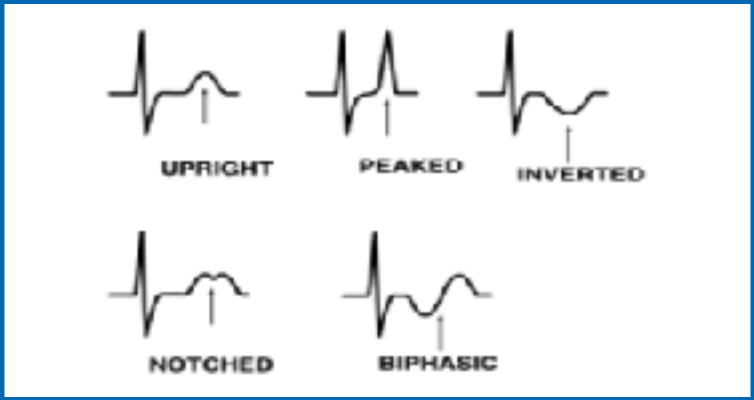
T wave overview

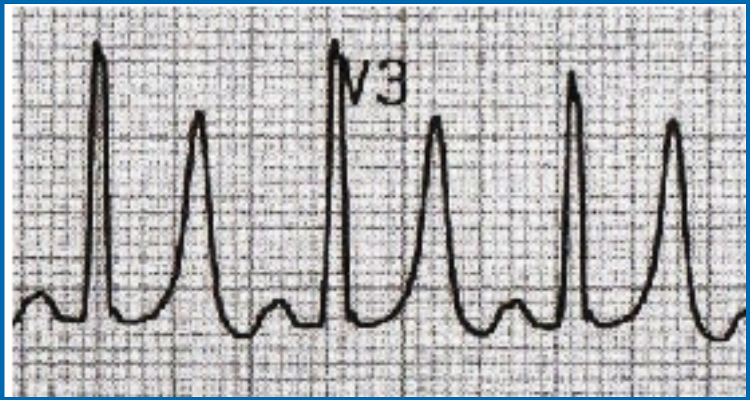
- represents ventricular repolarisation;
- upright in all leads except aVR and V1
- amplitude < 5mm in limb leads, < 10mm in precordial leads (10mm in men, 8mm in women)
- typical and normal to find positive T waves in the same leads that have tall R waves
- Slight “peaking” of the T wave may occur as a normal variant.
- the amplitude or height of normal T wave is one-third to two thirds that of the corresponding R wave



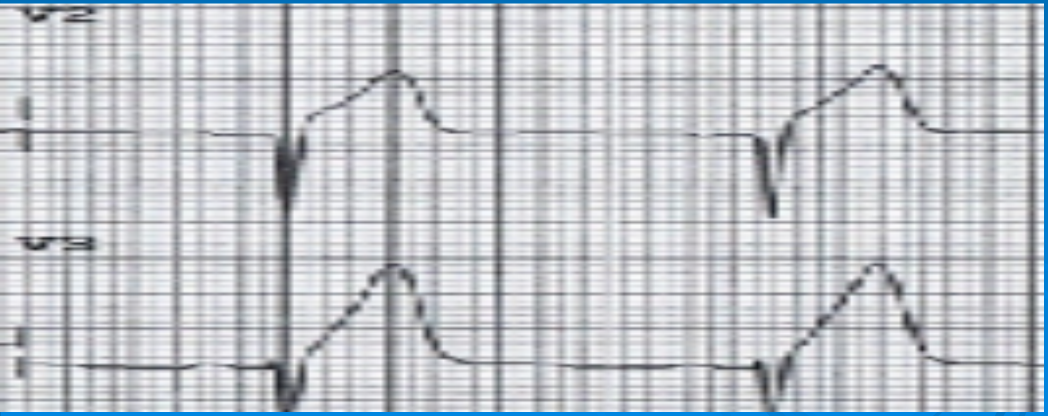
T wave overview

T wave abnormalities



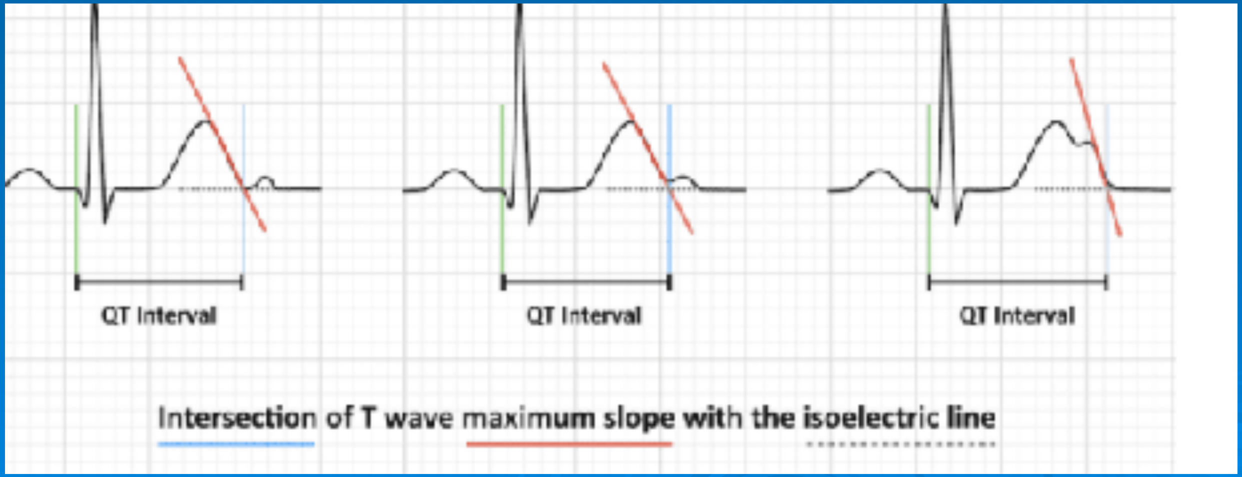


- Broad, asymmetrically peaked or '*hyperacute*' T-waves are seen in the early stages of ST-elevation MI (STEMI) and often precede the appearance of ST elevation and Q waves.



