Basic ECG learning (part 1)

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Cardiac Cycle

Cardiac Cycle: the electrical, pressure and volume changes that occur in a functional heart between successive heart beats.

- Phase of the cardiac cycle when myocardium is relaxed is termed ***diastole***.
- Phase of the cardiac cycle when the myocardium contracts is termed ***systole***.
  - ***Atrial systole***: when atria contract.
  - ***Ventricular systole***: when ventricles contract.

How many beat per day?

- 75*60=4500
- 4500*24=108000!

Cardiac Cycle

- Electrical changes in heart tissue cause mechanical changes, i.e. muscle contraction.

The ECG

"The ECG (*electrocardiogram*) is a transthoracic interpretation of the electrical activity of the heart."

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Electrocardiography

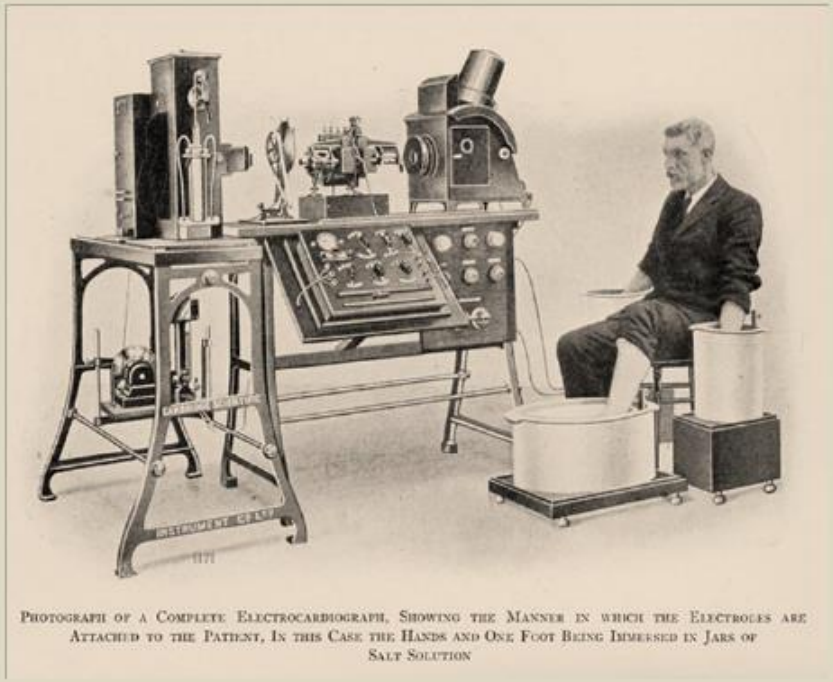
- Two common abbreviations for electrocardiogram: EKG and ECG.
- EKG comes from German language where cardiogram is written as kardiogram.
- The ECG records the electrical activity of the heart.
- Mechanical activity of the heart is sensed by echocardiography.

THE HISTORY OF ECG MACHINE

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

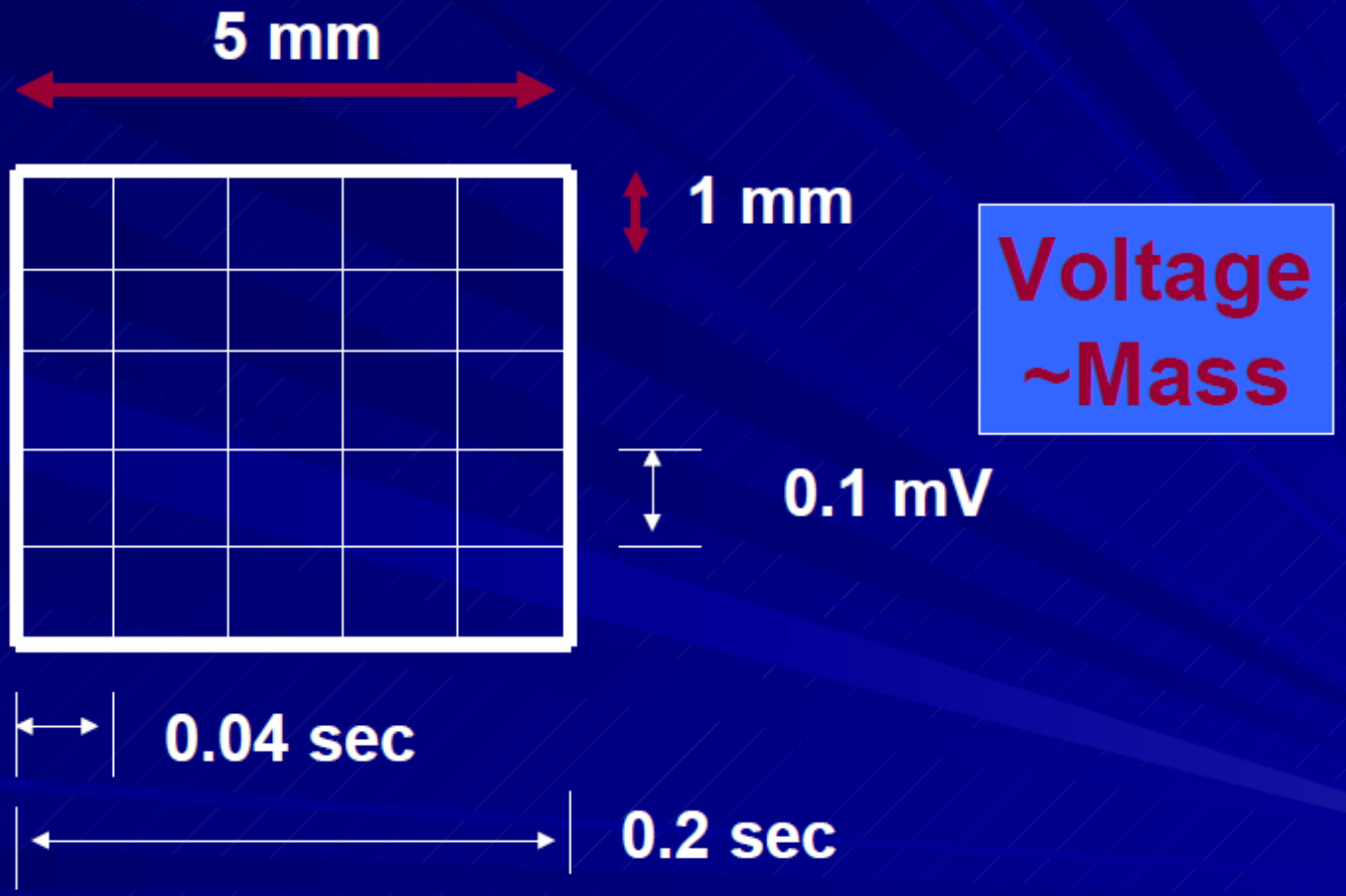
Modern ECG machine

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

Basics

- ECG graphs:
  - 1 mm squares
  - 5 mm squares
- Paper Speed:
  - 25 mm/sec standard
- Voltage Calibration:
  - 10 mm/mV standard

ECG Paper: Dimensions

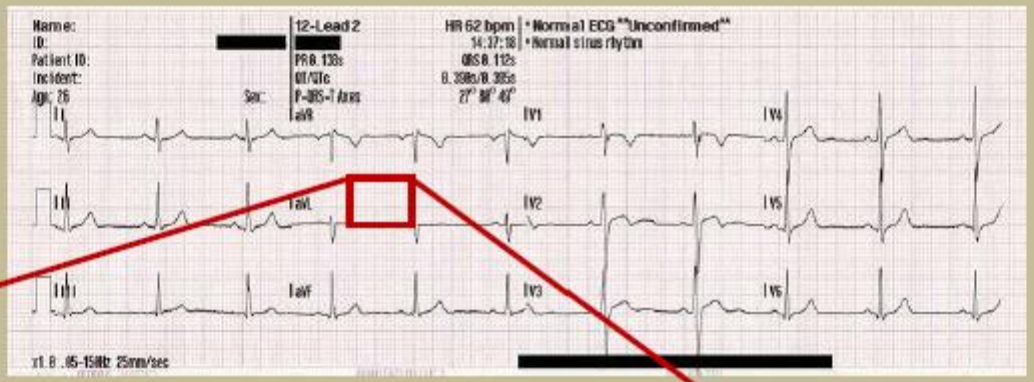


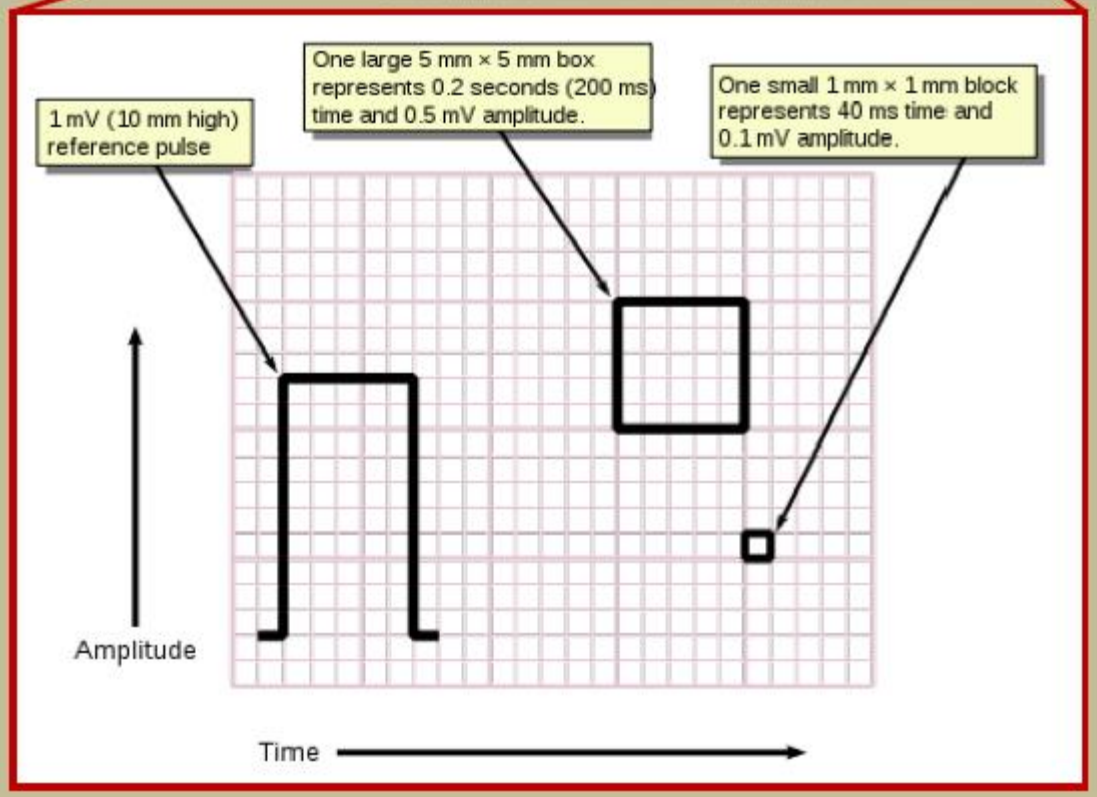
Voltage ~Mass

Speed = rate

The graph paper recording produced by the machine is termed an **electrocardiogram,**

It is usually called ECG or EKG





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 Leads

Leads are electrodes which measure the difference in electrical potential between either:

1. Two different points on the body (bipolar leads)

2. One point on the body and a virtual reference point with zero electrical potential, located in the center of the heart (unipolar leads)

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ECG Leads

The standard ECG has 12 leads:

3 Standard Limb Leads

3 Augmented Limb Leads

6 Precordial Leads

The axis of a particular lead represents the viewpoint from which it looks at the heart.

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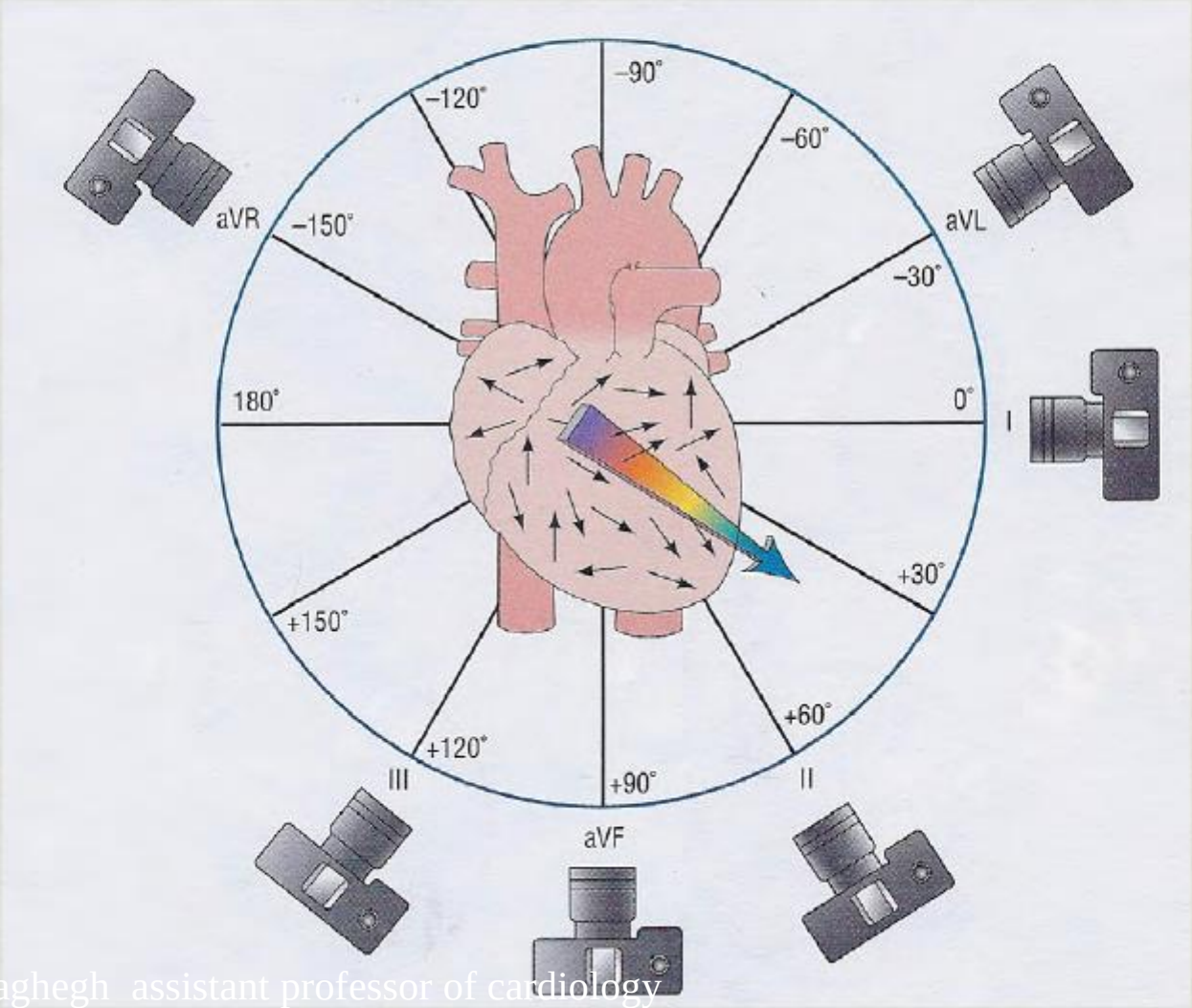
Axis



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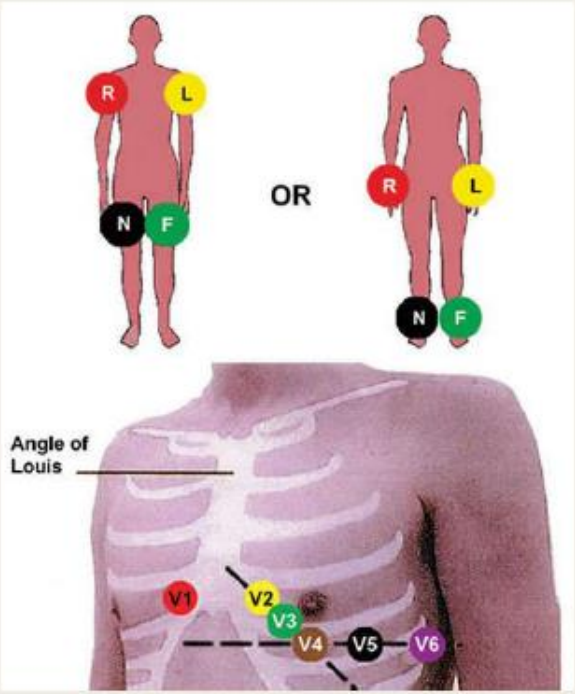
Electrodes

Usually consist of a conducting gel, embedded in the middle of a self-adhesive pad onto which cables clip. Ten electrodes are used for a 12-lead ECG.

Placement of electrodes

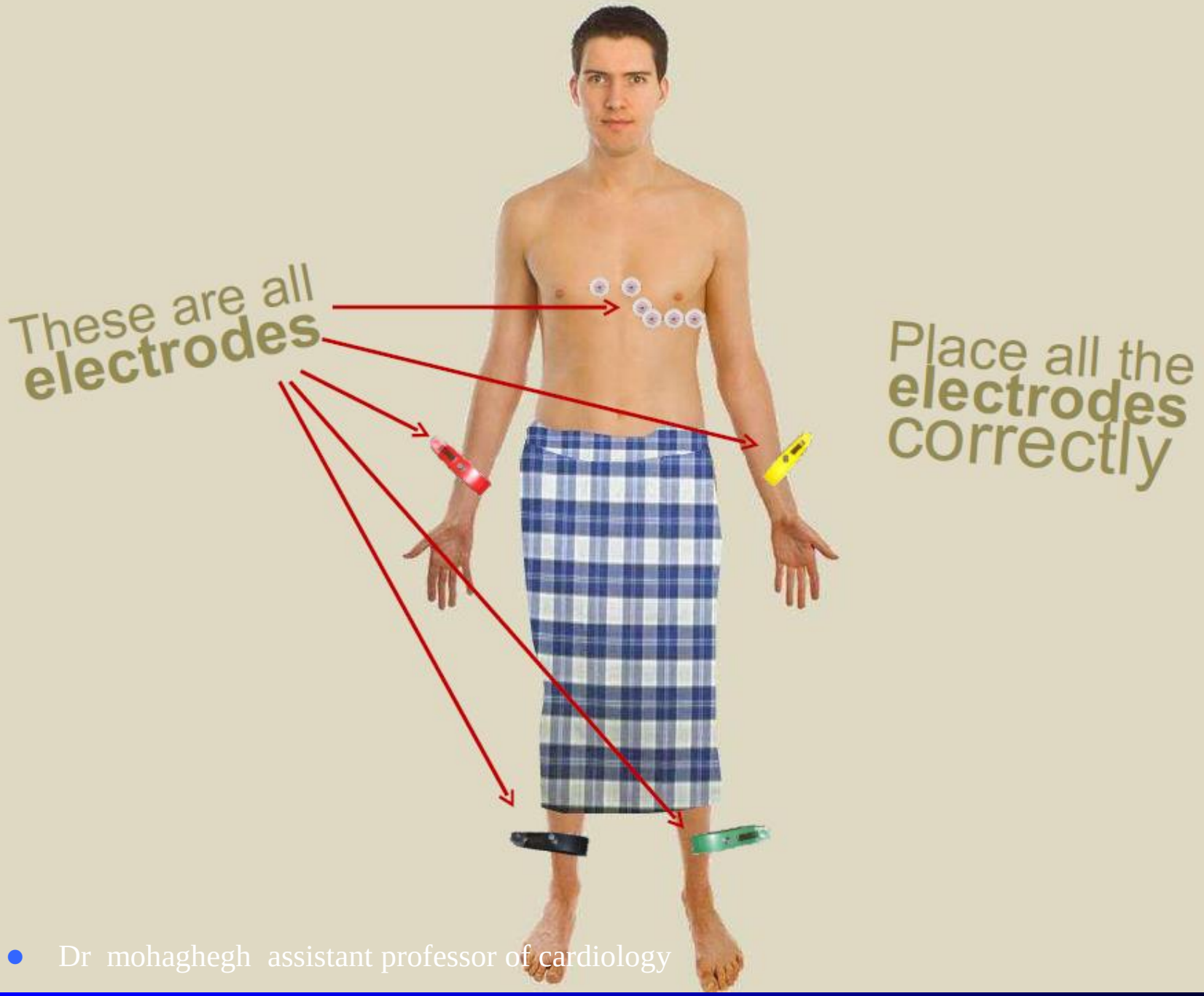


The limb electrodes

RA - On the right arm, avoiding thick muscle
LA – On the left arm this time.
RL - On the right leg, lateral calf muscle
LL- On the left leg this time.

The 6 chest electrodes

V1 - Fourth intercostal space, right sternal border.
V2 - Fourth intercostal space, left sternal border.
V3 - Midway between V2 and V4.
V4 - Fifth intercostal space, left midclavicular line.
V5 - Level with V4, left anterior axillary line.
V6 - Level with V4, left mid axillary line.