QT interval

- The **QT interval** is the time from the start of the Q wave to the end of the T wave.
- The QT interval *shortens* at faster heart rates
- The QT interval *lengthens* at slower heart rates
- The QT interval should be measured in either lead II or V5-6
- QTc is prolonged if > 440ms in men or > 460ms in women
- QTc > 500 is associated with increased risk of torsades de pointes



Causes of a prolonged QT

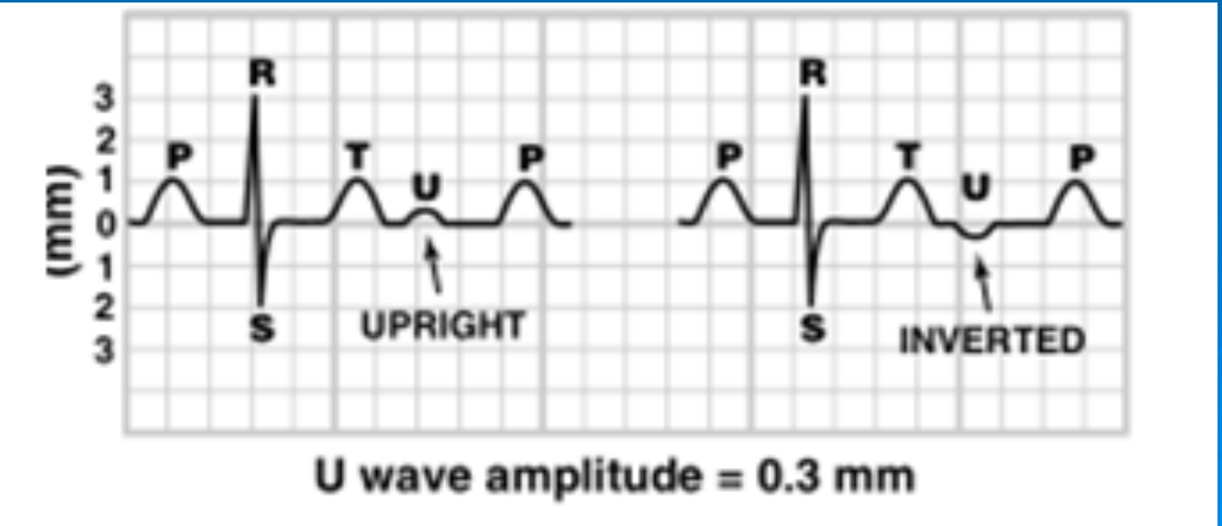
- Hypokalaemia
- Hypomagnesaemia
- Hypocalcaemia
- Hypothermia
- Myocardial ischemia
- ROSC Post-cardiac arrest
- Raised intracranial pressure
- Congenital long QT syndrome
- Medications/Drugs

U wave overview

- The U wave is a small (0.5 mm) deflection immediately following the T wave
- U wave is usually in the same direction as the T wave.
- U wave is best seen in leads V2 and V3.

The source of the U wave is unknown. Three common theories regarding its origin are:

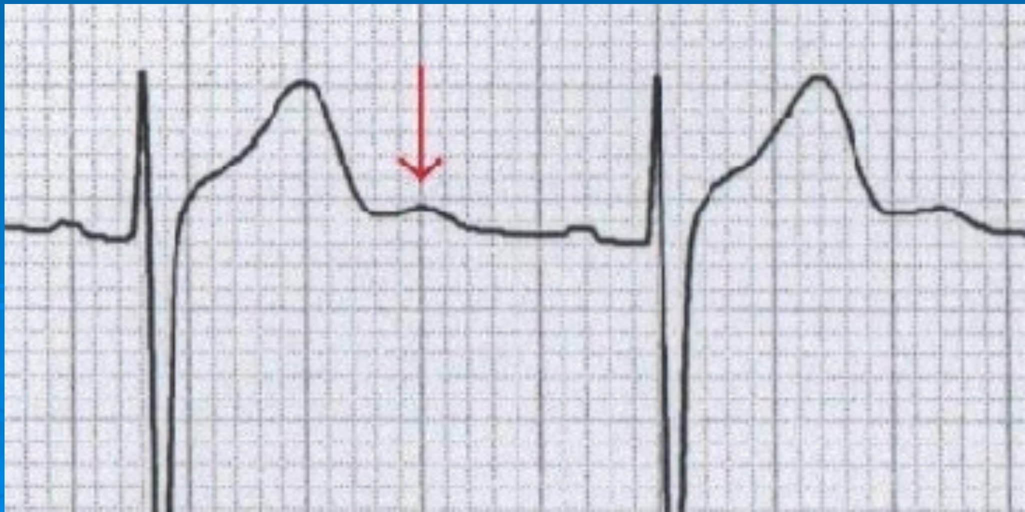
- Delayed repolarisation of Purkinje fibres
- Prolonged repolarisation of mid-myocardial “M-cells”
- After-potentials resulting from mechanical forces in the ventricular wall



U wave overview

Prominent U waves ***most commonly*** found with:

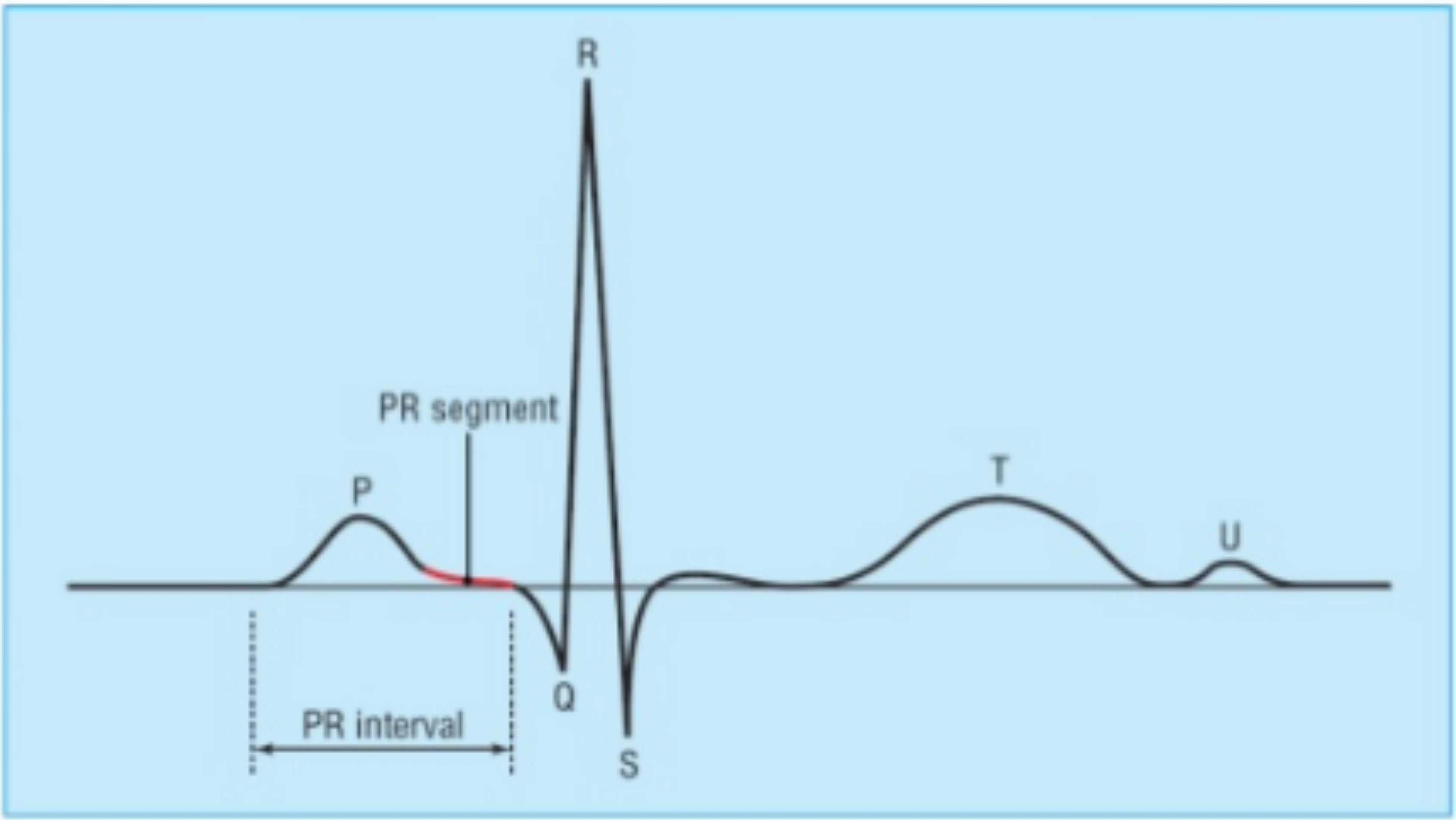
- Bradycardia
- Hypocalcaemia
- Hypomagnesaemia
- Hypothermia
- Left ventricular hypertrophy
- Hypertrophic cardiomyopathy



What do we look for ?
How to report an EKG?

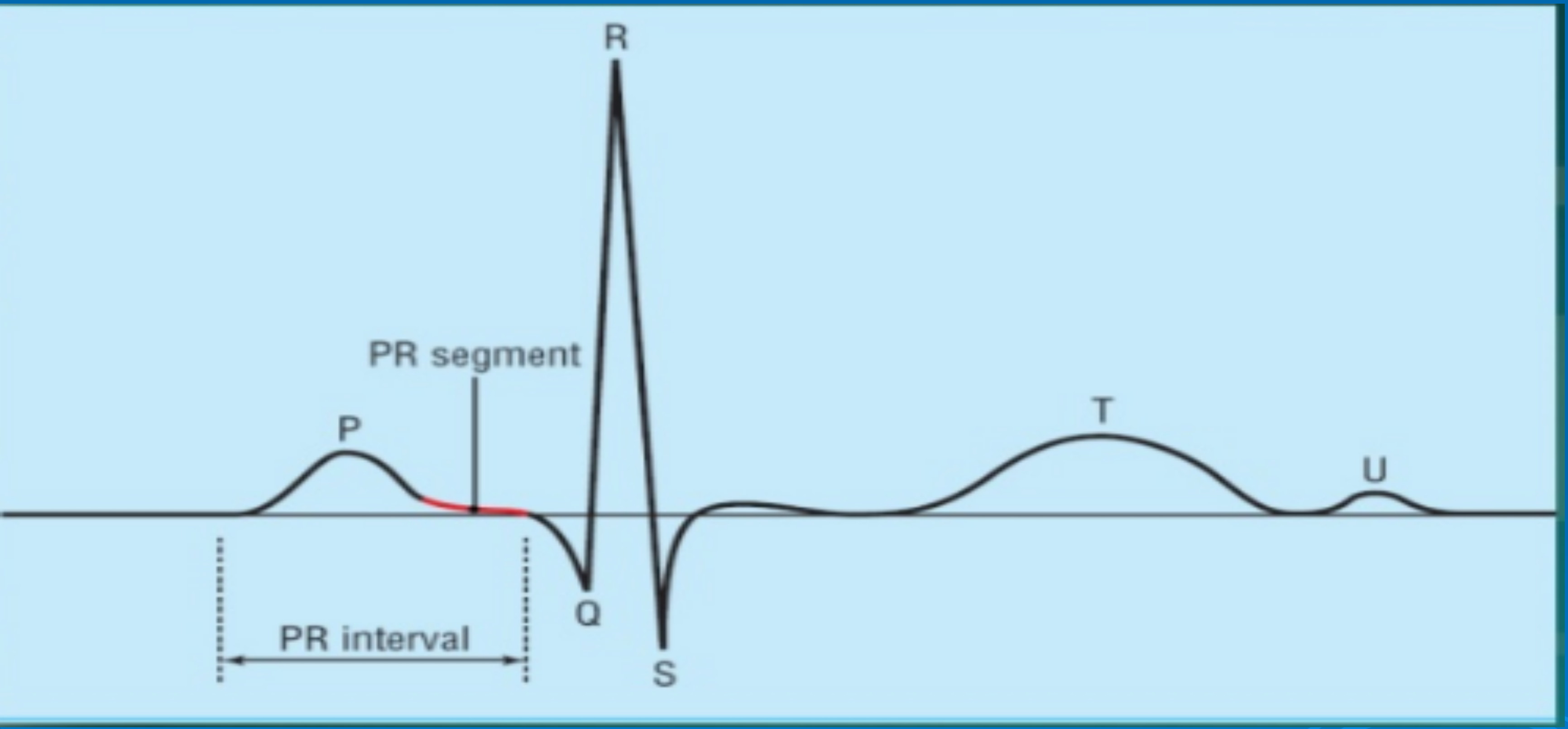
- Patient details, situation details (the time)
- Standardization (voltage calibration)
- Rhythm (sinus or not)
- Rhytmicity (rhytmical or not)
- Heart rate
- Mean QRS axis
- PR, QRS and QT intervals (duration)
- P wave (polarity, duration and height)
- QRS voltages
- Precordial R-wave progression
- Abnormal Q wave (wide and deep)
- ST segment (position according isoelectric line)
- T waves (polarity, symmetricity and height)
- U waves (if present)