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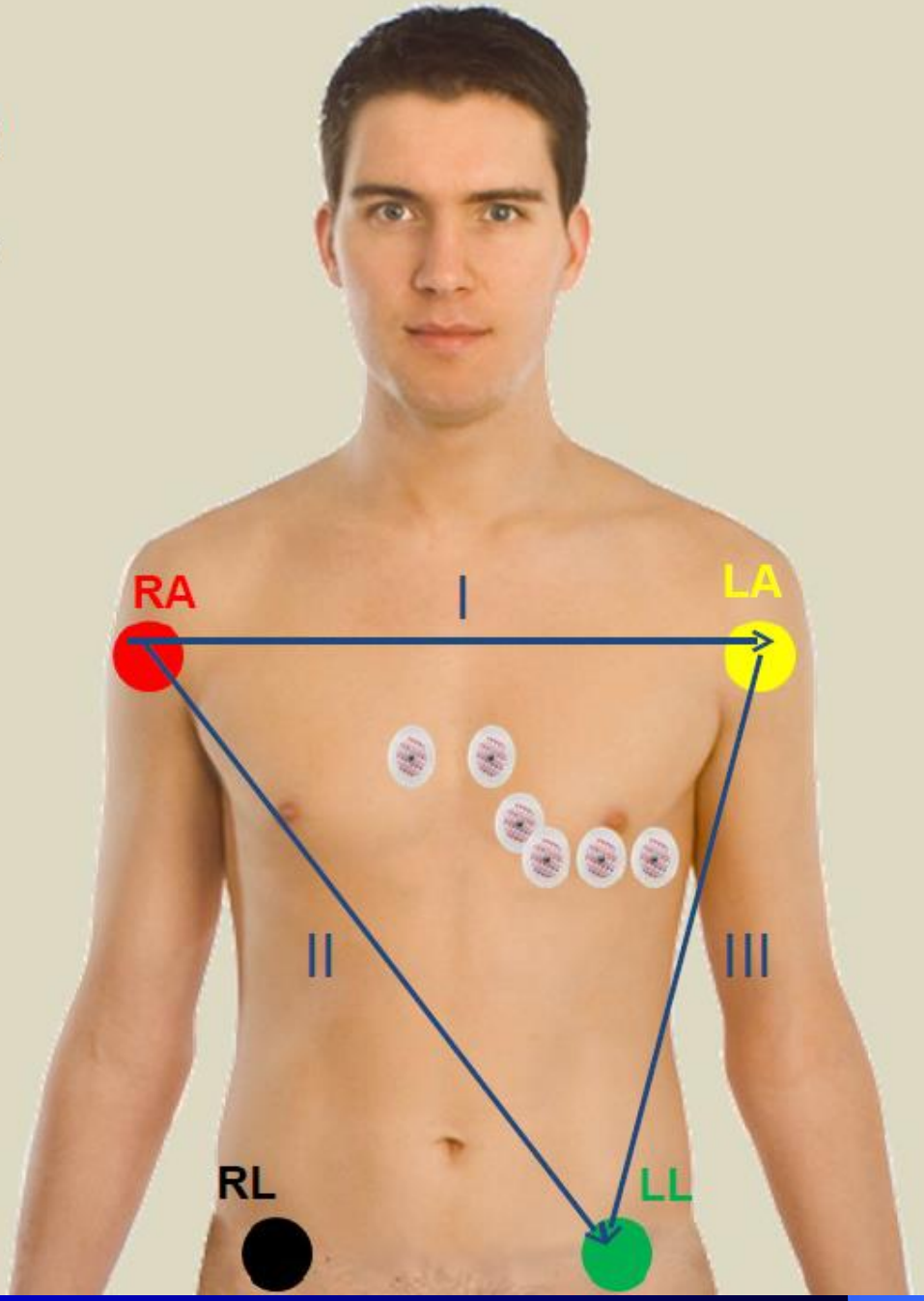
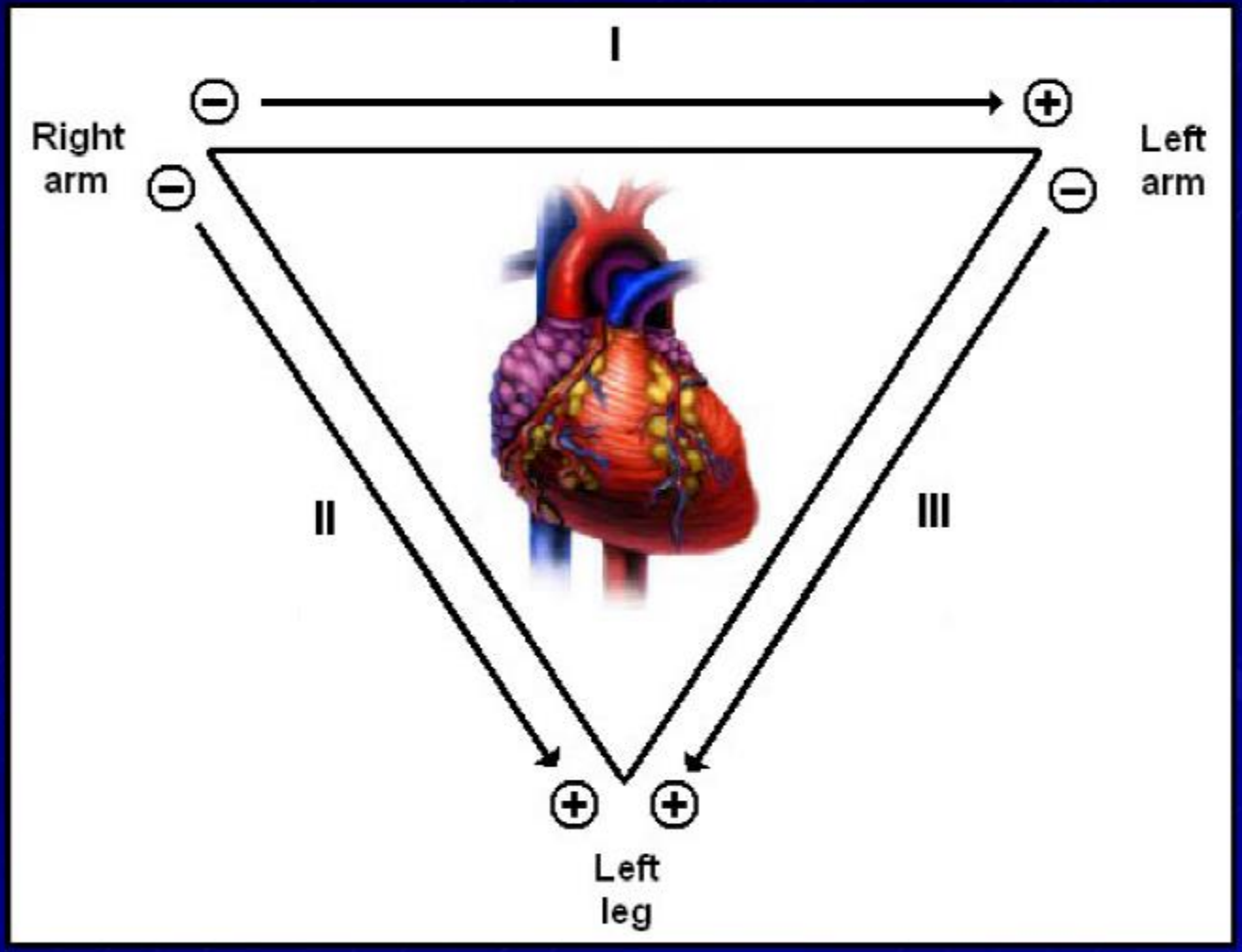
LEADS I, II, III

THEY ARE FORMED BY VOLTAGE TRACINGS BETWEEN THE LIMB ELECTRODES (RA, LA, RL AND LL). THESE ARE THE ONLY BIPOLAR LEADS. ALL TOGETHER THEY ARE CALLED THE **LIMB LEADS** OR

THE EINTHOVEN'S TRIANGLE



Standard Limb Leads



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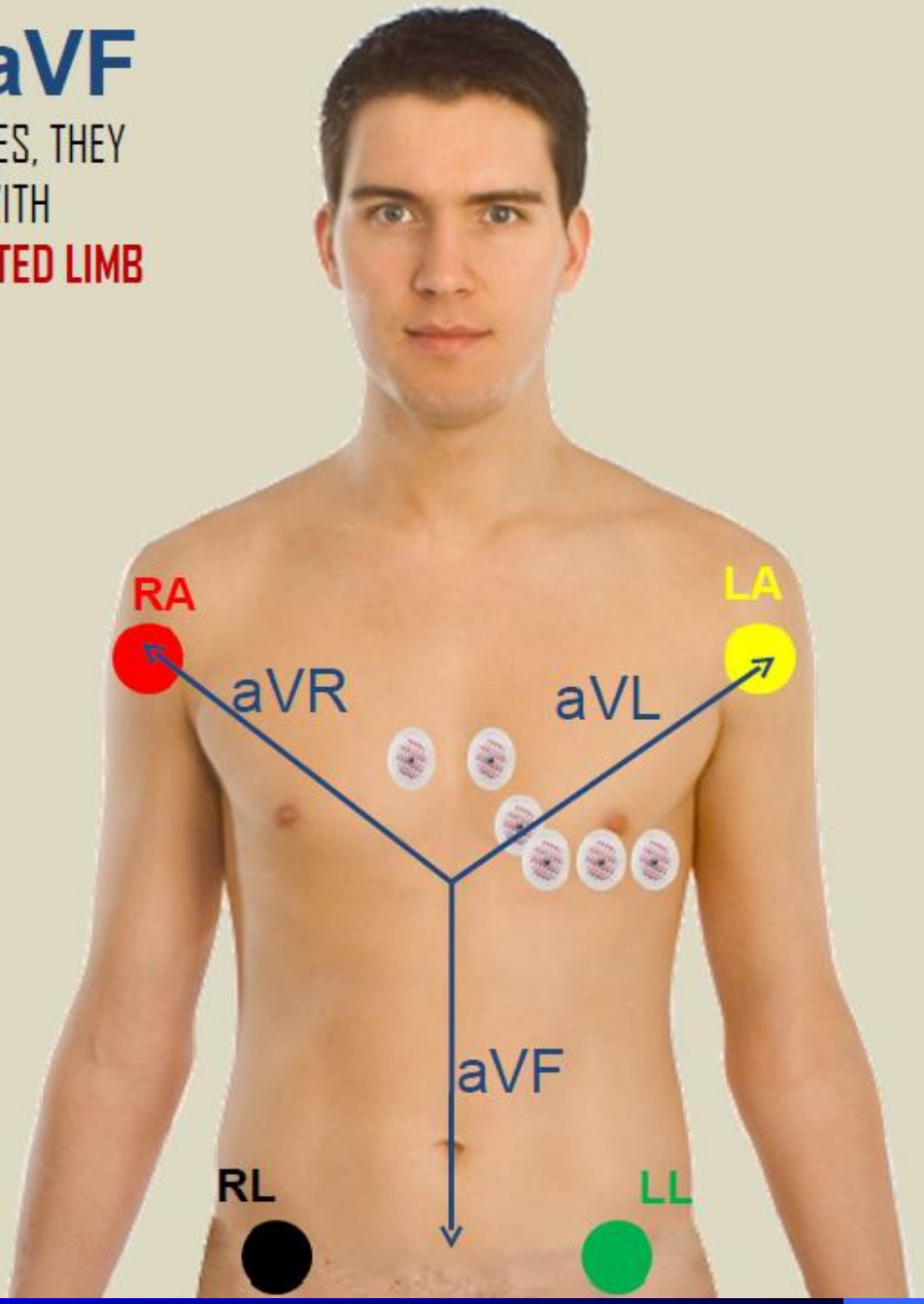
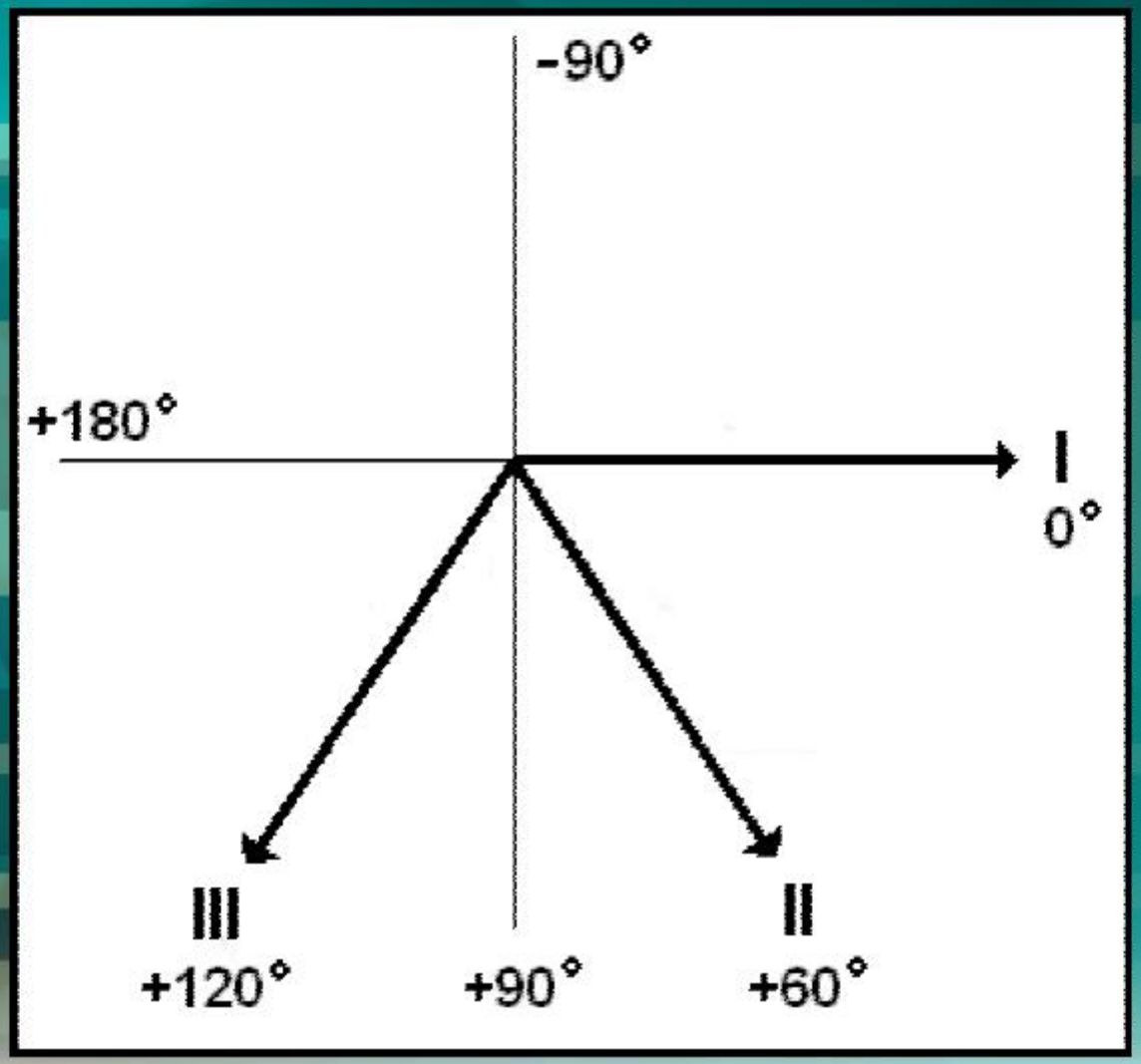
LEADS aVR, aVL, aVF

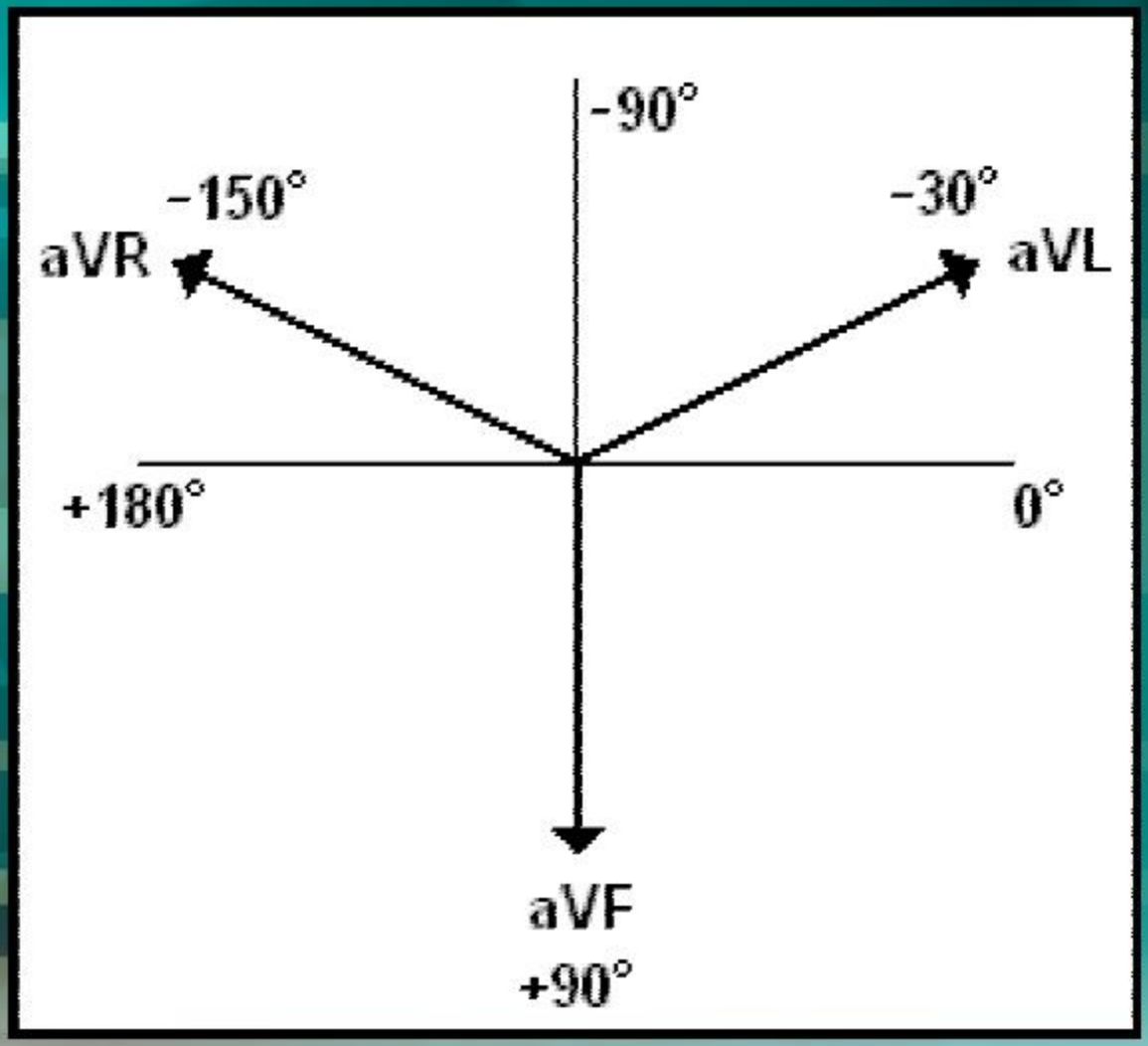
THEY ARE ALSO DERIVED FROM THE LIMB ELECTRODES, THEY MEASURE THE ELECTRIC POTENTIAL AT ONE POINT WITH RESPECT TO A NULL POINT. THEY ARE THE **AUGMENTED LIMB LEADS**



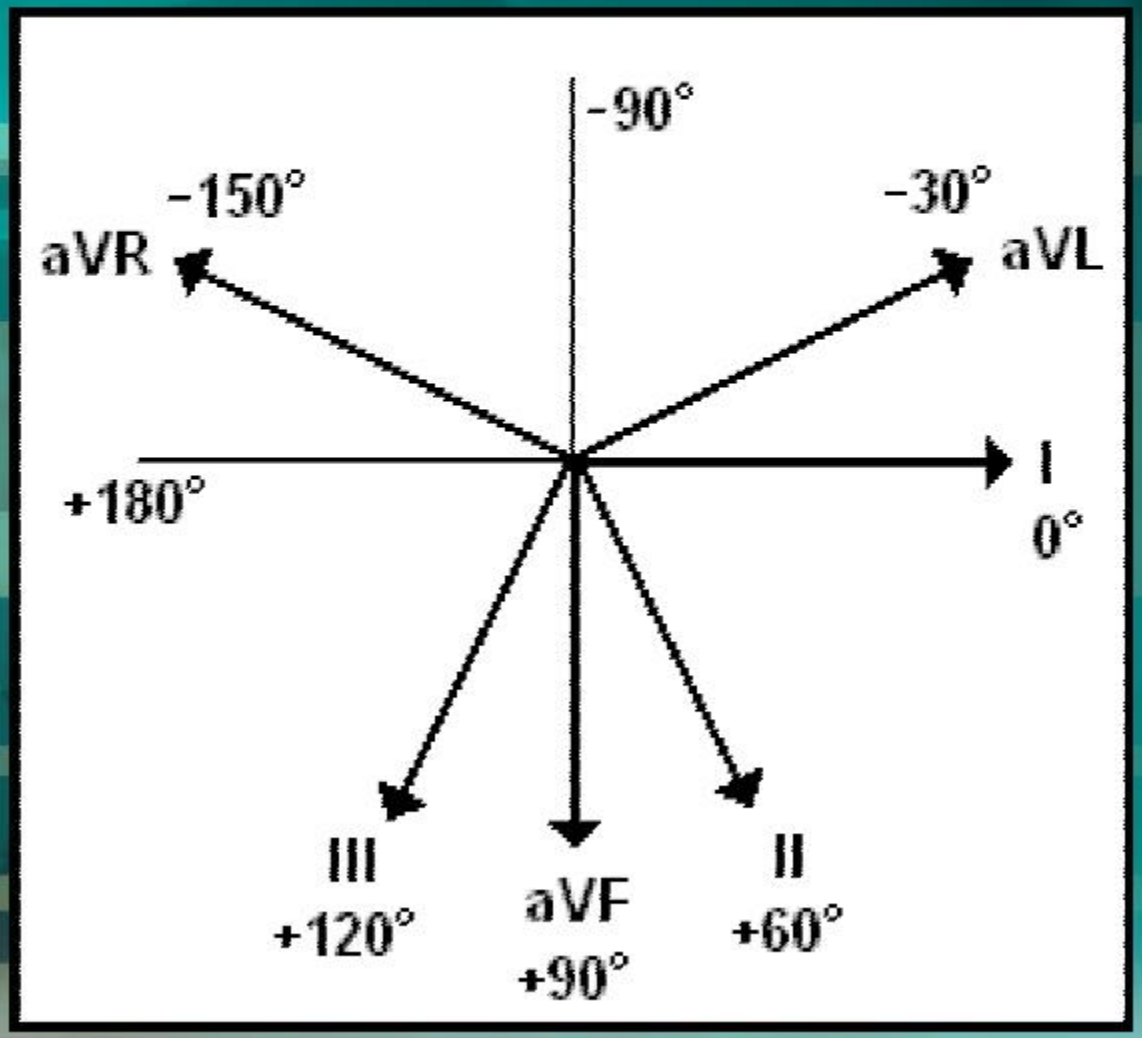
Standard Limb Leads



Augmented Limb Leads



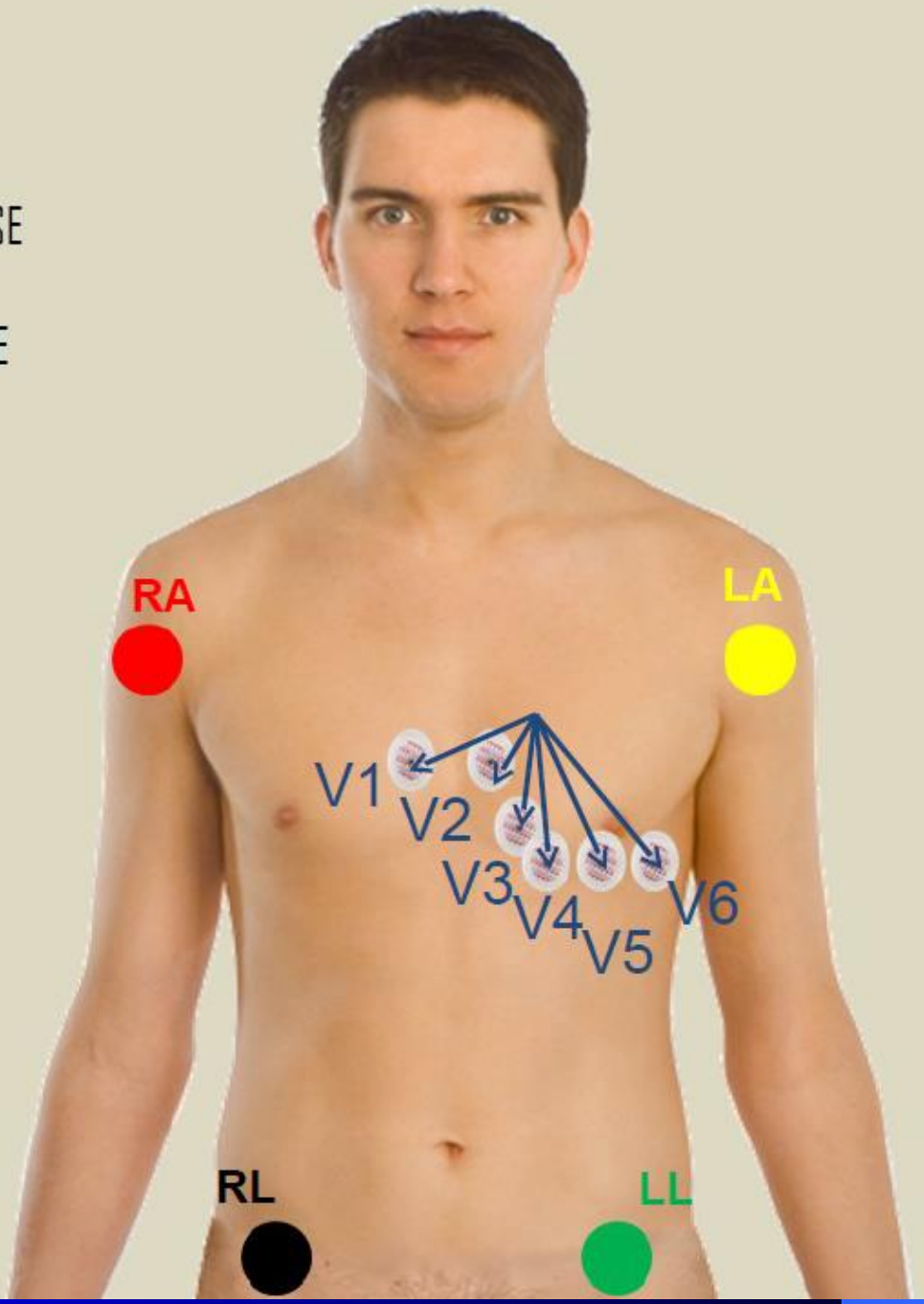
All Limb Leads



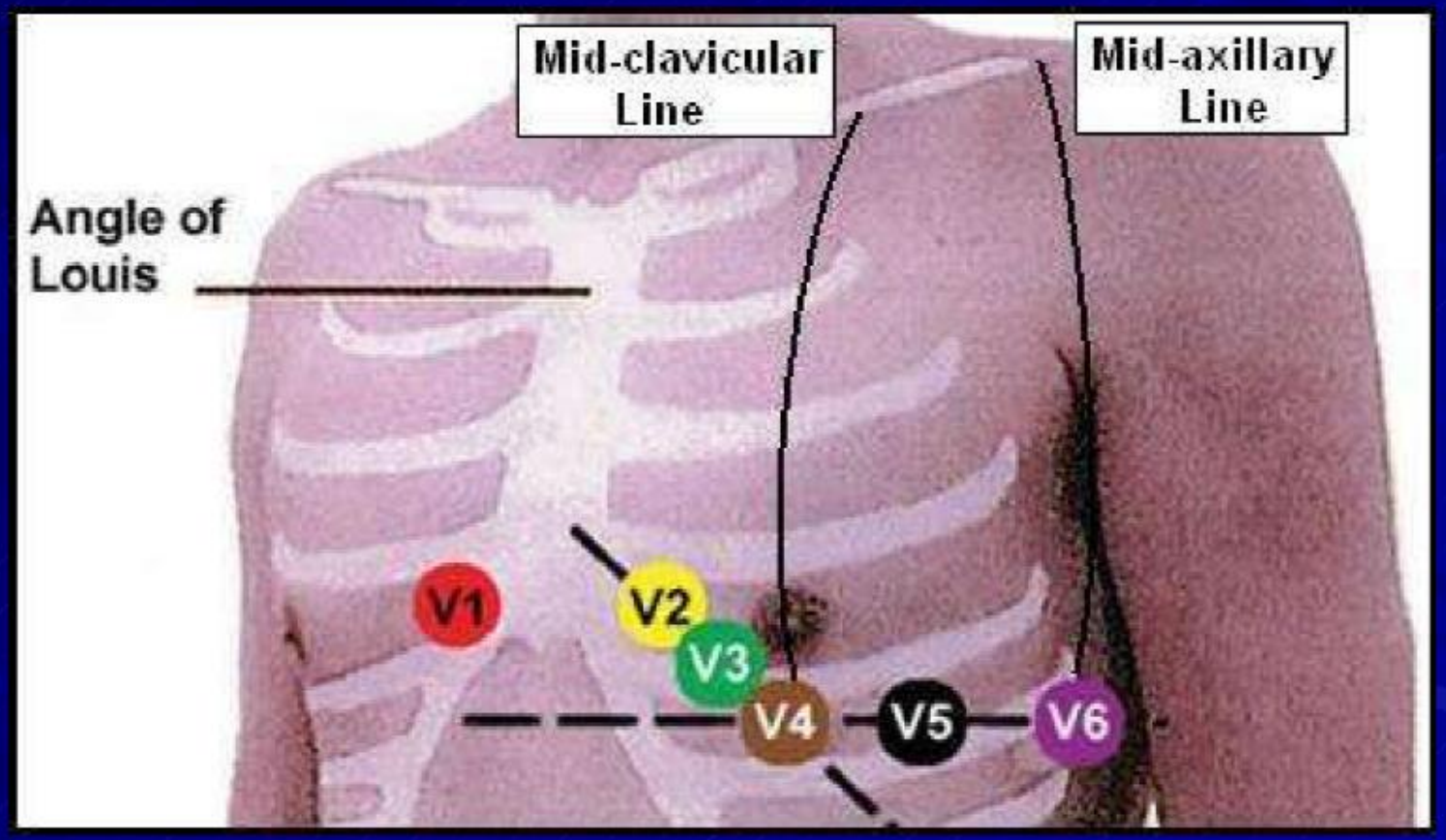
LEADS

V1,V2,V3,V4,V5,V6

THEY ARE PLACED DIRECTLY ON THE CHEST. BECAUSE OF THEIR CLOSE PROXIMITY OF THE HEART, THEY DO NOT REQUIRE AUGMENTATION. THEY ARE CALLED THE **PRECORDIAL LEADS**



Precordial Leads



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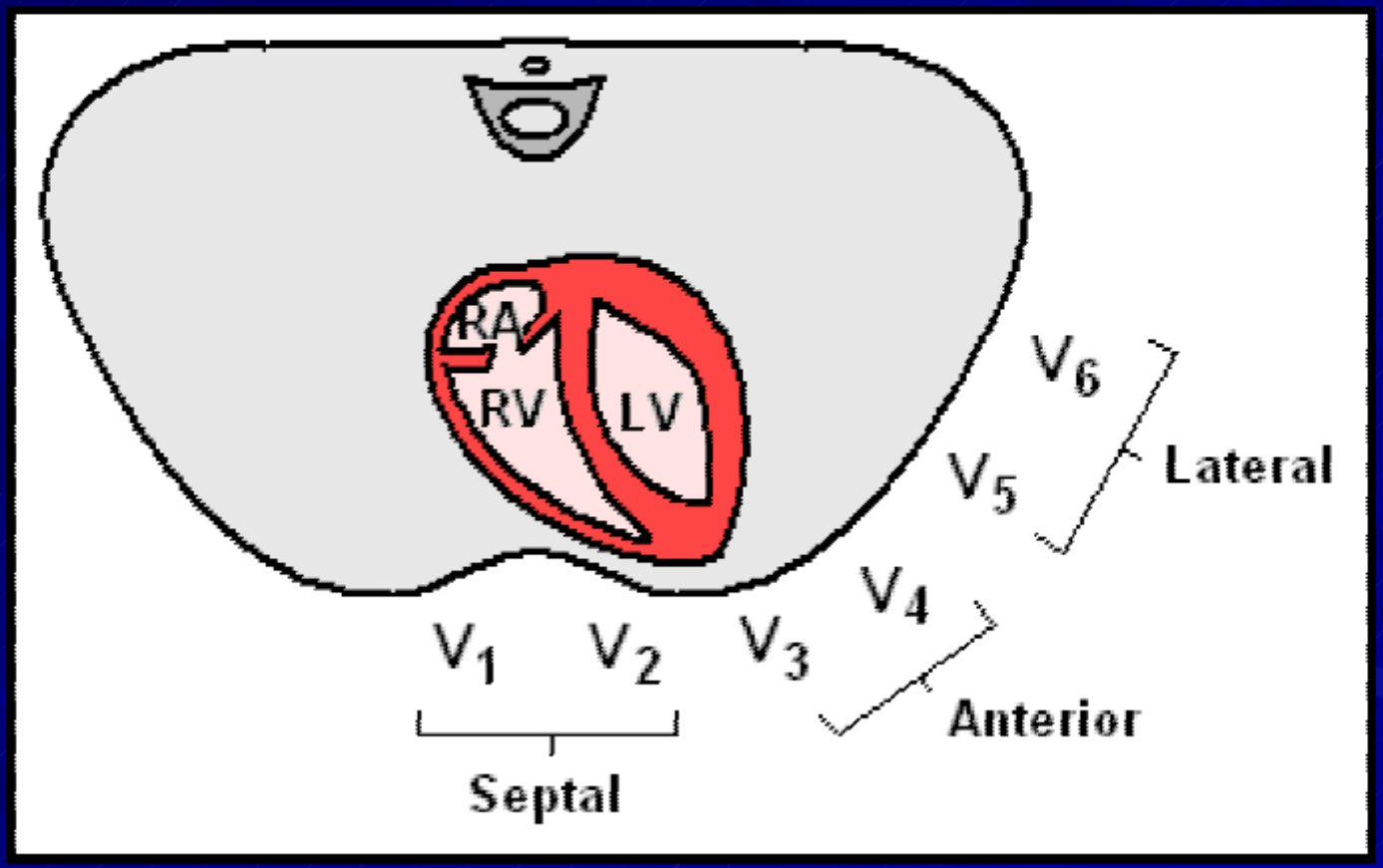
Precordial Leads



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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

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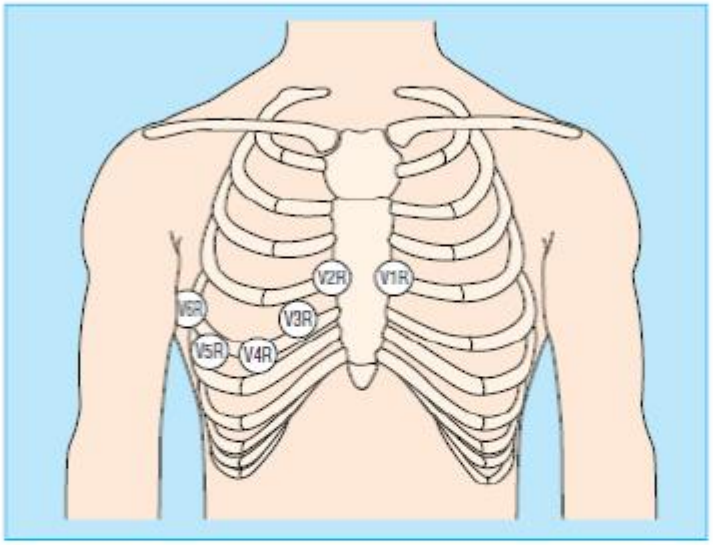
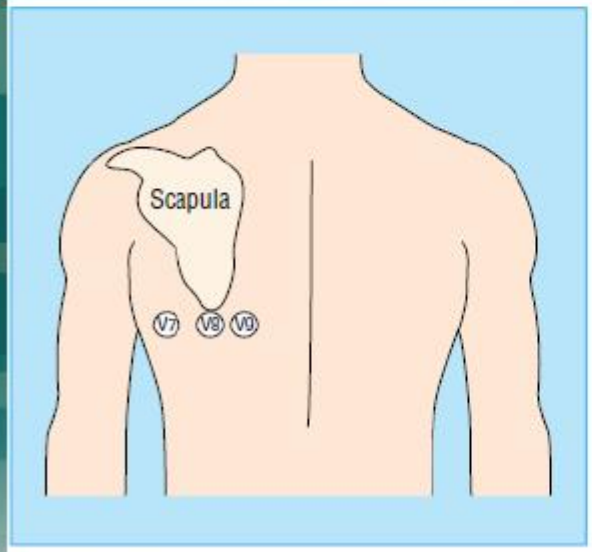
Right Sided & Posterior Chest Leads



Placement of right sided chest leads



Position of V7, V8, and V9 on posterior chest wall

Arrangement of Leads on the EKG

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

Anatomic Groups
(Anterior 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
(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

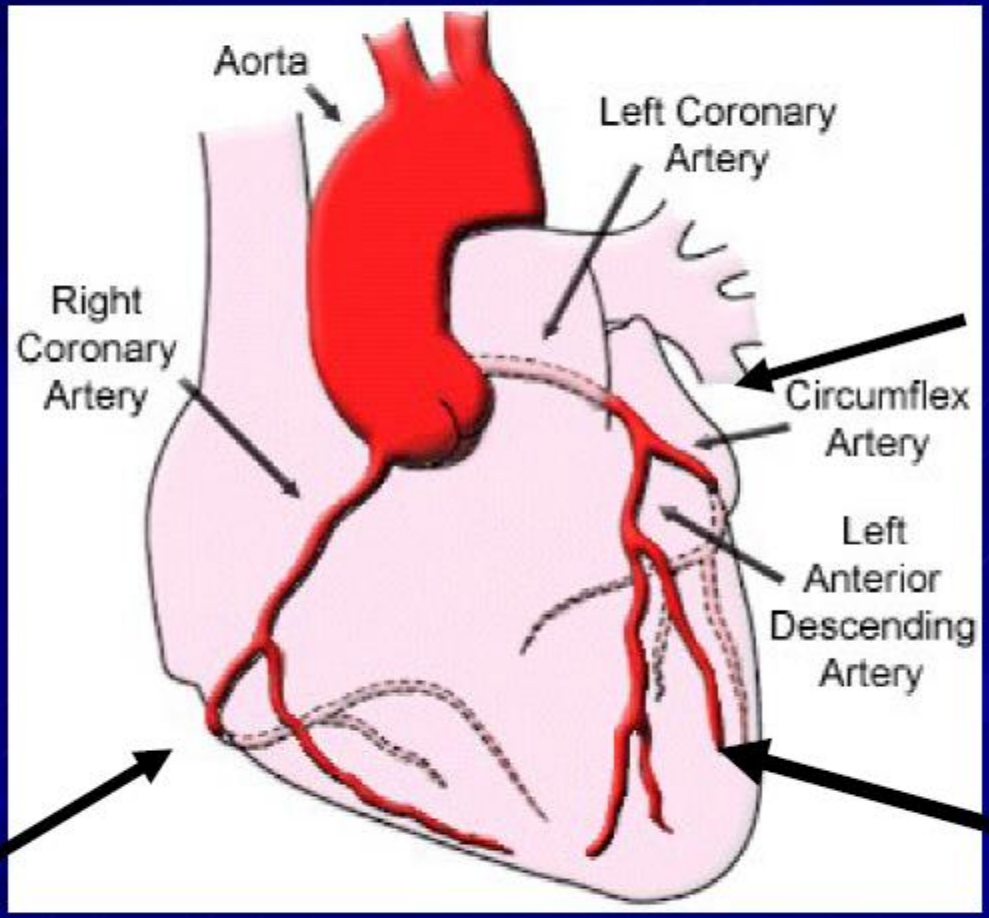
Anatomic Groups
(Inferior Wall)