ECG Rules
Rule 1



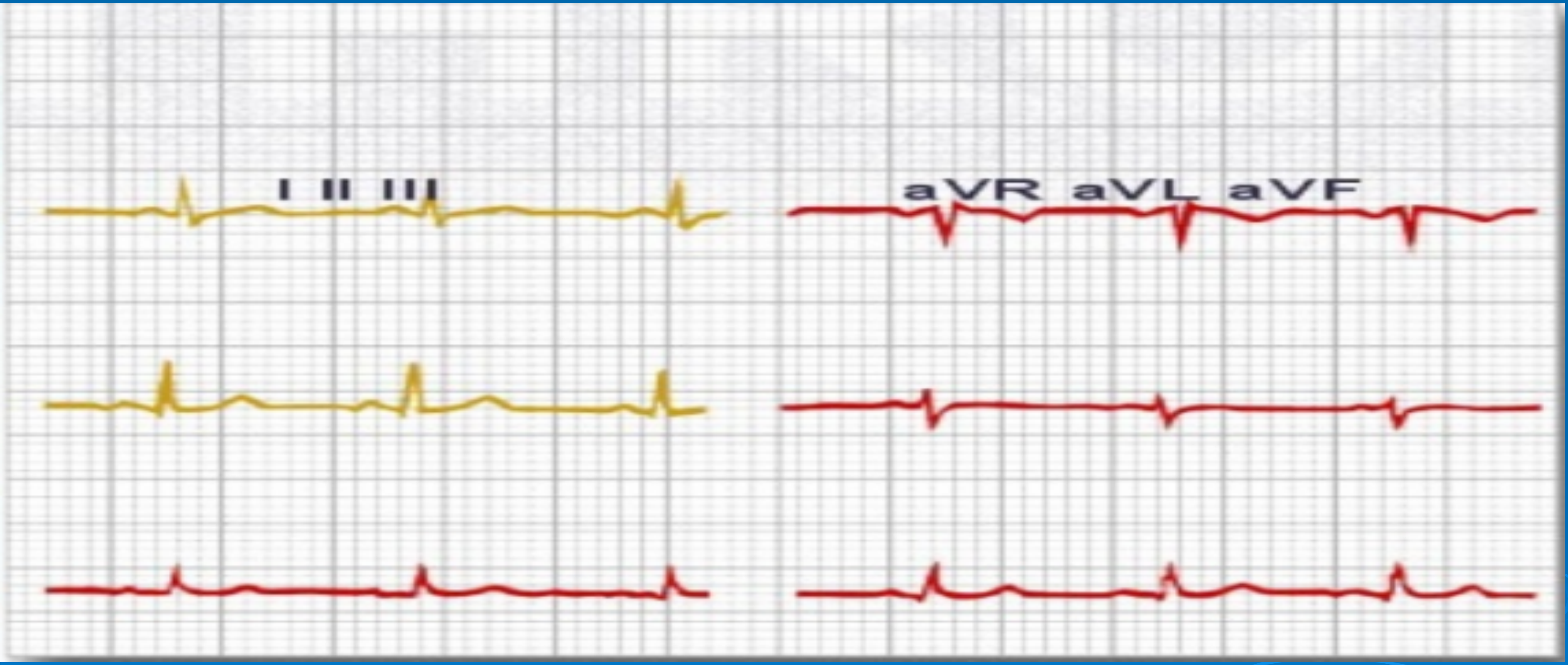
Normal duration of PR interval is 0.12-0.20 s (three to five small squares)

Rule 2



The width of the QRS complex should not exceed 110 ms, less than 3 little squares

Rule 3

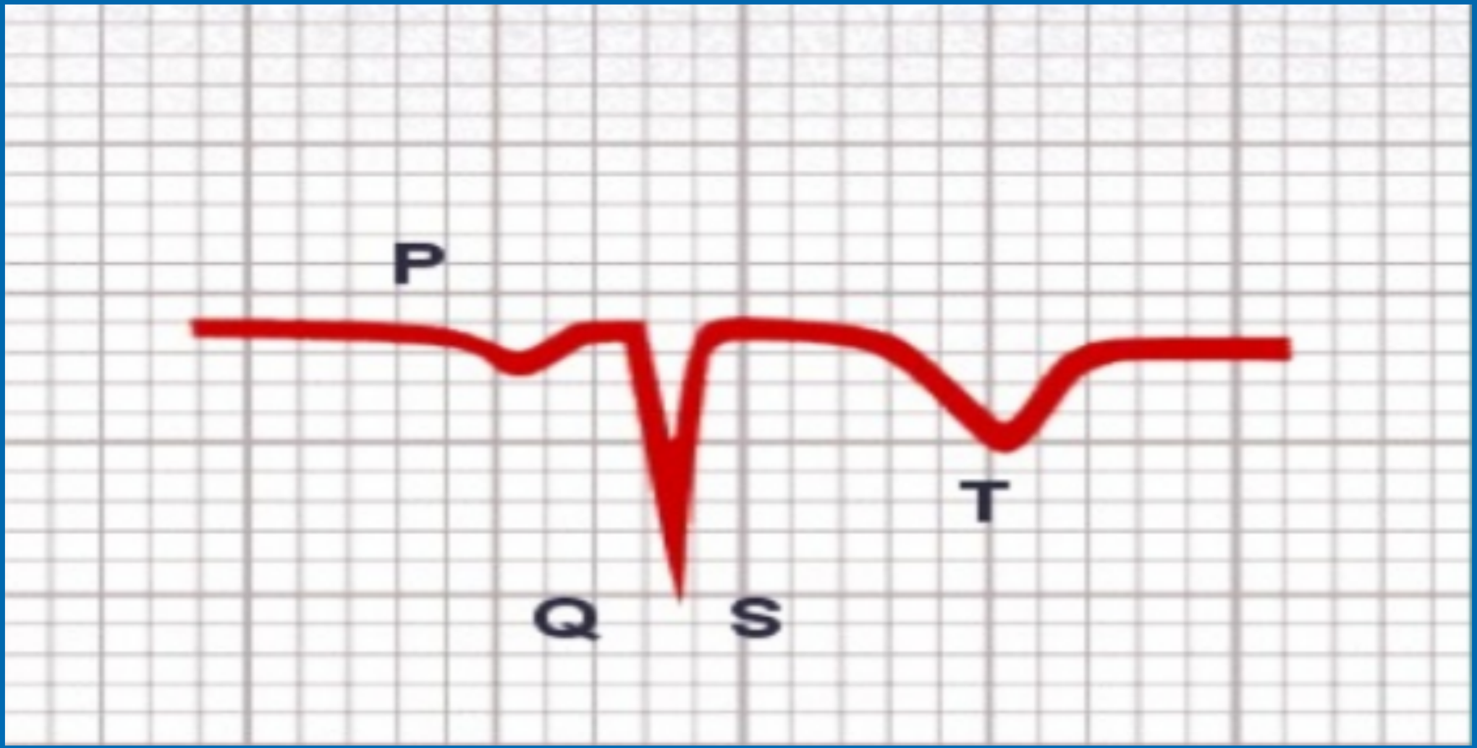


The QRS complex should be dominantly upright in leads I and II .