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

Anatomic Groups
(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

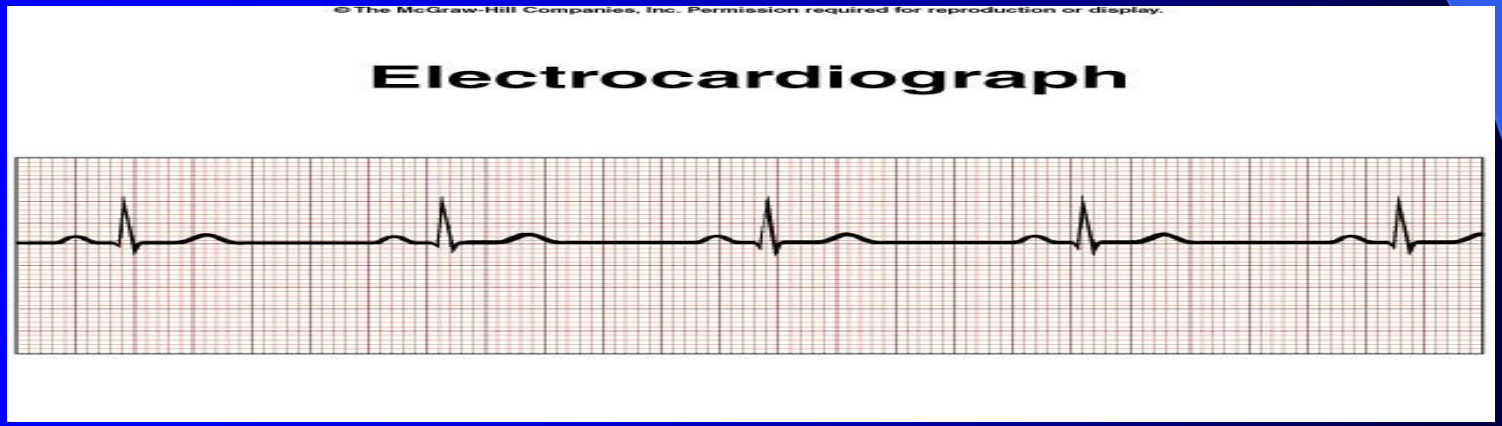
Anterior / Septal
V1-V4

Inferior
II, III, aVF

Electrocardiography

ECG - electrocardiogram

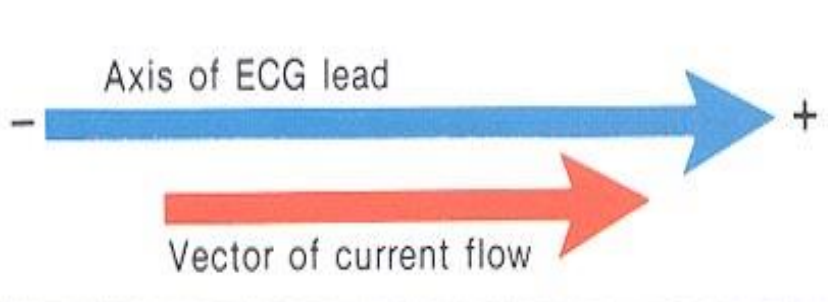
- graphic recording of electrical events

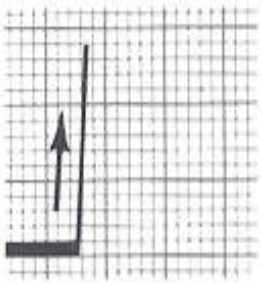


Electrophysiology

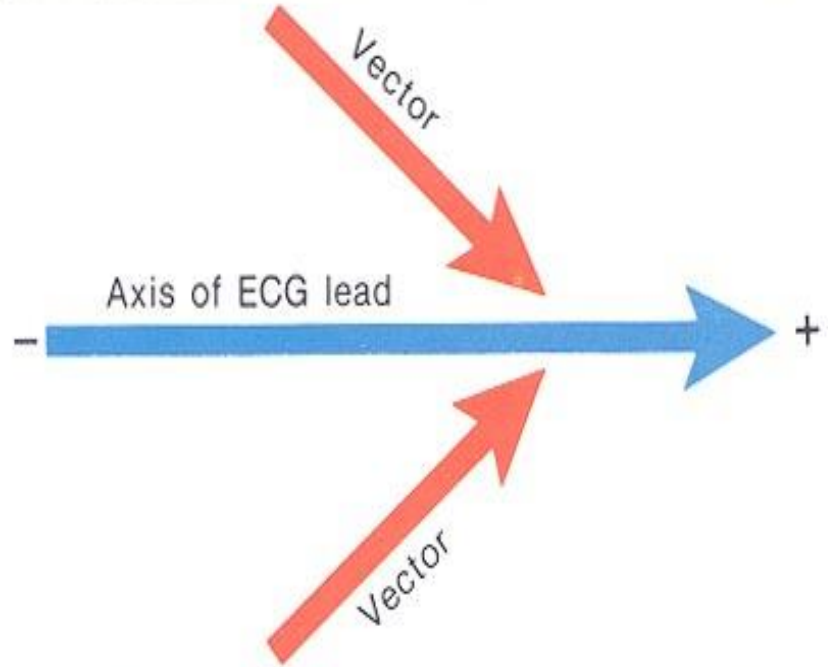
- If an electrode is placed so that wave of depolarization spreads toward the recording electrode, the ECG records a positive (upward) deflection.
- If wave of depolarization spreads away from recording electrode, a negative (downward) deflection occurs.

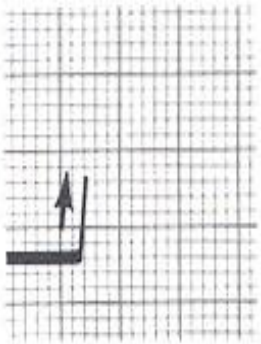
Electrophysiology





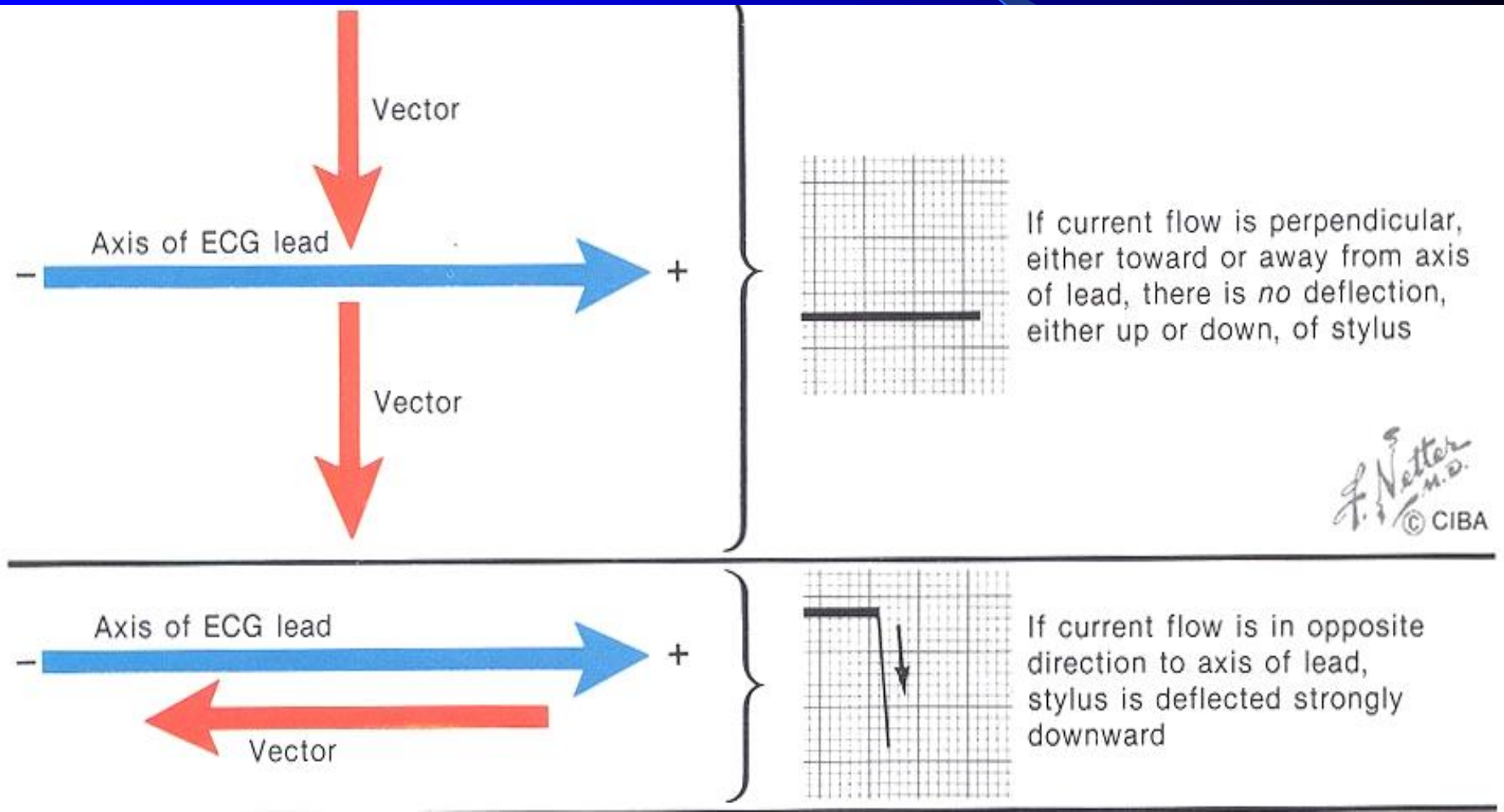
If current flows in same direction as axis of lead, ECG stylus is deflected strongly upward from baseline in that lead





If current flows obliquely to axis of lead, stylus is deflected less strongly upward, its height varying with angle that vector of current makes with axis

Electrophysiology



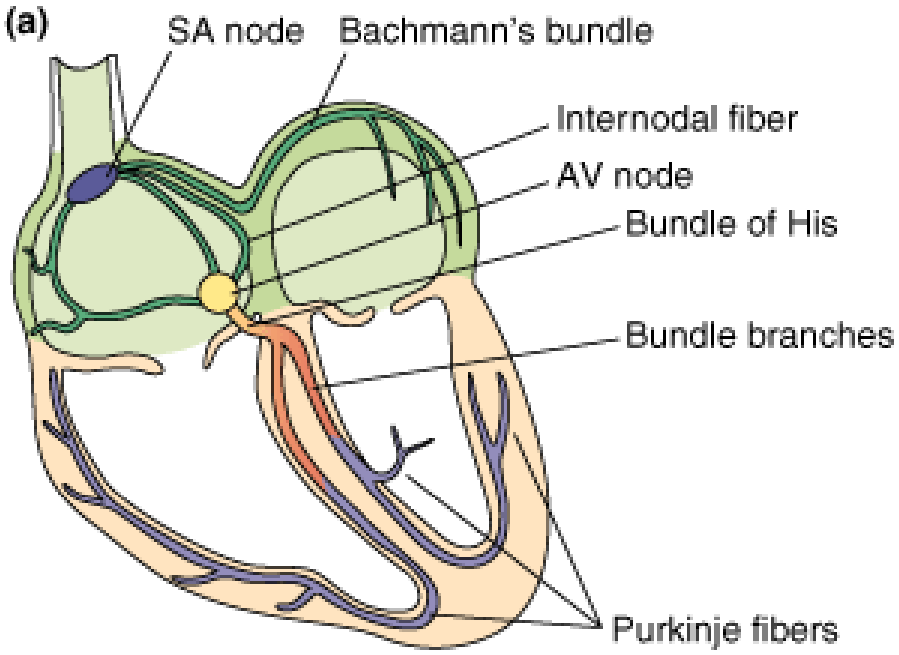
Electrophysiology

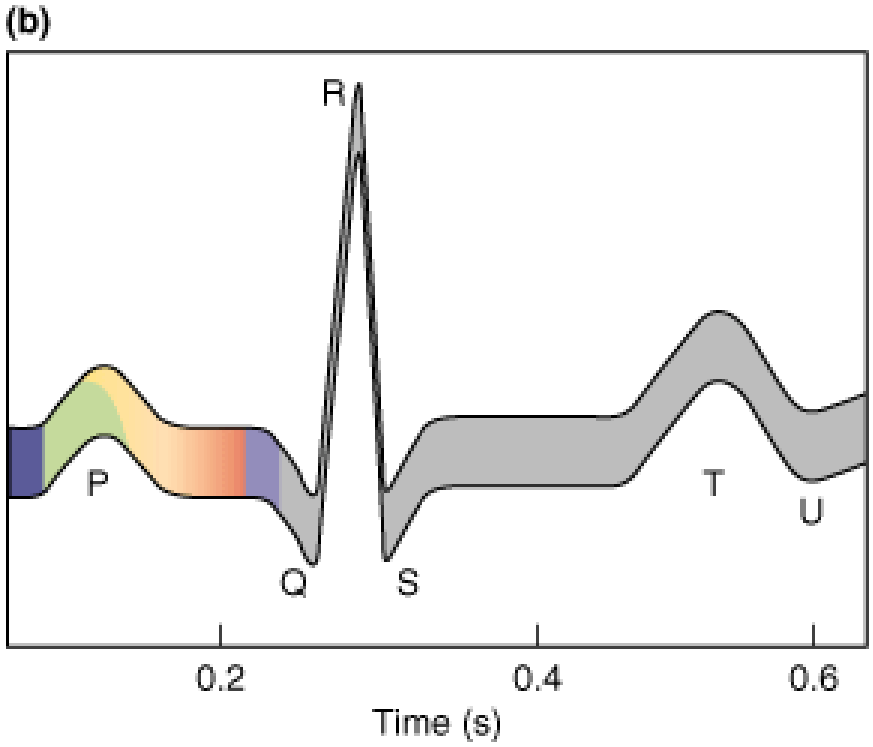
- When myocardial muscle is completely polarized or depolarized, the ECG will not record any electrical potential but rather a flat line, ***isoelectric line***.
- After depolarization, myocardial cells undergo repolarization to return to electrical state at rest.

Electrical Events of the Cardiac Cycle

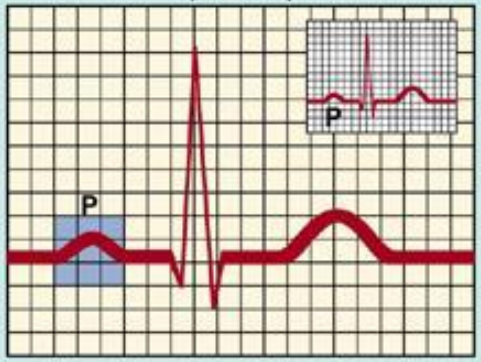
- Sinoatrial (SA) node is the normal pacemaker of heart and is located in right atrium.
- Depolarization spreads from SA node across atria and results in the P wave.
- Three tracts within atria conduct depolarization to atrioventricular (AV) node.
  - Conduction slows in AV node to allow atria to empty blood into ventricles before vent. systole.
- Bundle of His connects AV to bundle branches.
- Purkinje fibers are terminal bundle branches.

▶ Conduction System of the Heart



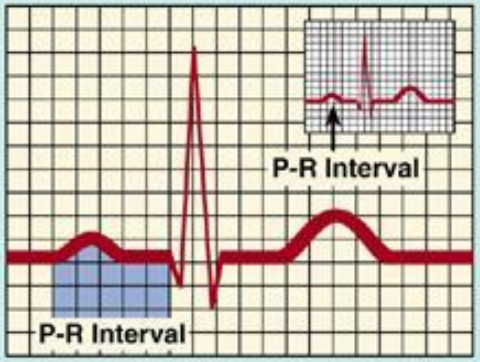


Atrial Depolarization (P-wave)



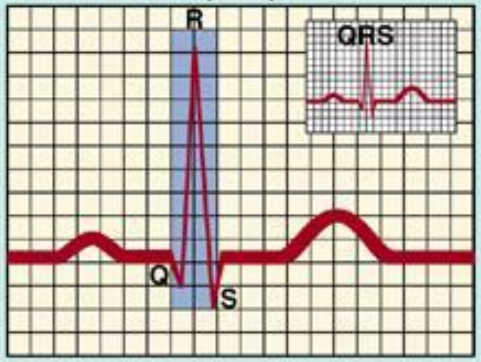
The depolarization of both atria is represented by the P-wave. The P-wave is the first ECG deflection.

P-R Interval



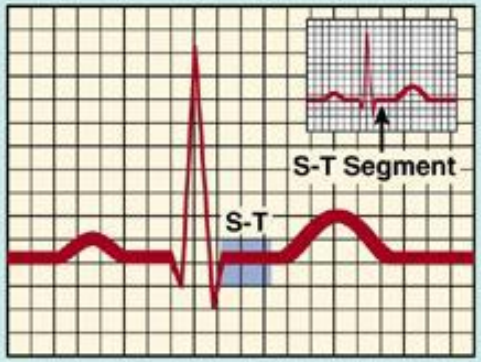
Electrical transmission from the atria to the venticles. Includes the P-wave and P-R Segment.

Ventricular Depolarization (QRS)



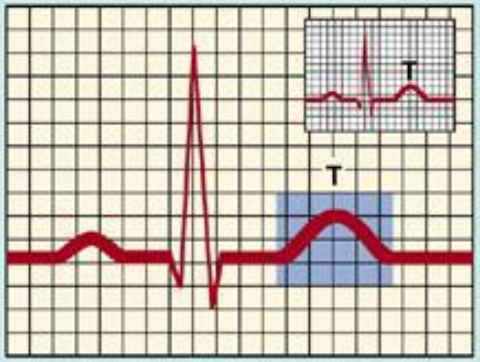
Ventricular depolarization is indicated by the QRS complex. The R-wave is the initial positive deflection; the negative deflection before the R-wave is the Q; the negative deflection after the R-wave is the S-wave.

Ventricular Repolarization (S-T Segment)



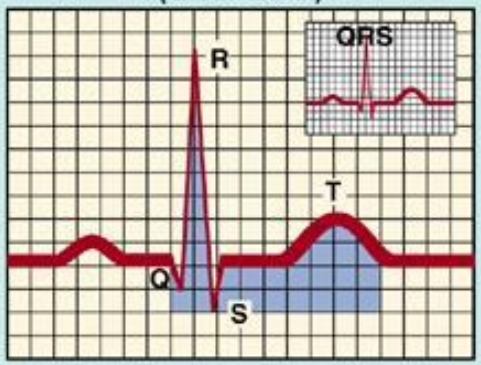
Earlier phase repolarization of both ventricles extends from the end of the QRS to the beginning of the T-wave. The point at which the S-T segment joins the QRS is known as the J (junction)-point.

Ventricular Repolarization (T-wave)



The repolarization of both ventricles is represented by the T-wave. The S-T segment and the T-wave are sensitive indicators of the oxygen demand-oxygen supply status of the ventricular myocardium.

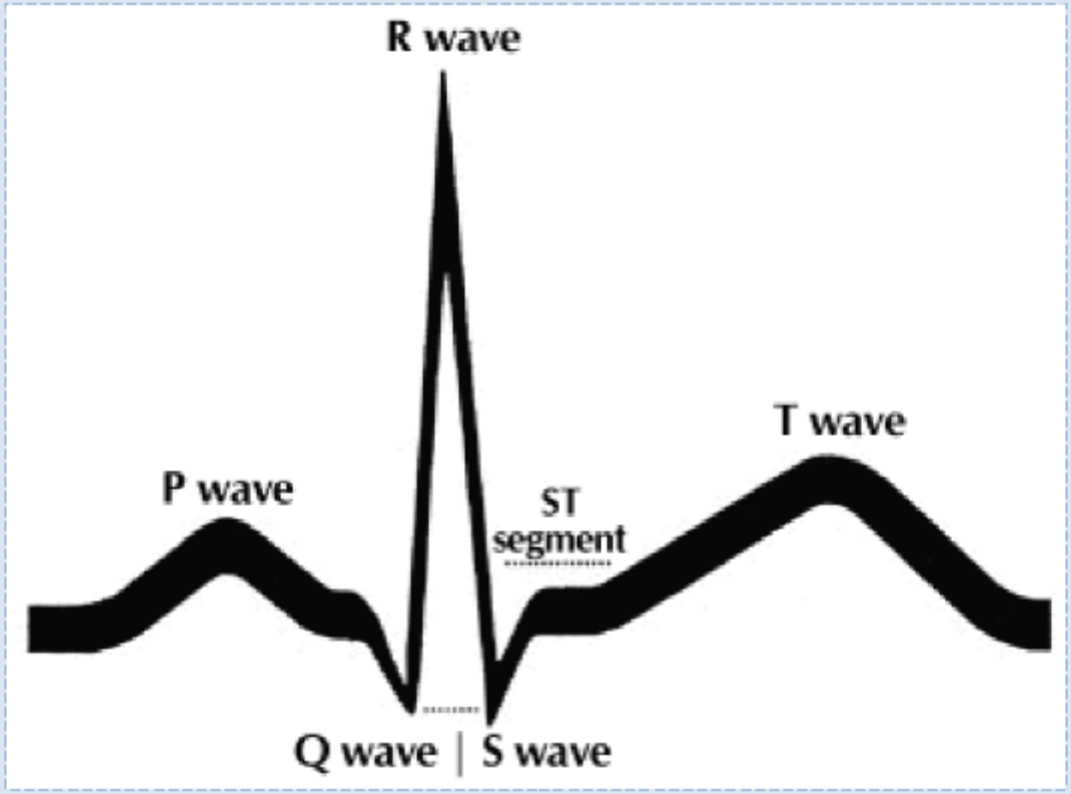
Ventricular Depolarization and Repolarization (Q-T Interval)