Rule 4

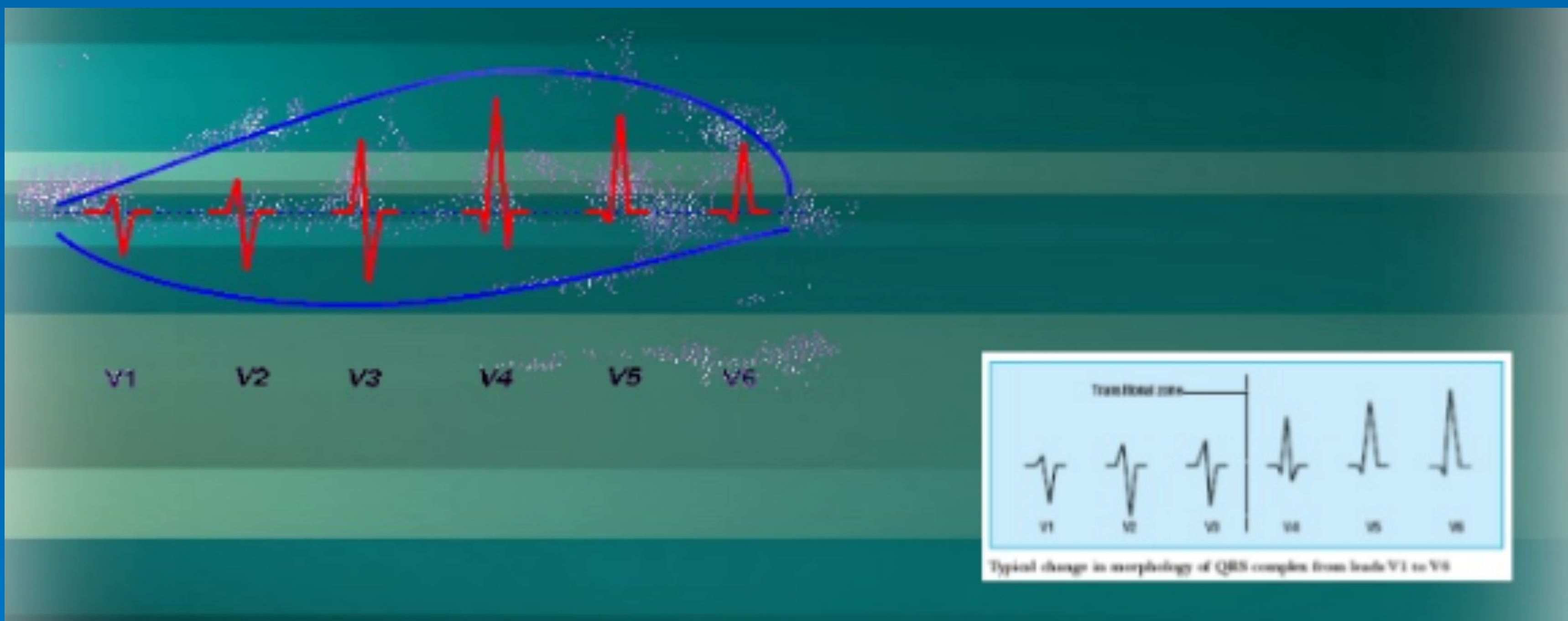
QRS and T waves tend to have the same general direction in the limb leads .

Rule 5



All waves are negative in lead aVR.

Rule 6



The R wave must grow from V1 to at least V4.
The S wave must grow from V1 to at least V3 and disappear in V6 .

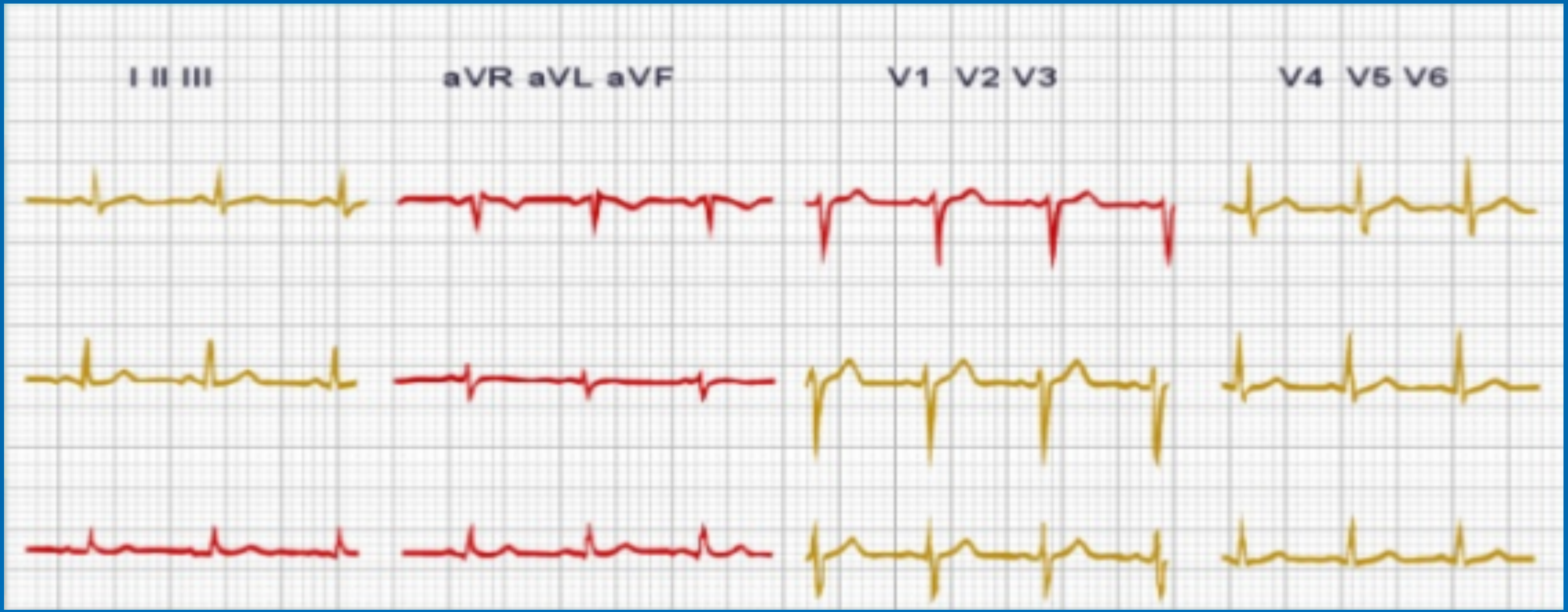
Rule 7

The ST segment should start isoelectric except in V1 and V2 where it may be elevated.

Rule 8

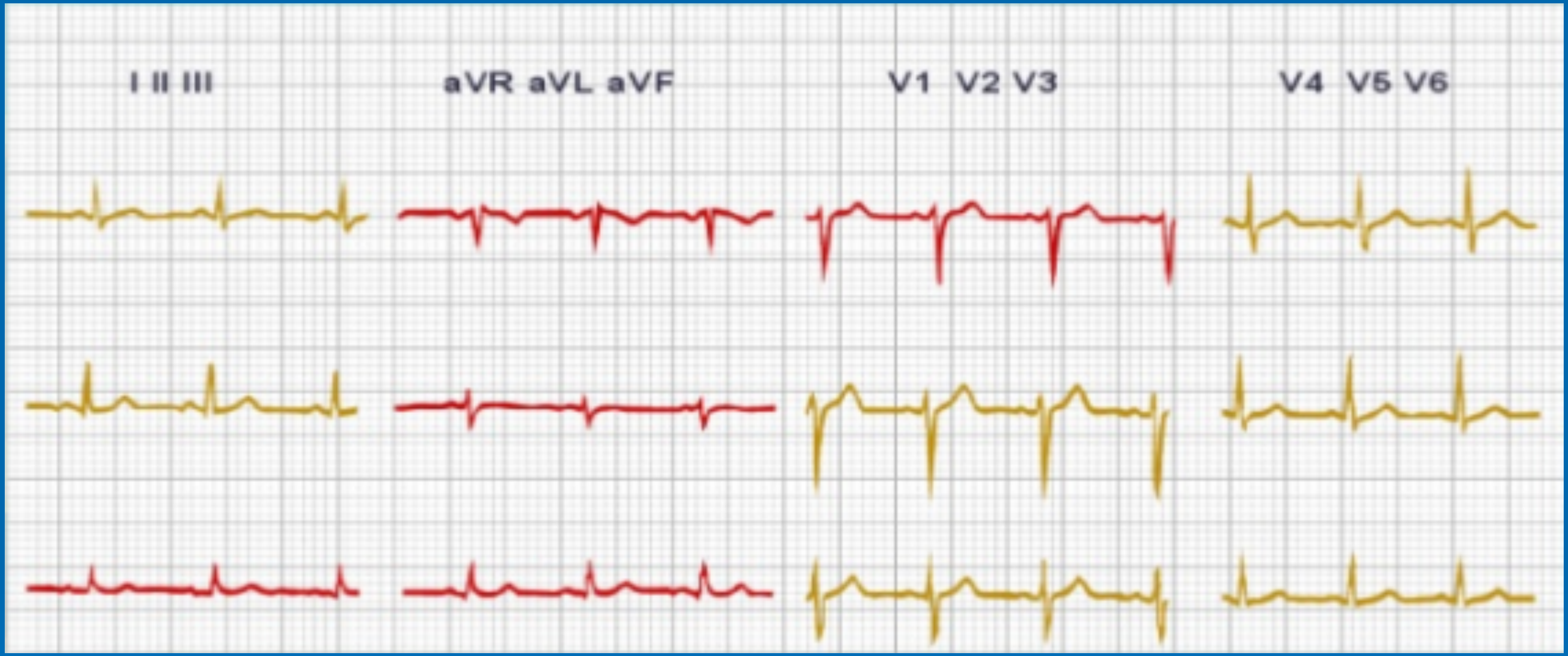
The P waves should be upright in I, II, and V2 to V6 .