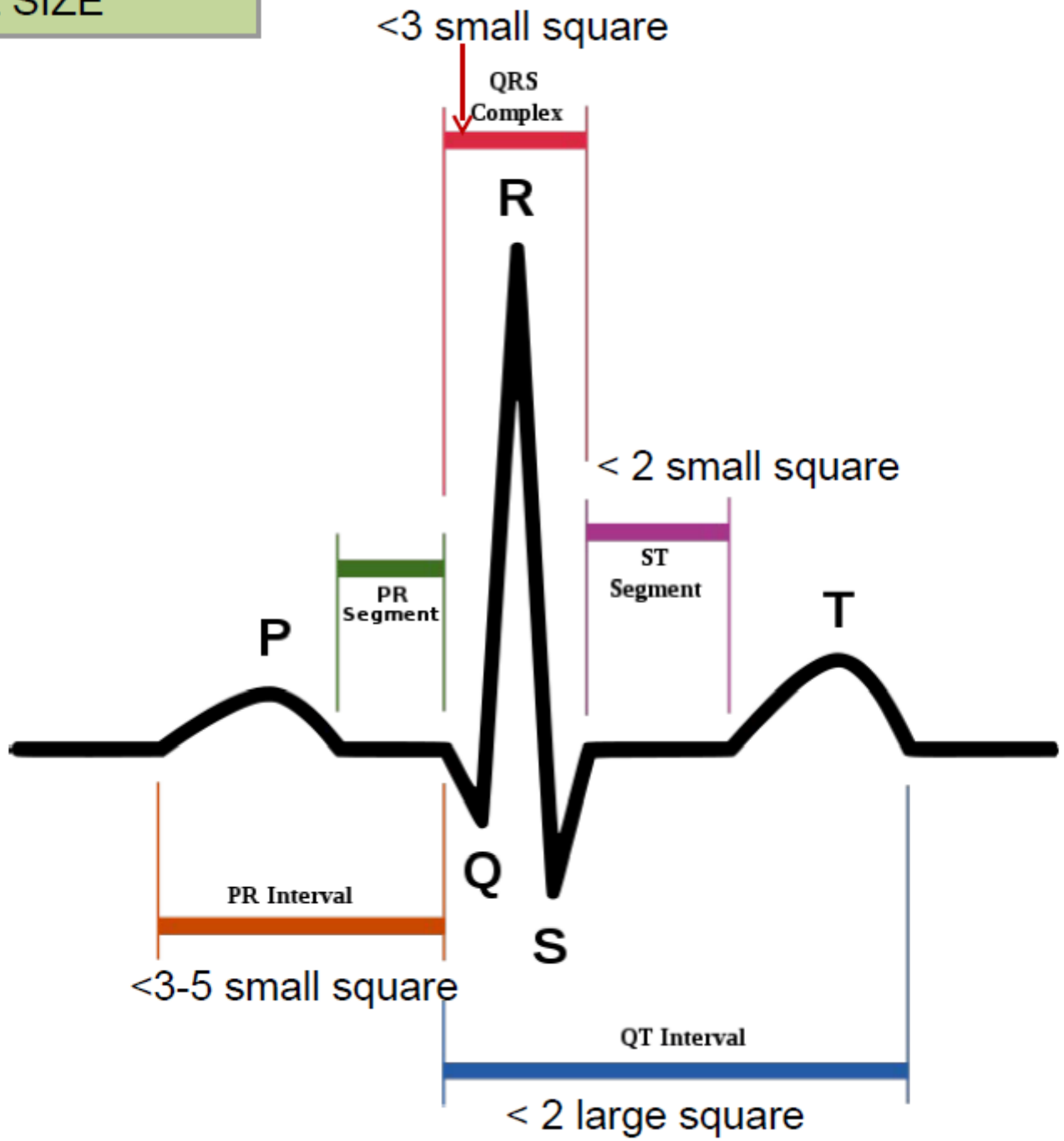
Includes the QRS complex, S-T segment, and T-wave.

A NORMAL ECG WAVE

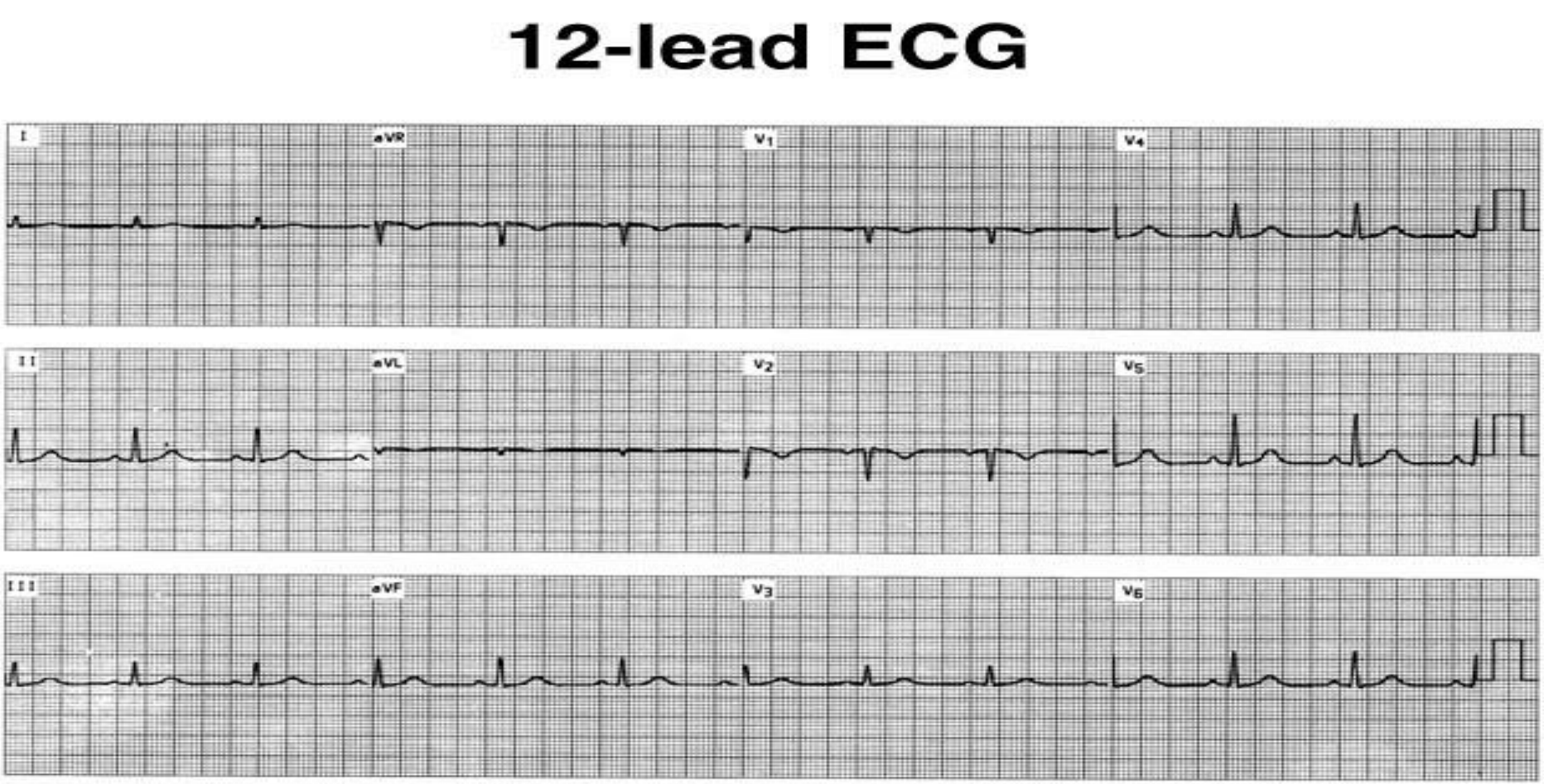
REMEMBER



THE NORMAL SIZE



12-Lead ECG Strip



Steps involved

- Heart Rate
- Rhythm
- Axis
- Wave morphology
- Intervals and segments analysis
- Chamber enlargement
- Specific changes

CALCULATING RATE

As a general interpretation, look at **lead II** at the bottom part of the ECG strip. This lead is the **rhythm strip** which shows the rhythm for the whole time the ECG is recorded. Look at the number of square between one R-R interval. To calculate rate, use any of the following formulas:

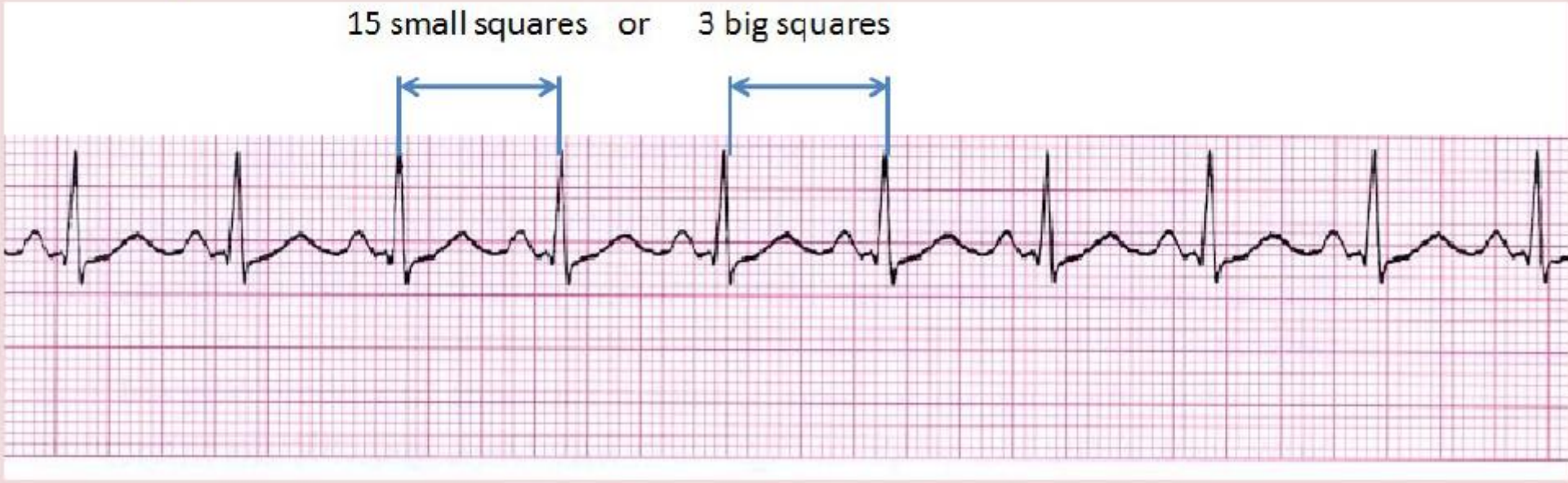
$$\text{Rate} = \frac{\mathbf{300}}{\text{the number of } \mathbf{BIG\ SQUARE} \text{ between R-R interval}}$$

OR

$$\text{Rate} = \frac{\mathbf{1500}}{\text{the number of } \mathbf{SMALL\ SQUARE} \text{ between R-R interval}}$$

CALCULATING RATE

For example:

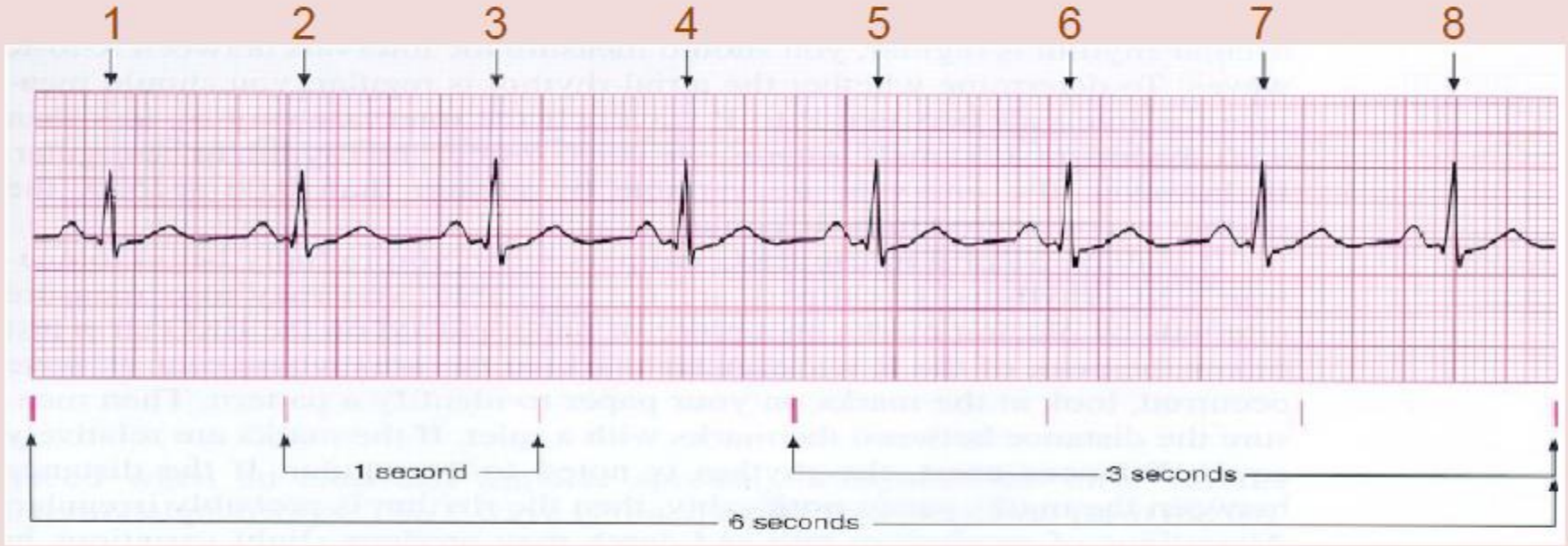


$$\text{Rate} = \frac{300}{3} \quad \text{or} \quad \text{Rate} = \frac{1500}{15}$$

Rate = **100** beats per minute

CALCULATING RATE

If you think that the **rhythm is not regular**, count the number of electrical beats in a 6-second strip and multiply that number by 10.(Note that some ECG strips have 3 seconds and 6 seconds marks) Example below:



There are 8 waves in this 6-seconds strip.

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

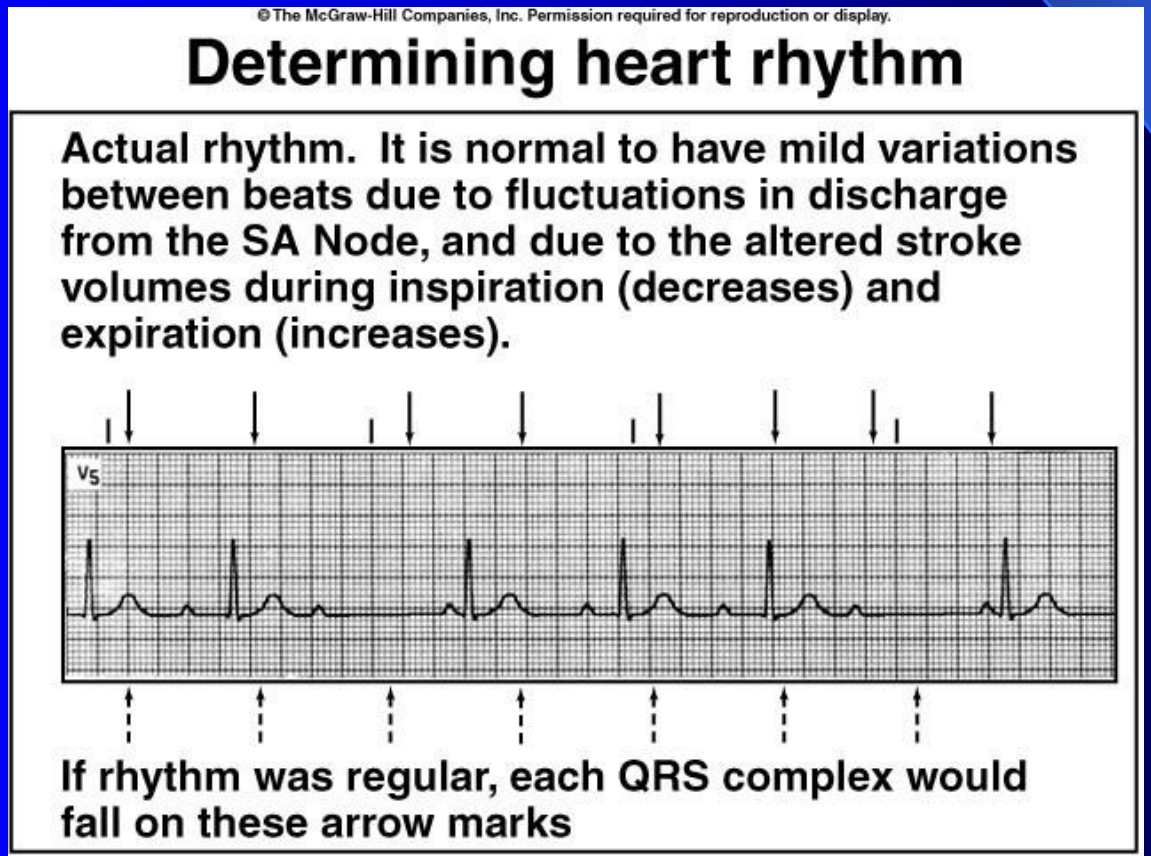
The Rule of 300

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

Interpretation of ECG: Rhythm

- Normal heart rhythm has consistent R-R interval.
- Mild variations due to breathing also normal.



Interpretation of ECG: Rhythm

Normal Sinus Rhythm

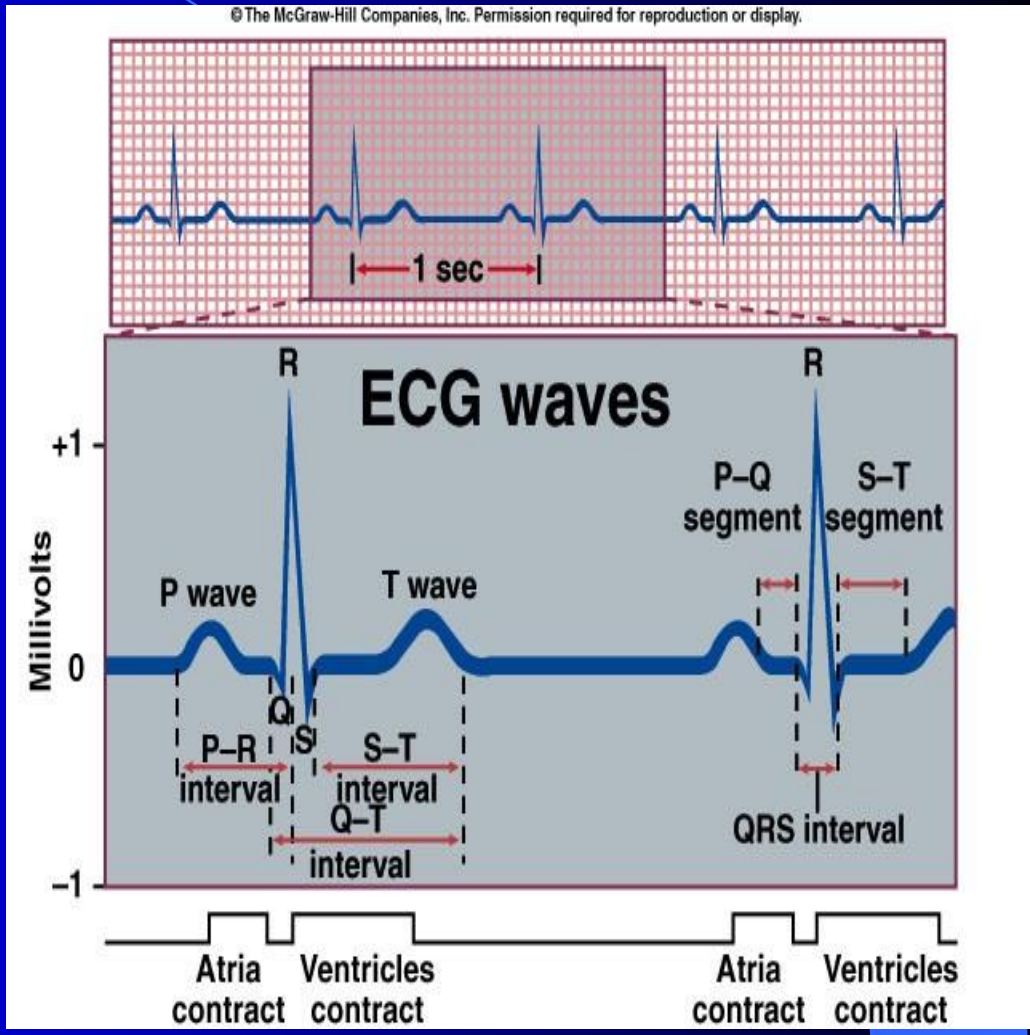
- Rate: 60-100 b/min
- Rhythm: regular
- P waves: upright in leads I, II, aV_F
- PR interval: < .20 s
- QRS: < .10 s

Sinus Bradycardia

- Rate: < 60 bpm
- Rhythm: regular

Sinus Tachycardia

- Rate: > 100 bpm

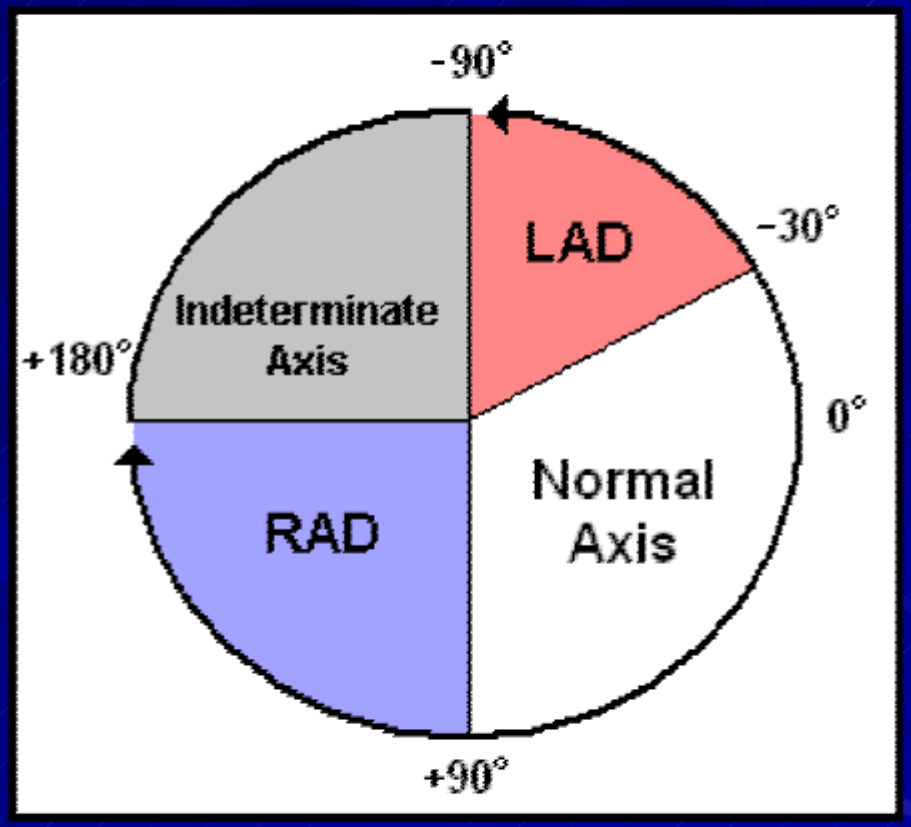


The QRS Axis

By near-consensus, the normal QRS axis is defined as ranging from -30° to +90°.