Rule 9

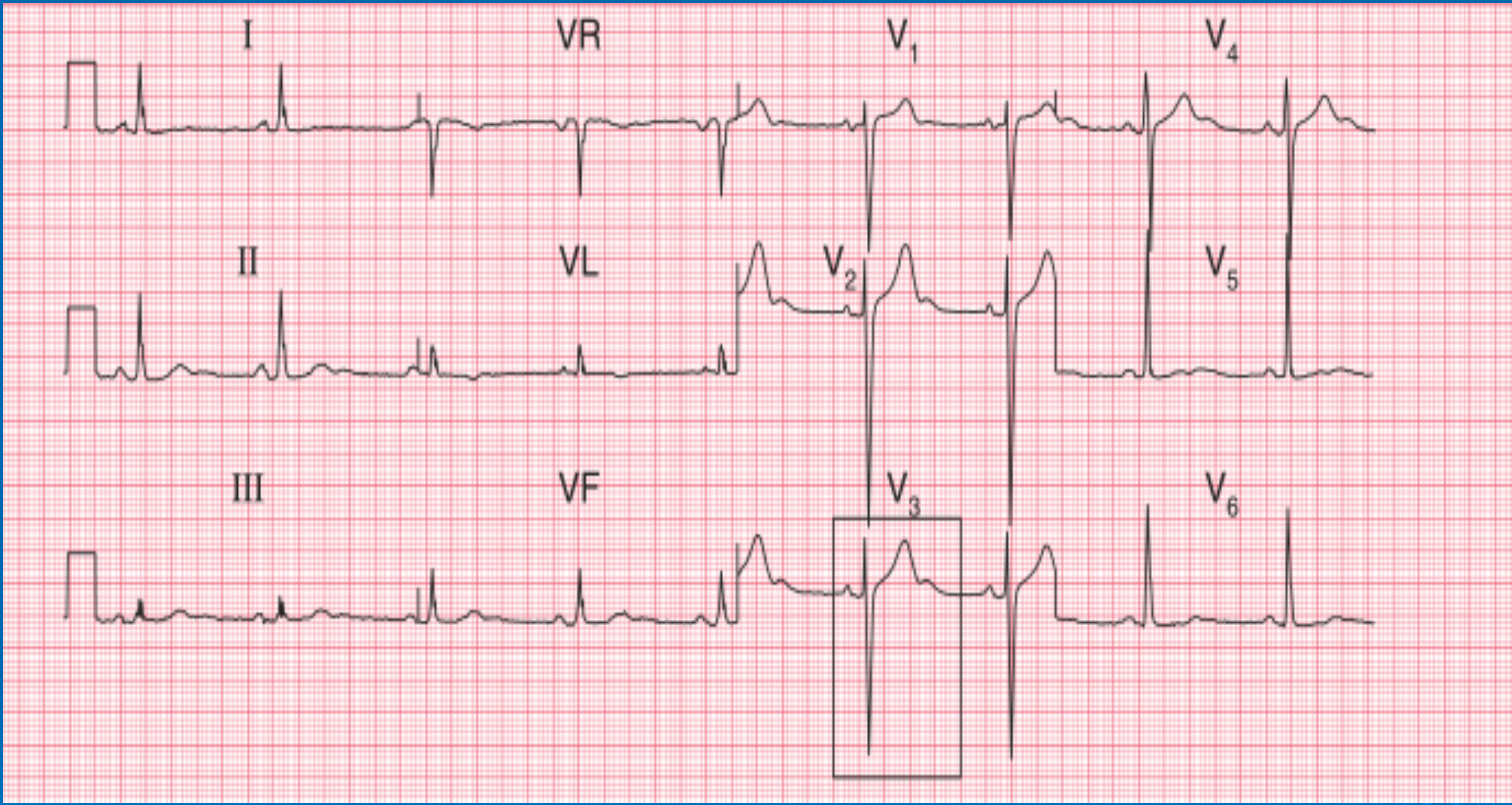


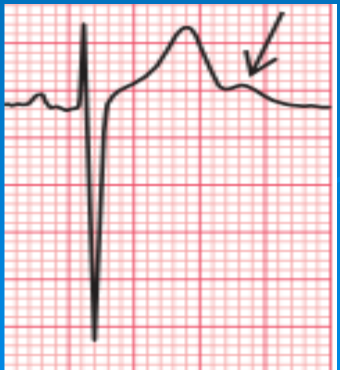
There should be no Q wave or only a small q less than 0.04 seconds in width in I, II, V2 to V6.

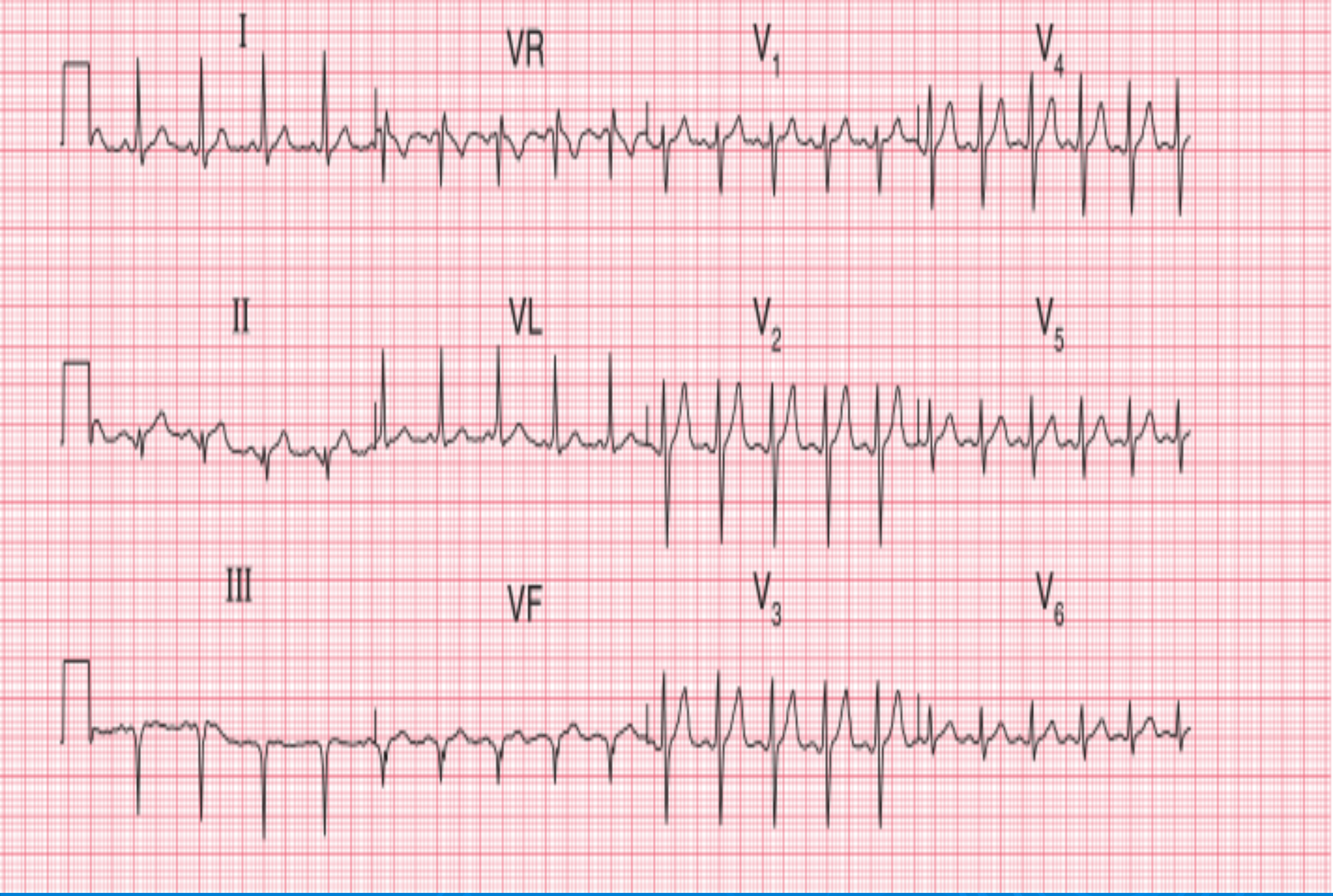
Rule 10

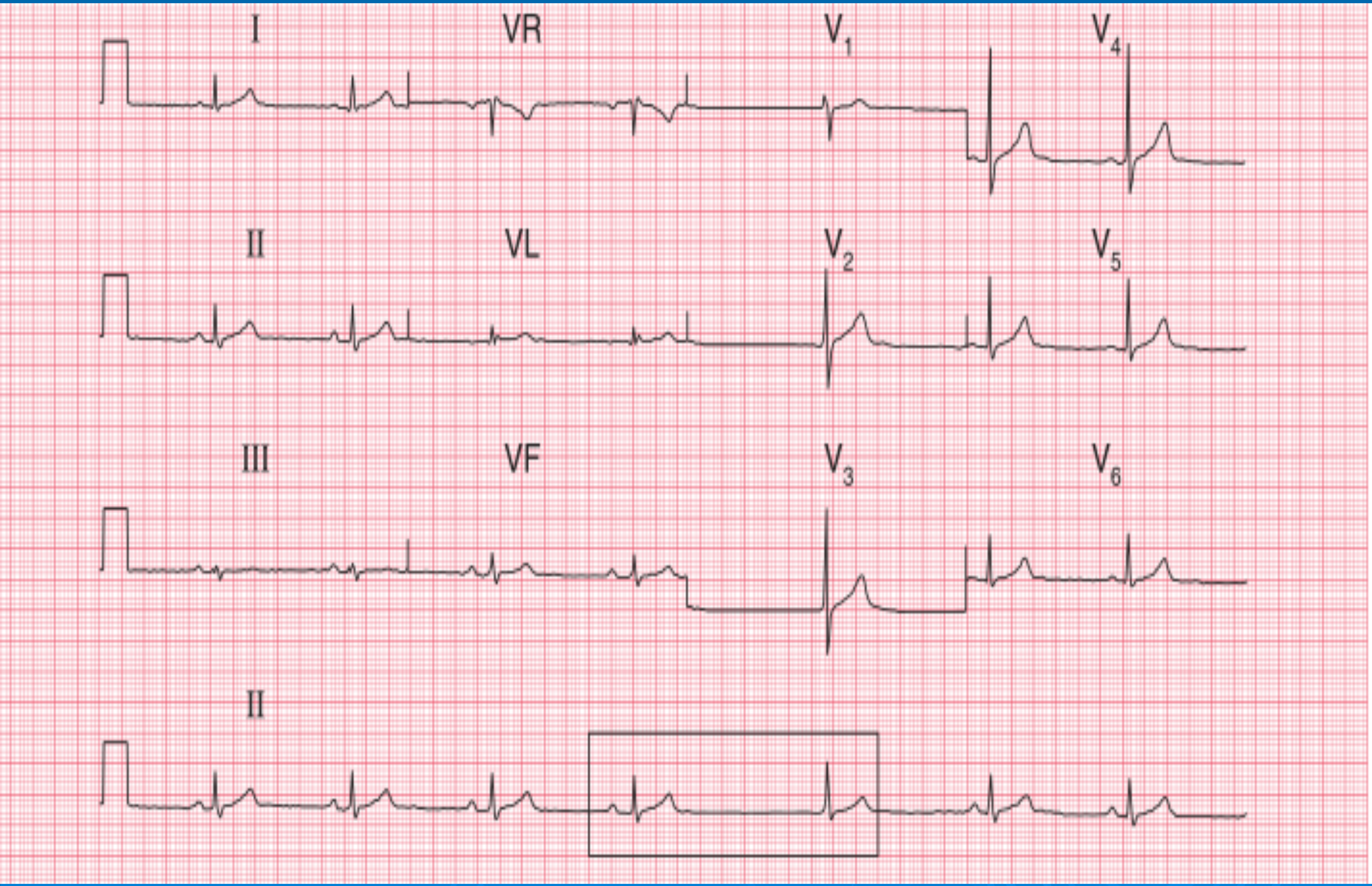


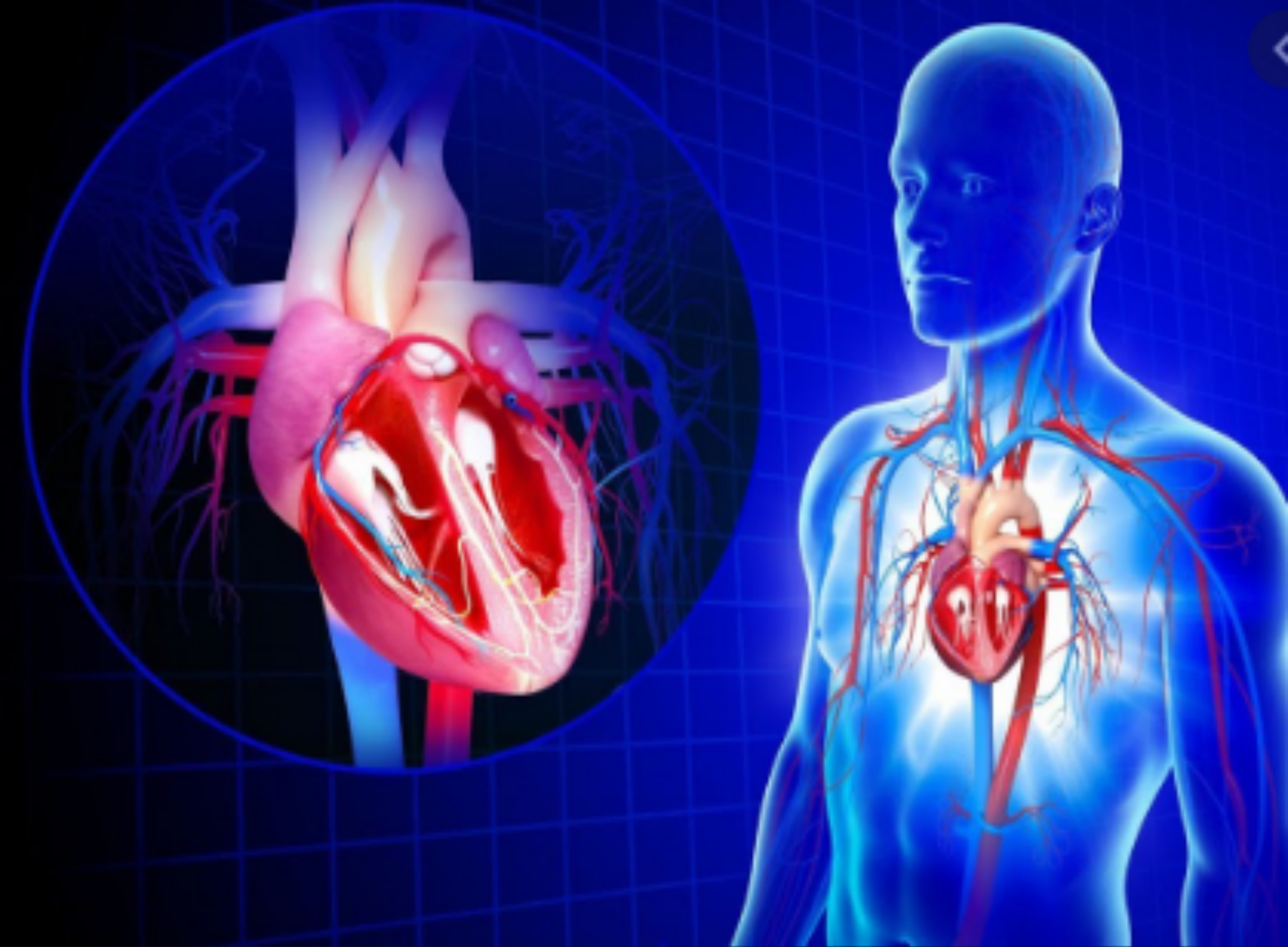
The T wave must be upright in I, II, V2 to V6 .


I
VR
V1
V4
II
VL
V2
V5
III
VF
V3
V6




I
VR
V1
V4
II
VL
V2
V5
III
VF
V3
V6


I
VR
V1
V4
II
VL
V2
V5
III
VF
V3
V6
II



THANK YOU