-30° to -90° is referred to as a left axis deviation (LAD)

+90° to +180° is referred to as a right axis deviation (RAD)



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Determining the Axis

Predominantly Positive

Predominantly Negative

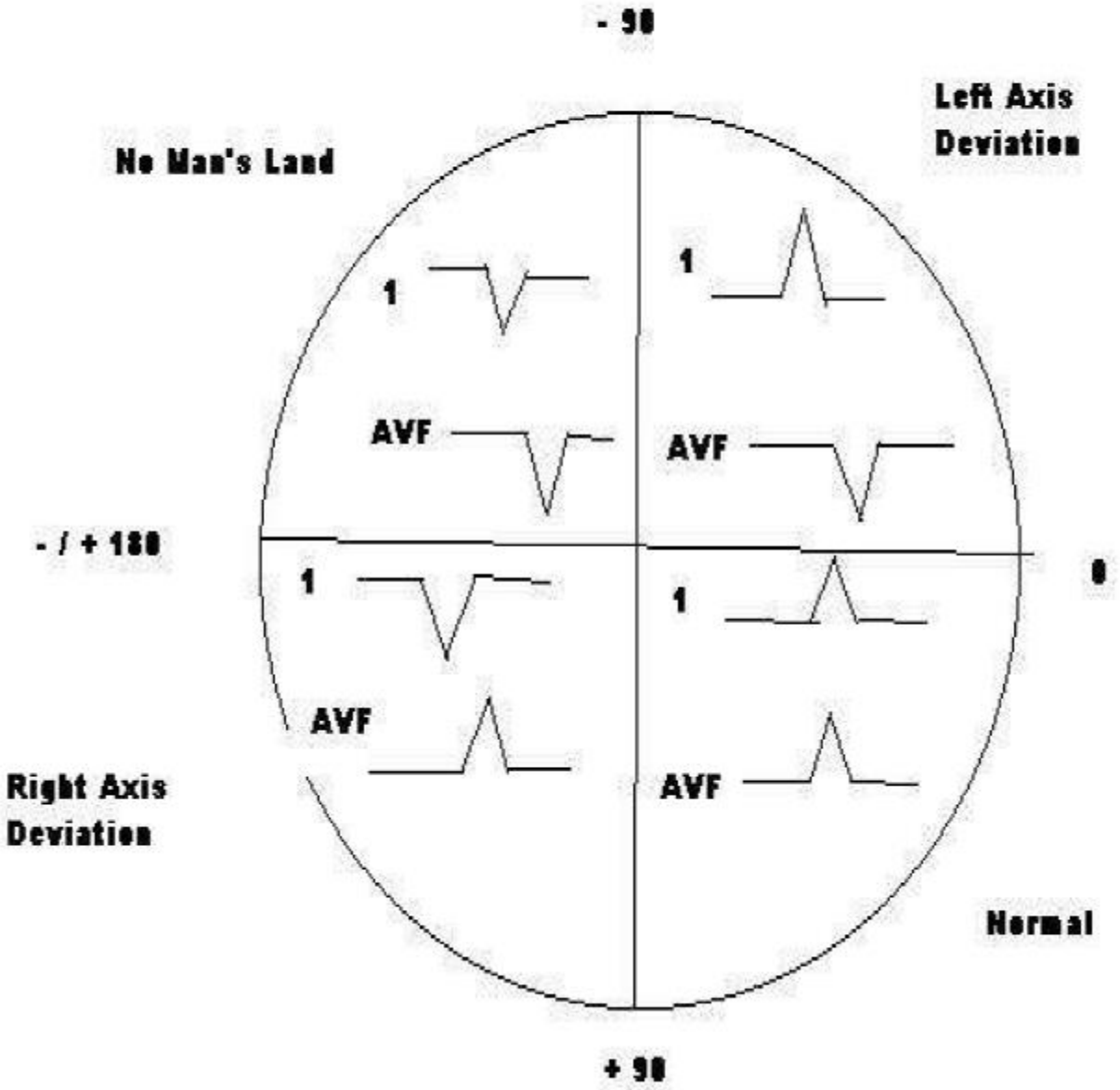
Equiphasic

The Quadrant Approach

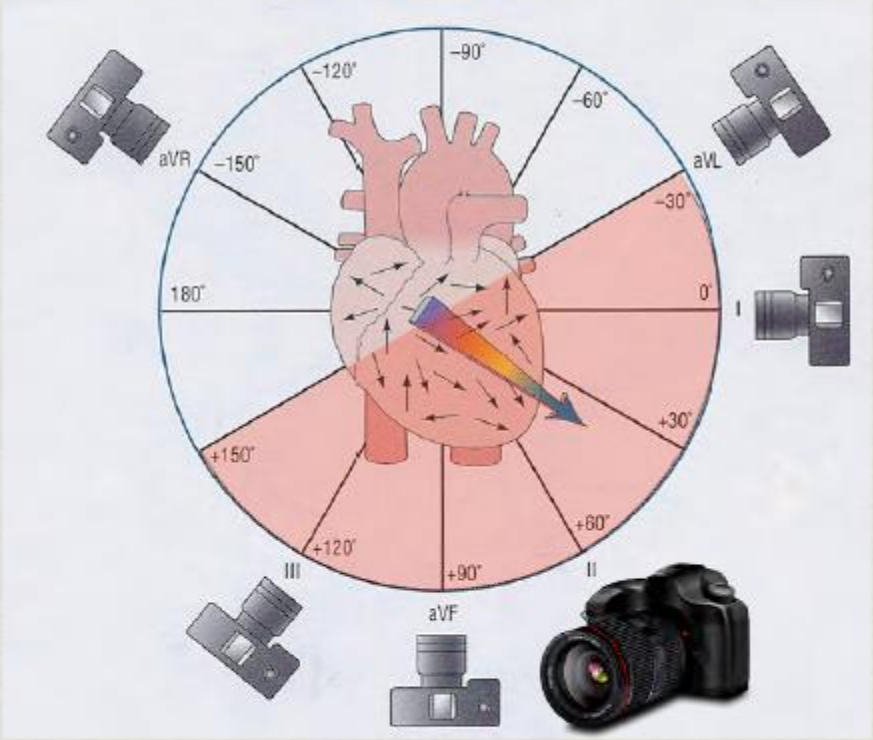
1. Examine the QRS complex in leads I and aVF to determine if they are predominantly positive or predominantly negative. The combination should place the axis into one of the 4 quadrants below.

		Lead aVF	
		Positive	Negative
Lead I	Positive	Normal Axis	LAD
	Negative	RAD	Indeterminate Axis

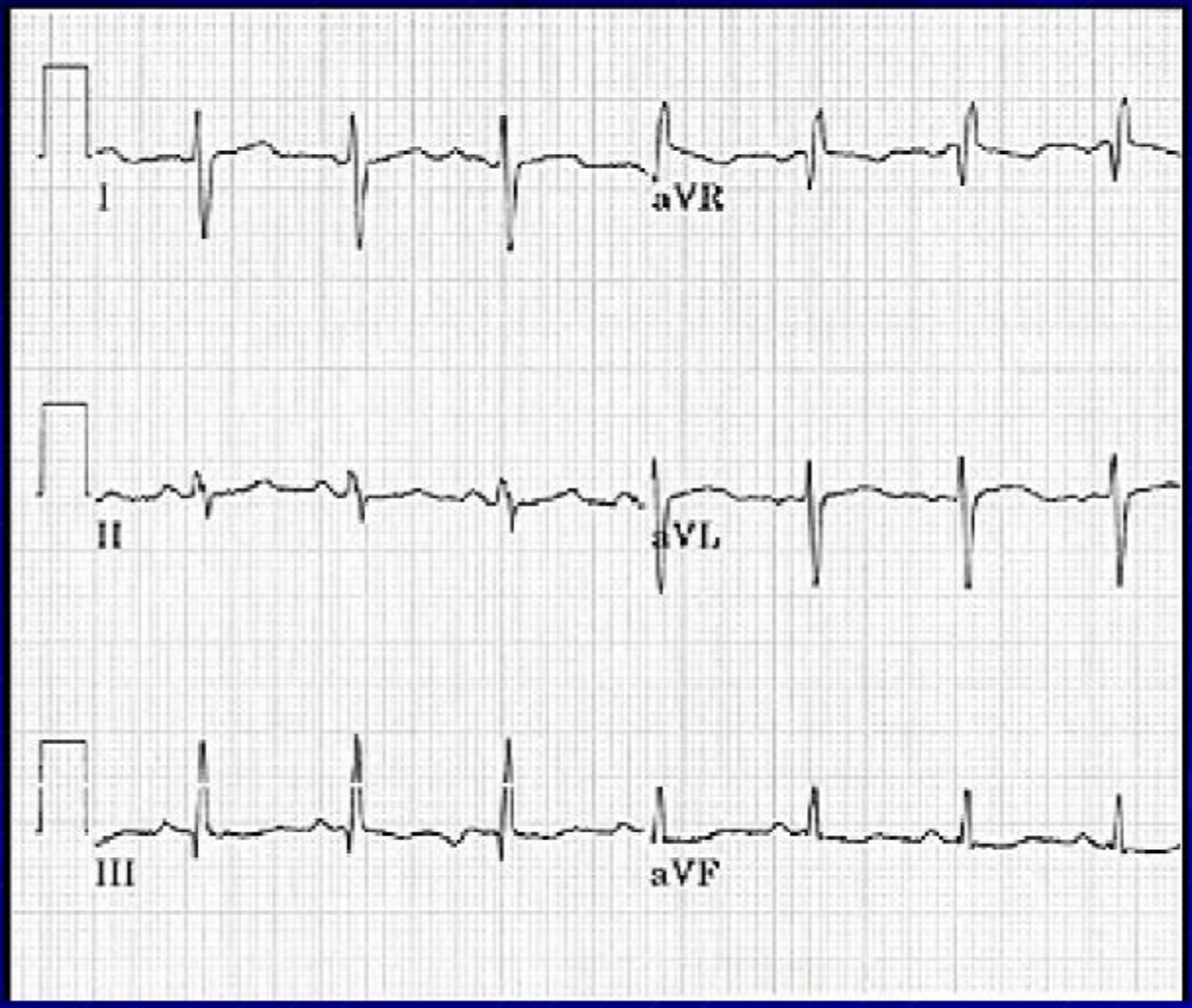
2 Lead Method fo AXIS determination



Axis

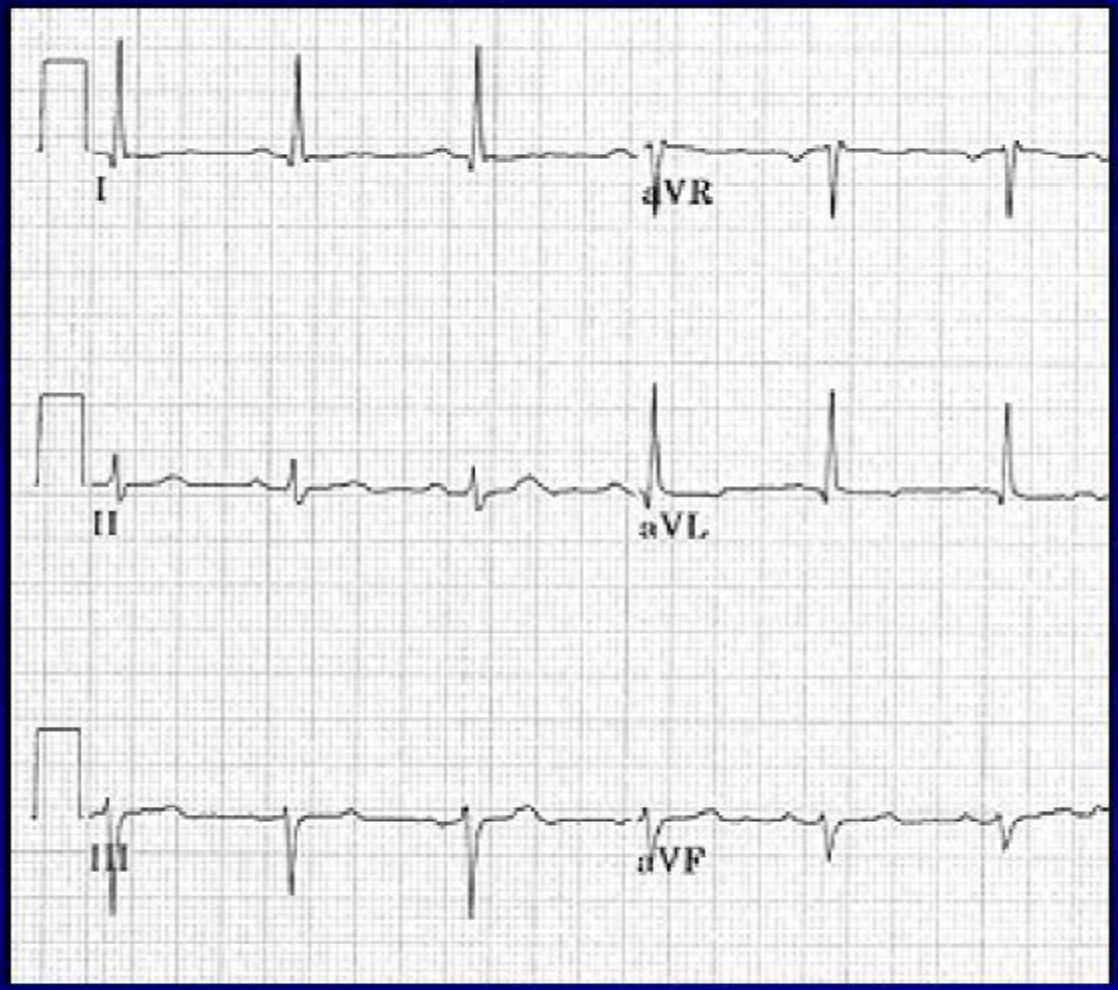


Example 1



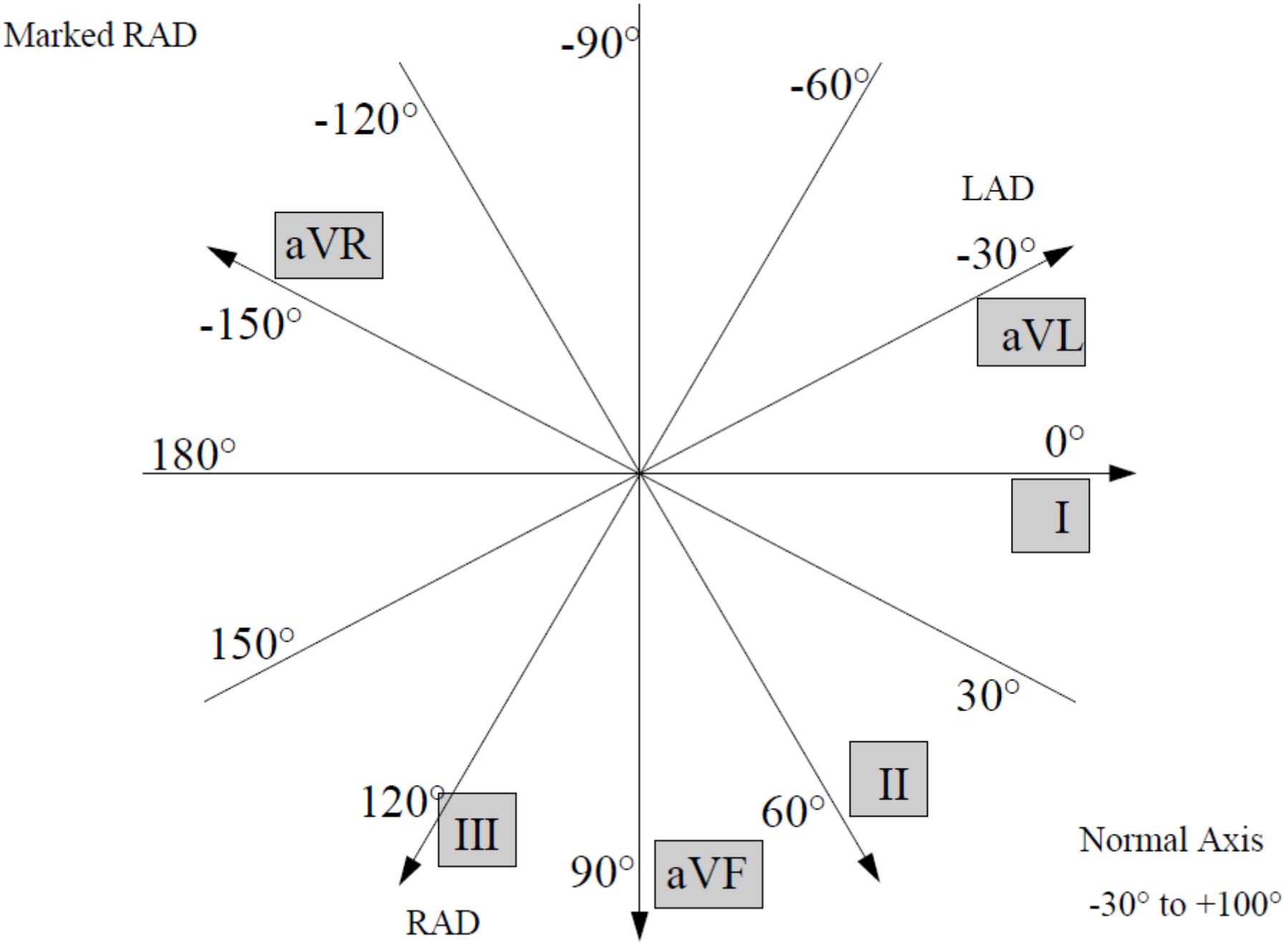
Negative in I, positive in aVF → RAD

Example 2



Positive in I, negative in aVF → Predominantly positive in II →

Normal Axis (non-pathologic LAD)


Marked RAD
-90°
-60°
-120°
LAD
aVR
-30°
-150°
aVL
180°
0°
I
150°
30°
II
120°
III
60°
90°
aVF
RAD
Normal Axis
-30° to +100°

- The Normal ECG

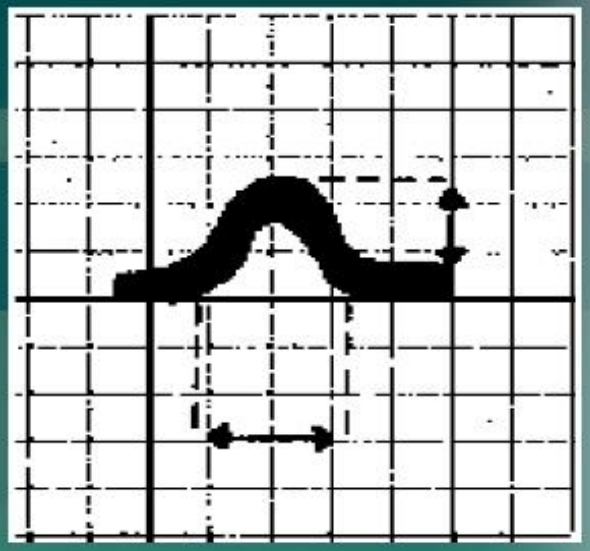
Normal Sinus Rhythm

- *Originates in the sinus node*
- *Rate between 60 and 100 beats per min*
- *P wave axis of +45 to +65 degrees, ie. Tallest p waves in Lead II*
- *Monomorphic P waves*
- *Normal PR interval of 120 to 200 msec*
- *Normal relationship between P and QRS*
- *Some sinus arrhythmia is normal*


V1
V2
V3
V4
V5
V6
25mm/s 10mm/mV 50Hz ADF Auto Isochron
BPL
25mm/s 10mm/mV 50Hz ADF Auto Isochron

P wave

- Always positive in lead I and II
- Always negative in lead aVR
- < 3 small squares in duration
- < 2.5 small squares in amplitude
- Commonly biphasic in lead V1
- Best seen in leads II



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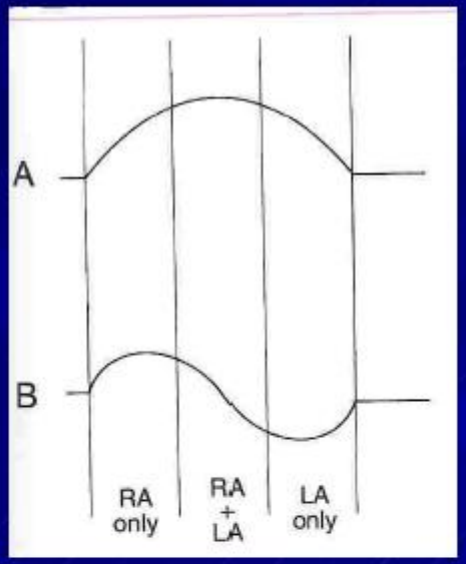
Normal P wave



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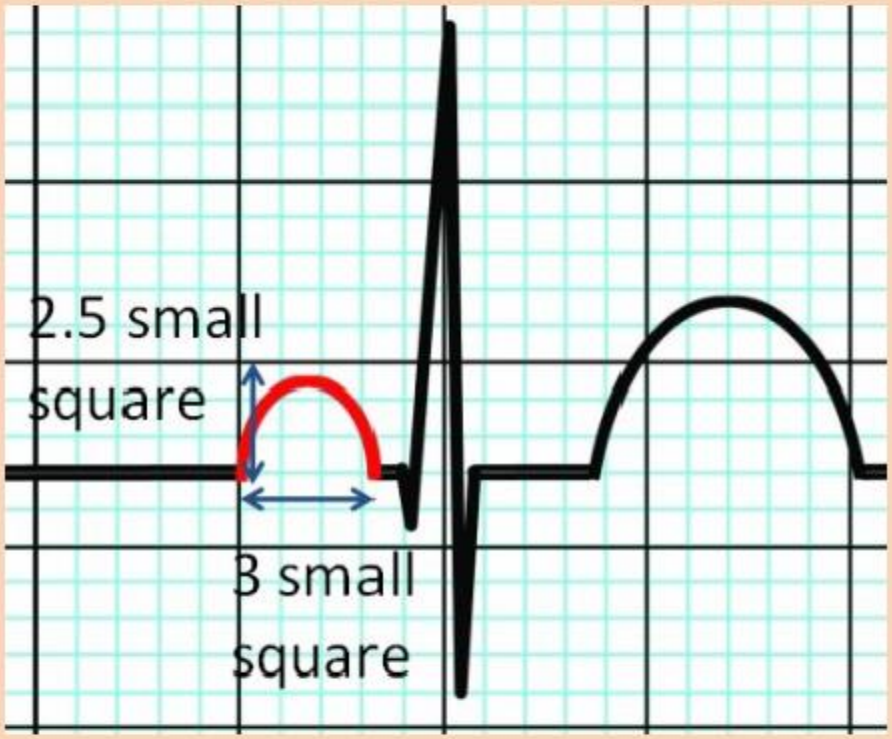
P -WAVE

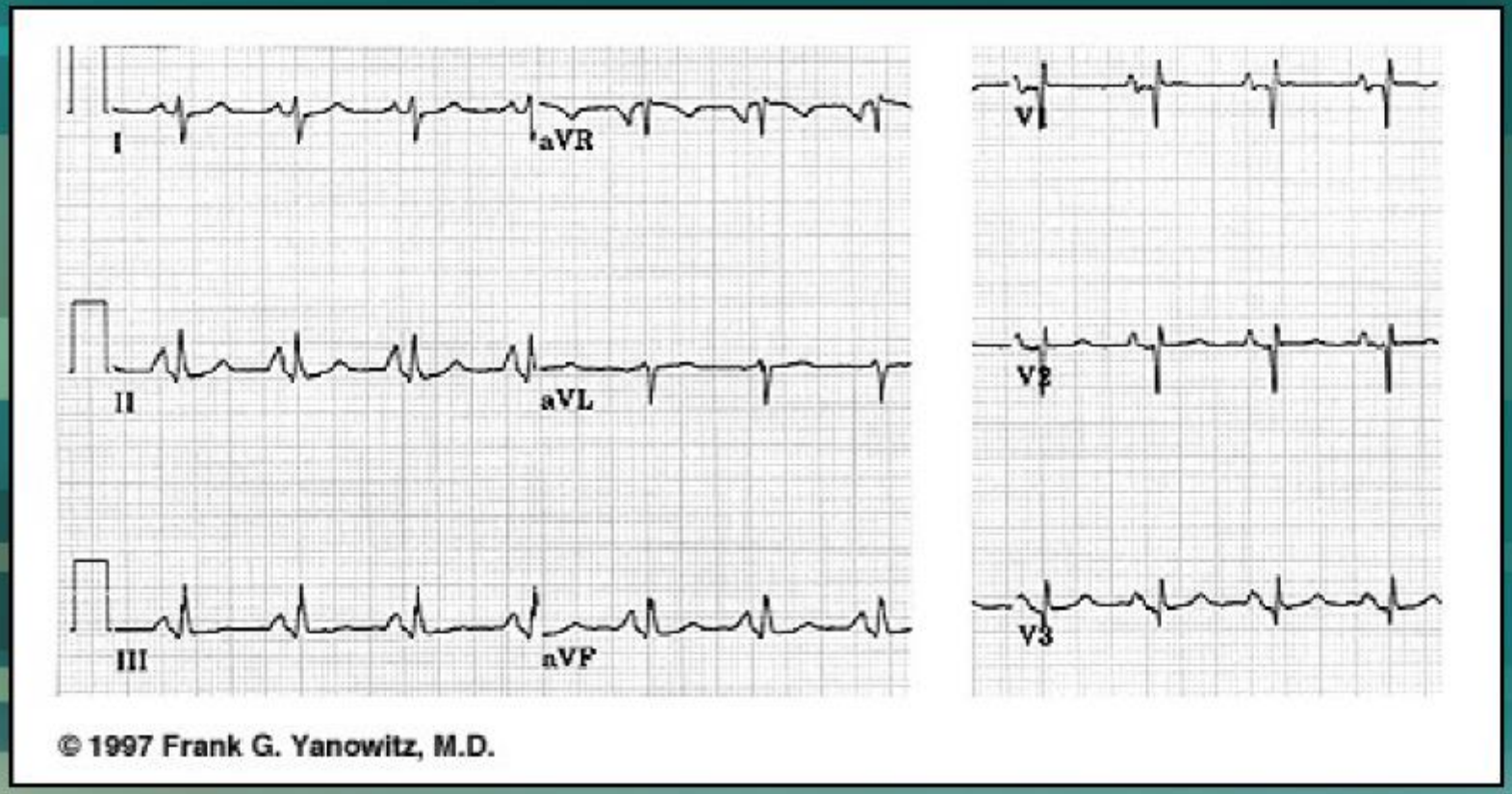


Normal P- wave

3 small square wide, and 2.5 small square high.
Always positive in lead I and II in NSR
Always negative in lead aVR in NSR
Commonly biphasic in lead V1

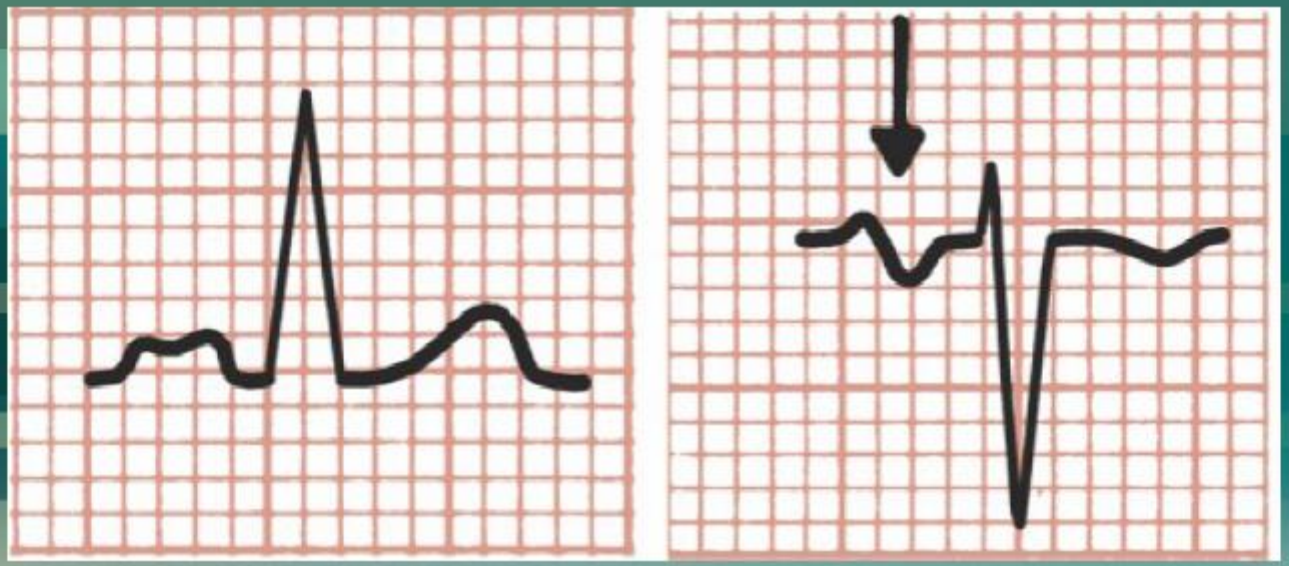
Right Atrial Enlargement

- Tall (> 2.5 mm), pointed P waves (P Pulmonale)



Left Atrial Enlargement

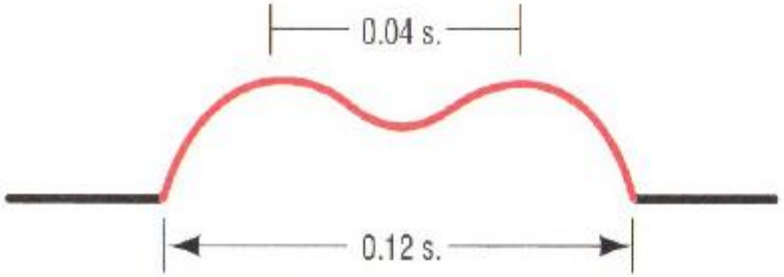
- Notched/bifid ('M' shaped) P wave (P 'mitrale') in limb leads



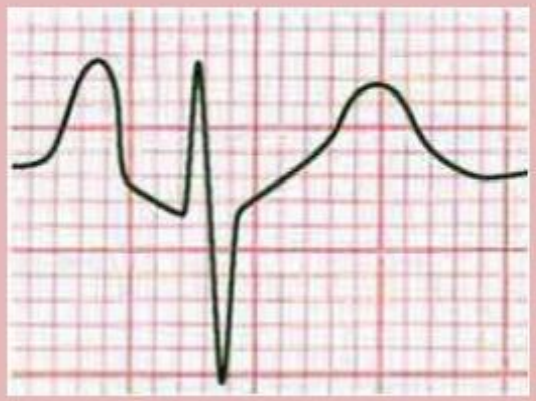
P Pulmonale

Figure 12-4: A peaked P wave taller than 2.5 mm in the limb leads indicates P-pulmonale.

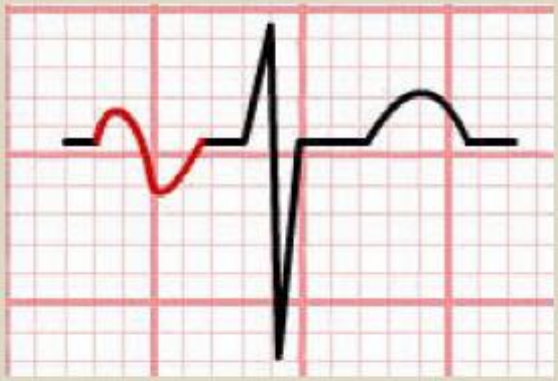
P Mitrale



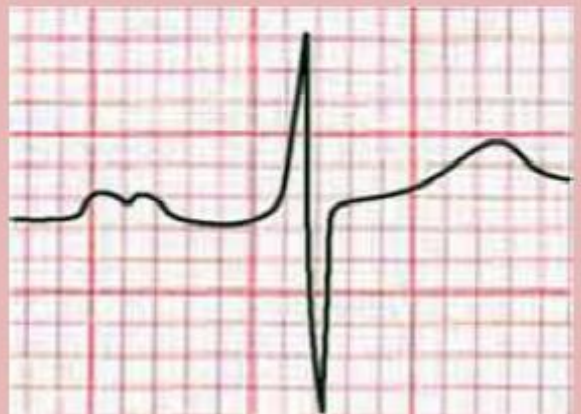
P -WAVE



P pulmonale
Tall peaked P wave. Generally due to **enlarged right atrium**- commonly associated with congenital heart disease, tricuspid valve disease, pulmonary hypertension and diffuse lung disease.



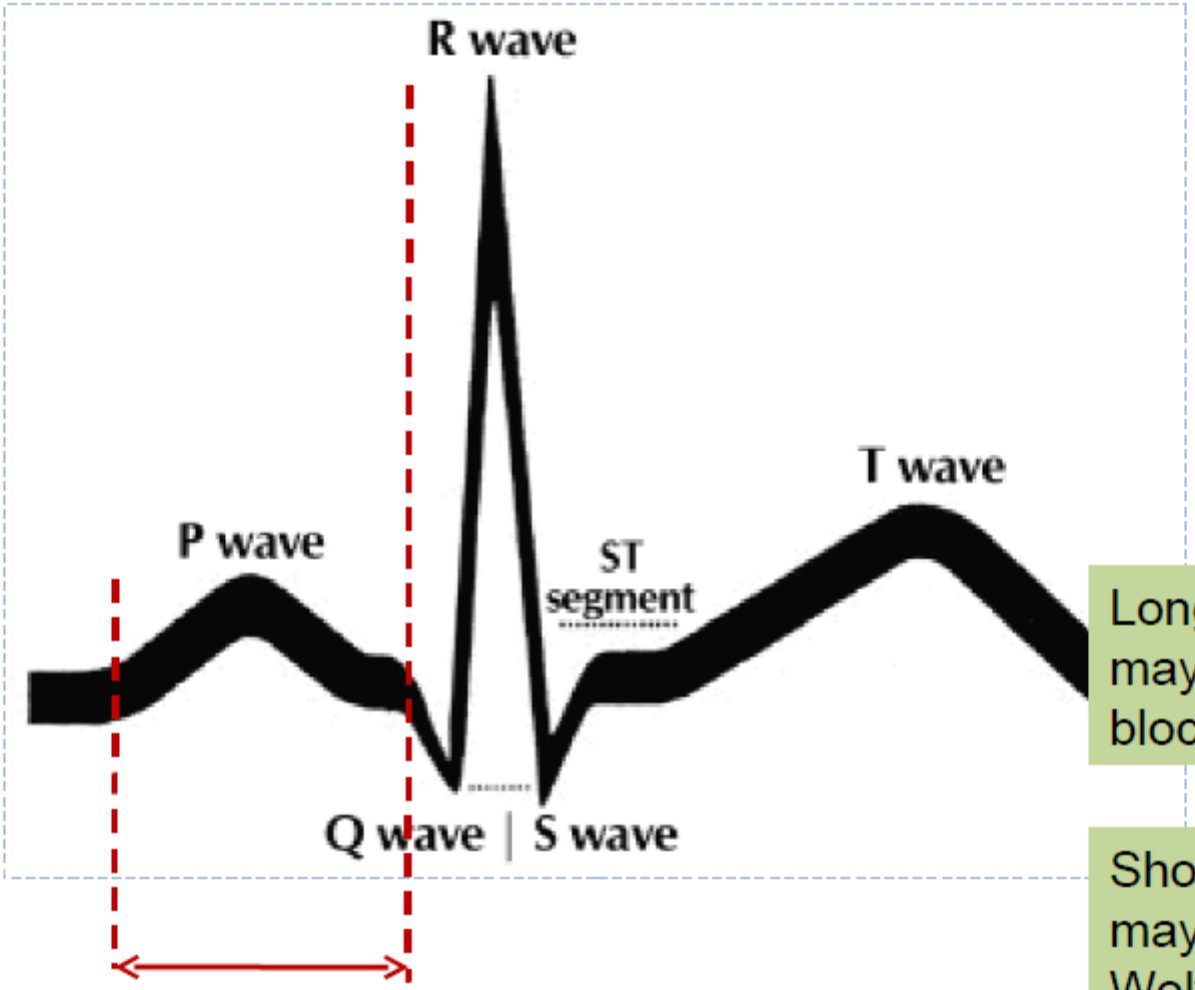
Biphasic P wave
Its terminal negative deflection more than 40 ms wide and more than 1 mm deep is an ECG sign of **left atrial enlargement**.



P mitrale
Wide P wave, often bifid, may be due to **mitral stenosis** or left atrial enlargement.

PR INTERVAL

NORMAL PR INTERVAL



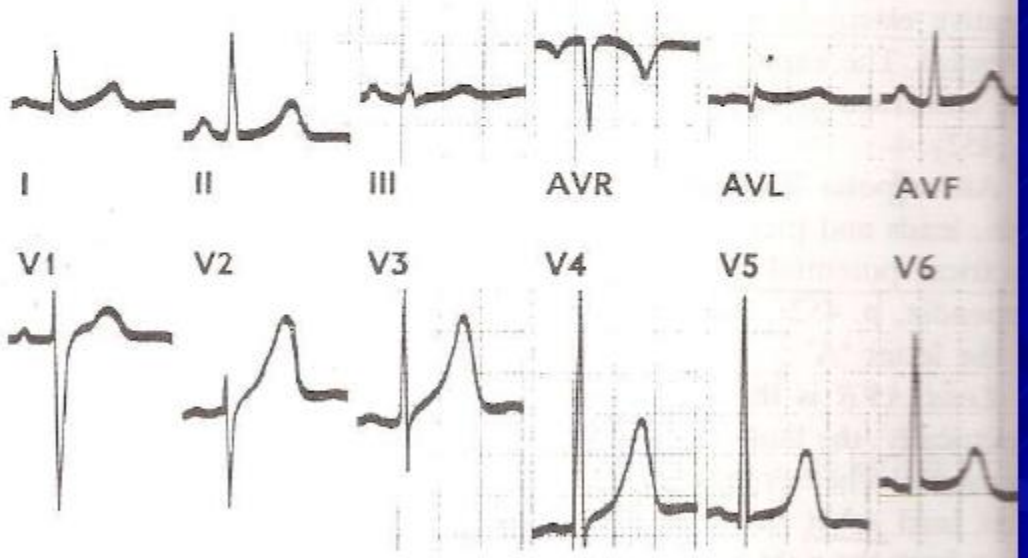
PR-Interval 3-5 small square (120-200ms)

Long PR interval may indicate heart block

Short PR interval may disease like Wolf-Parkinson-White

Normal QRS complex

- Completely negative in lead aVR , maximum positivity in lead II
- rS in right oriented leads and qR in left oriented leads (septal vector)
- Transition zone commonly in V3-V4
- RV5 > RV6 normally
- Normal duration 50-110 msec, not more than 120 msec
- Physiological q wave not > 0.03 sec


I
II
III
AVR
AVL
AVF
V1
V2
V3
V4
V5
V6

Normal T wave

- Same direction as the preceding QRS complex
- Blunt apex with asymmetric limbs
- Height < 5mm in limb leads and <10 mm in precordial leads
- Smooth contours
- May be tall in athletes

- U wave:

Best seen in mid precordial leads

height< 25% preceding T wave

Maximum amplitude 1-2 mm

Isoelectric in AVL

Visible at HR<65

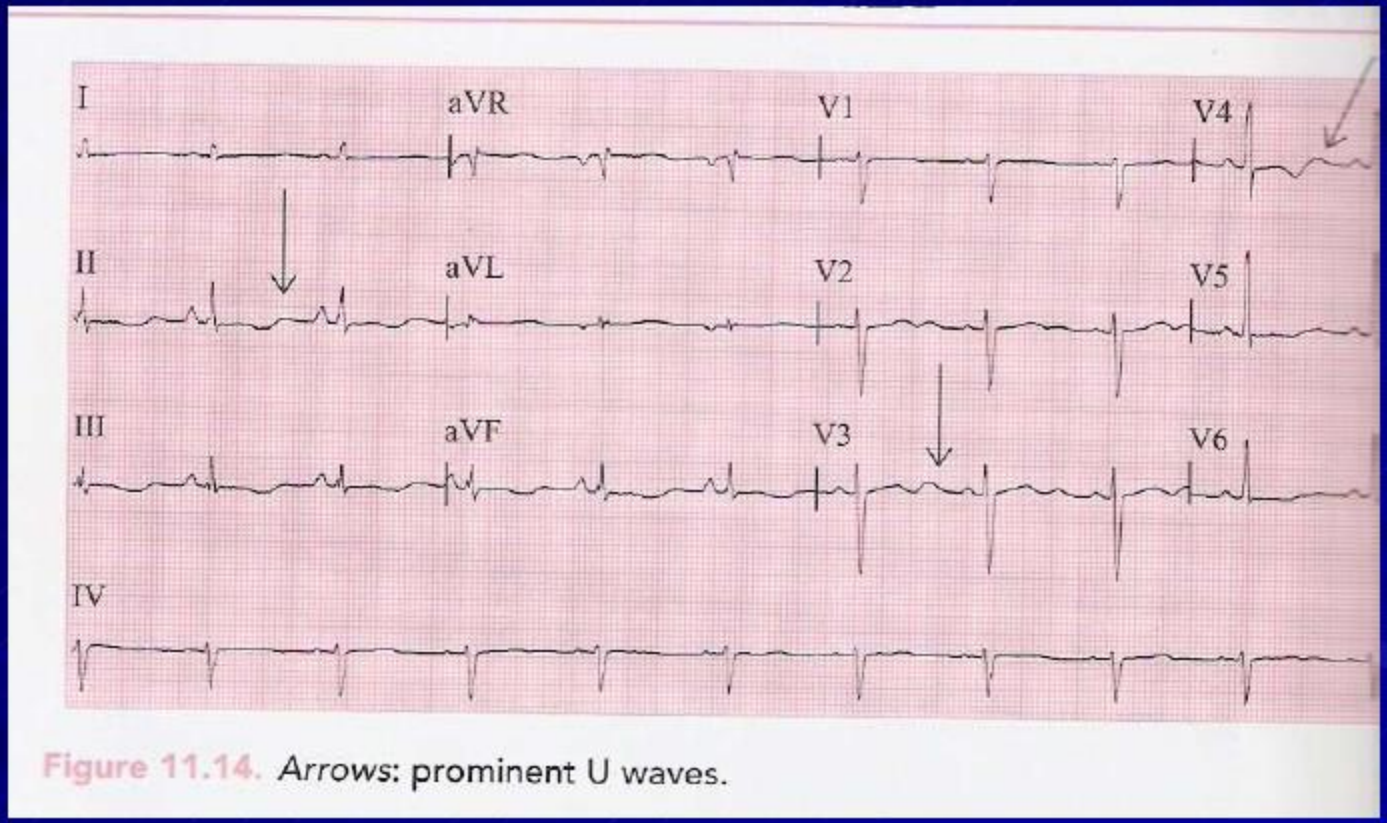


Figure 11.14. *Arrows*: prominent U waves.

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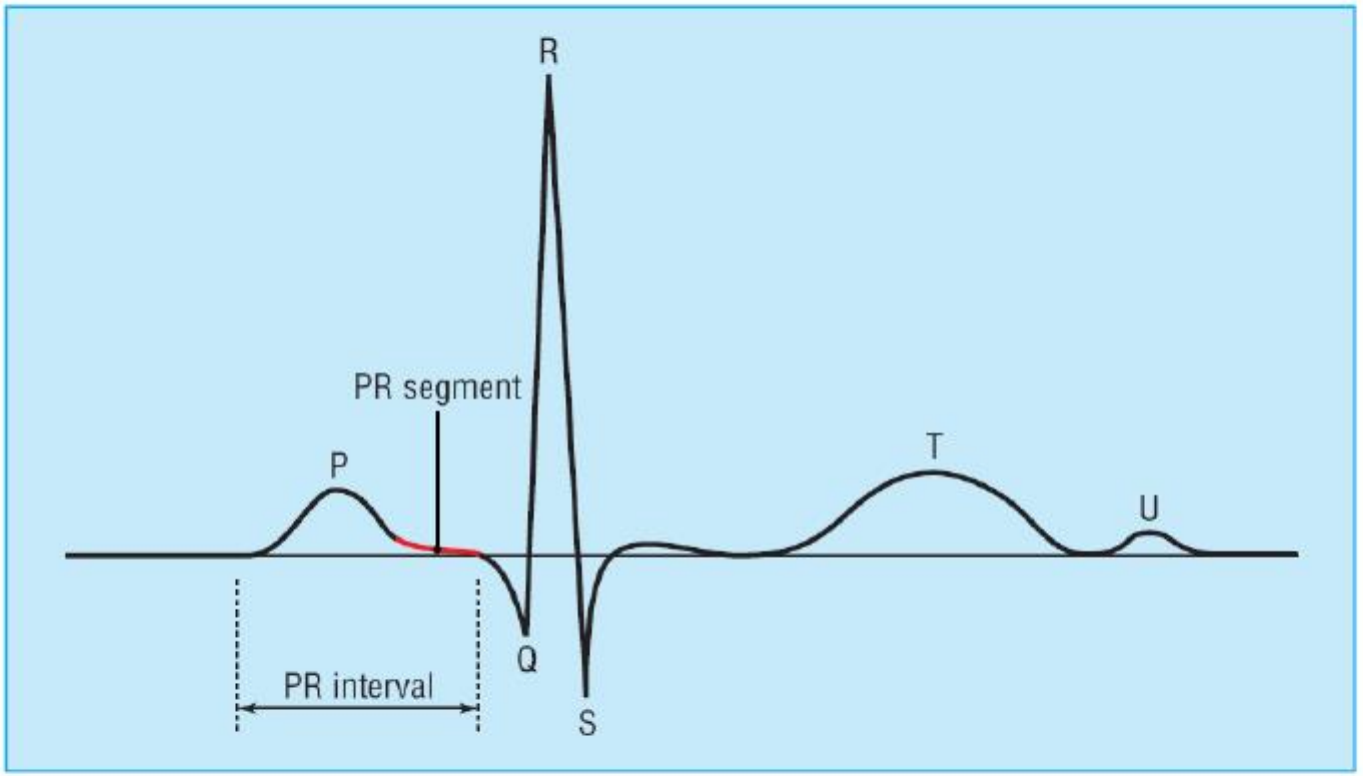
QT interval

1. Total duration of Depolarization and Repolarization
2. QT interval decreases when heart rate increases
3. For HR = 70 bpm, QT<0.40 sec.
4. QT interval should be 0.35- 0.45 s,
5. Should not be more than half of the interval between adjacent R waves (R-R interval).

ECG RULES

- Professor Chamberlains 10 rules of normal:-

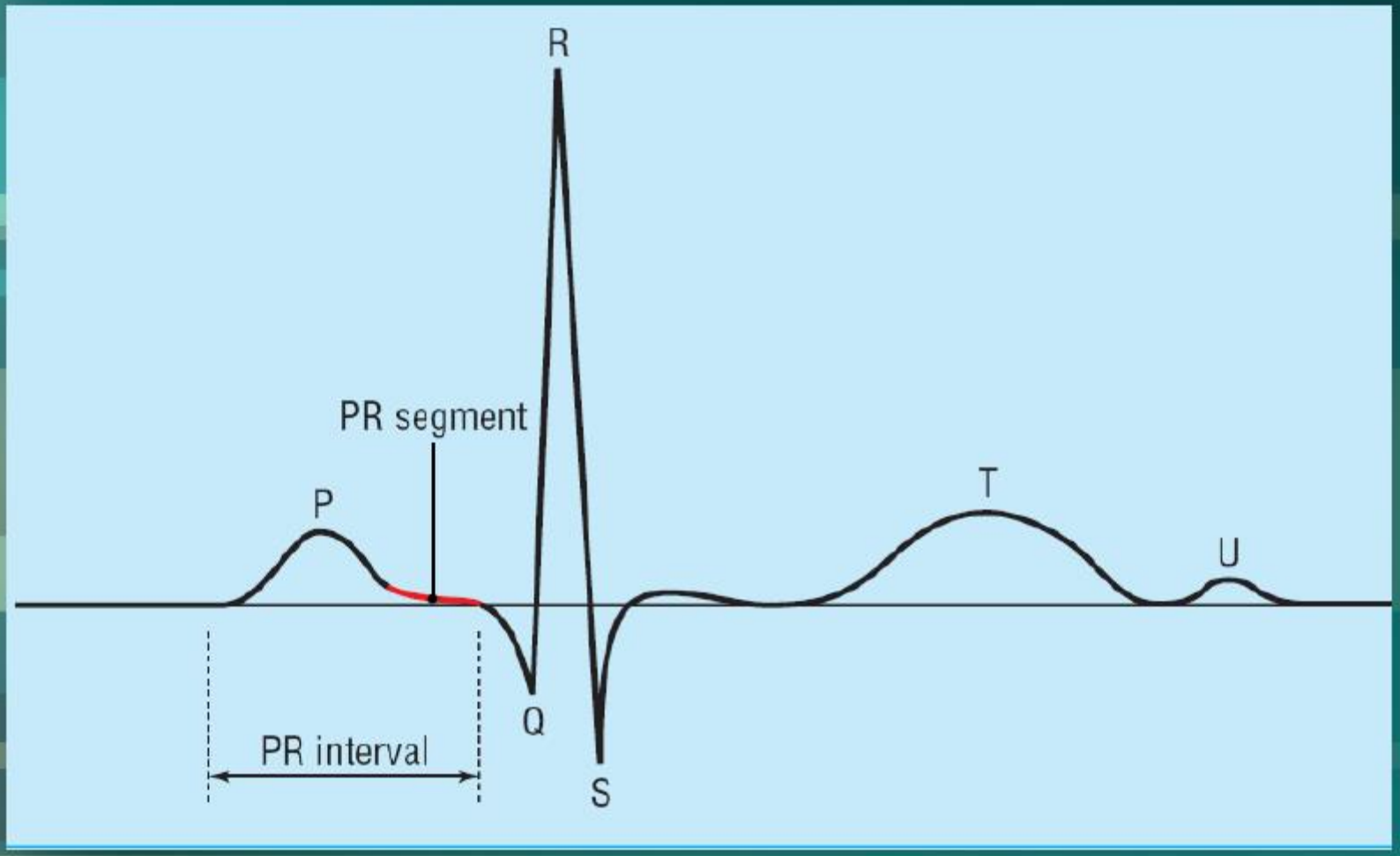
RULE 1



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

PR interval should be 120 to 200 milliseconds or 3 to 5 little squares

RULE 2

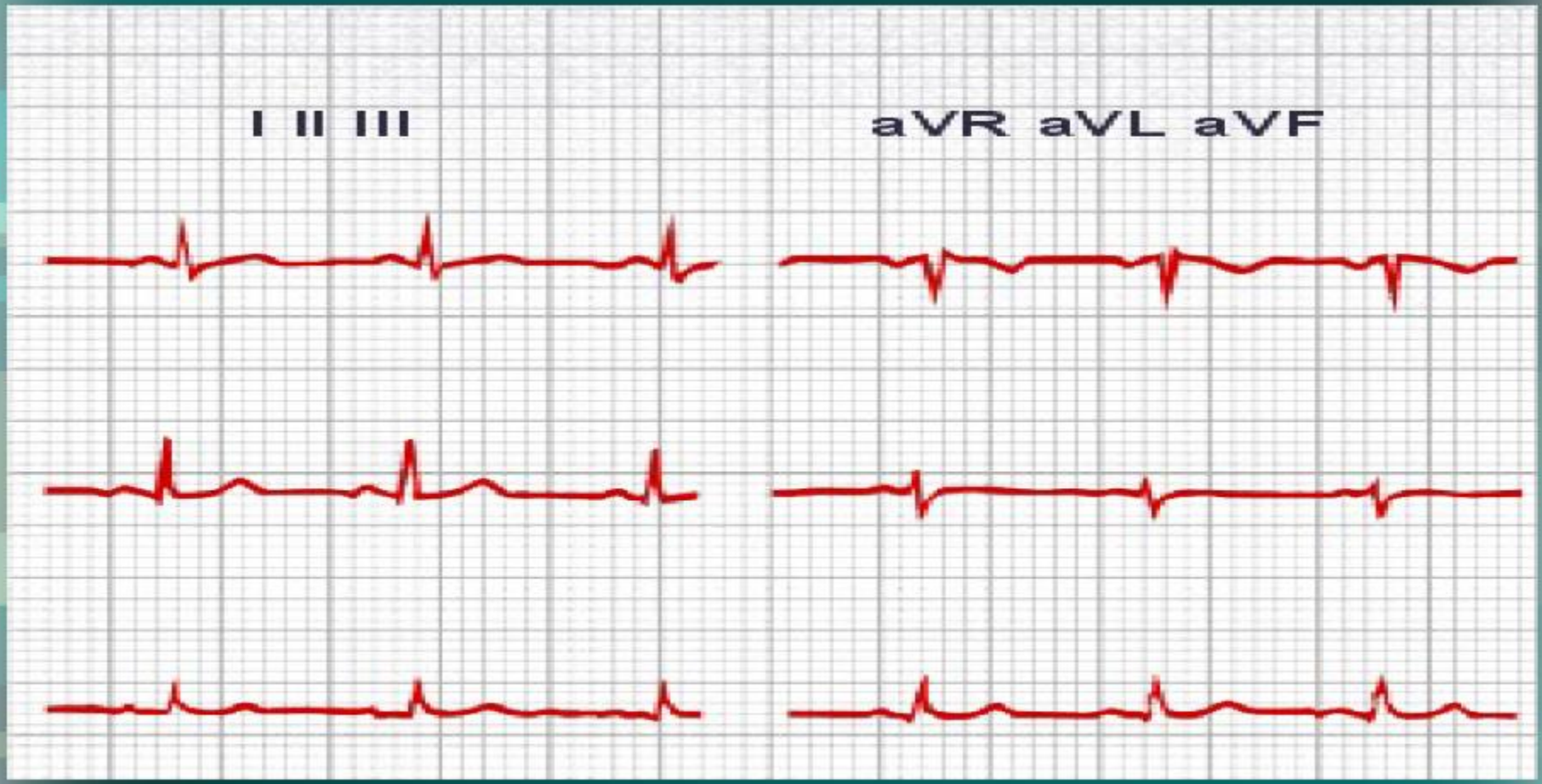


The width of the QRS complex should not exceed 110 ms, less than 3 little squares

RULE 3

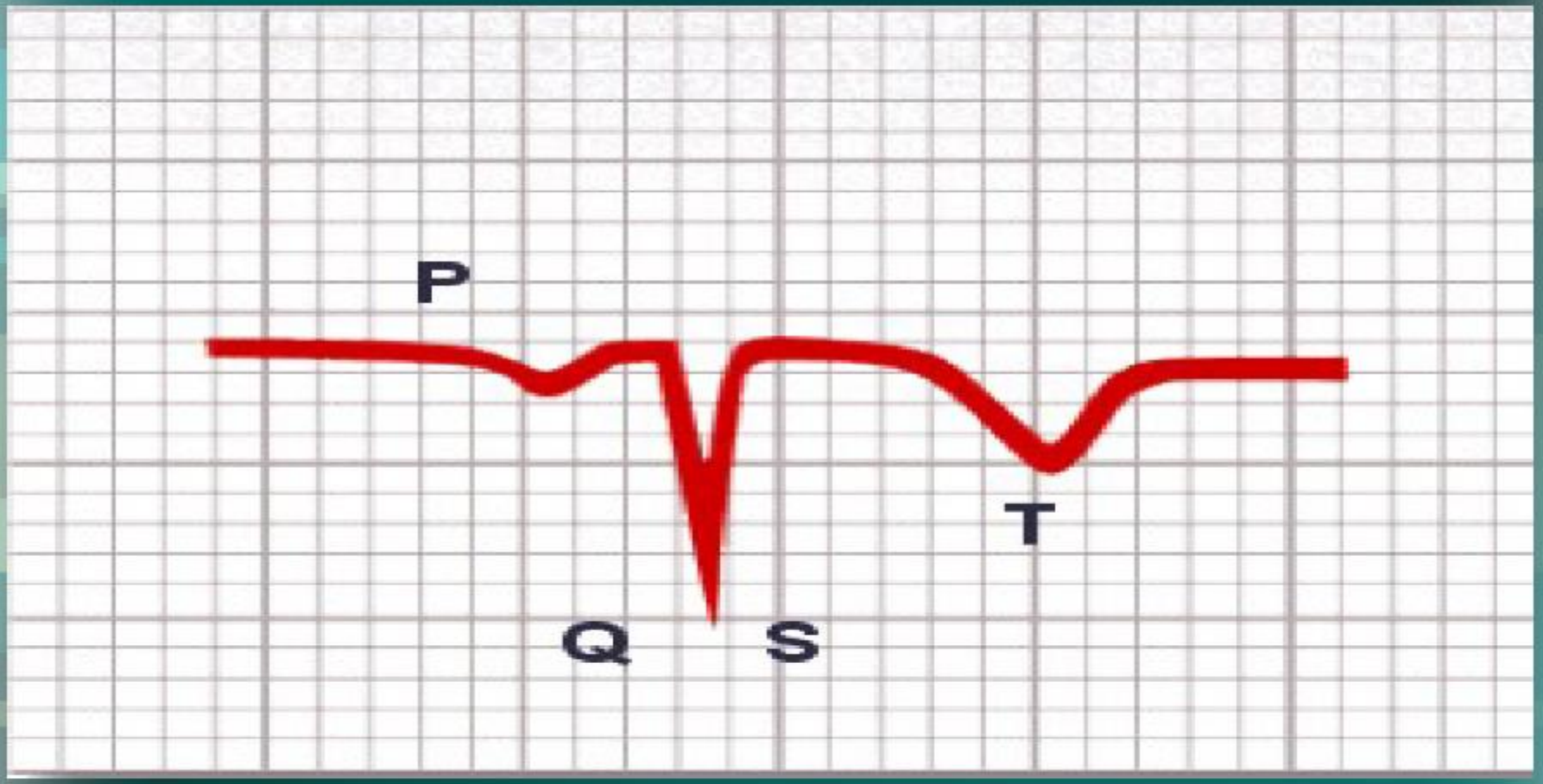
The QRS complex should be dominantly upright in leads I and II

RULE 4



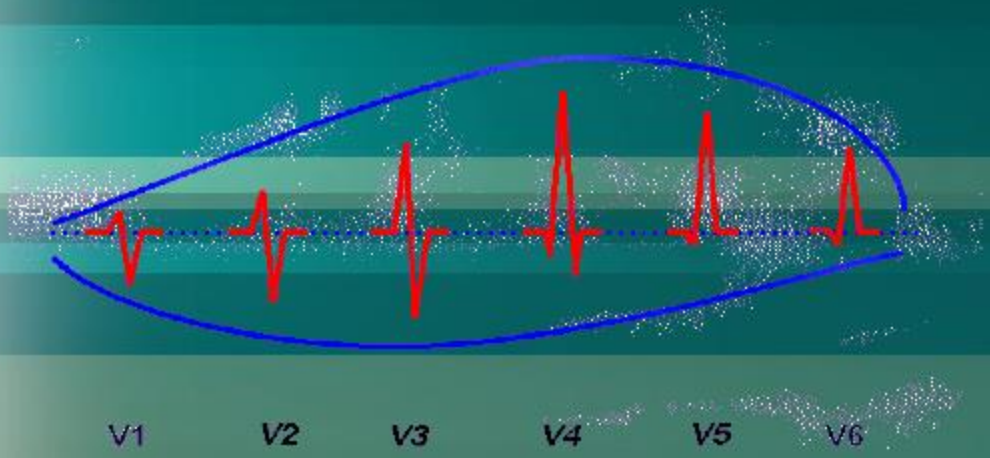
QRS and T waves tend to have the same general direction in the limb leads

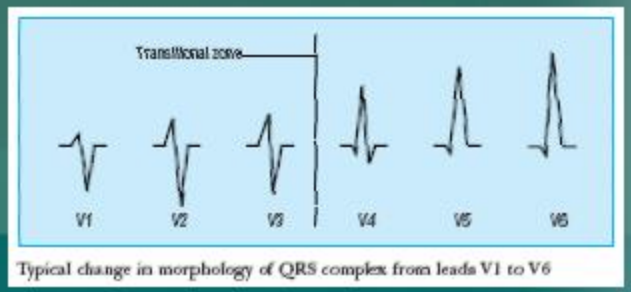
RULE 5



All waves are negative in lead aVR

RULE 6





Typical change in morphology of QRS complex from leads V1 to V6

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

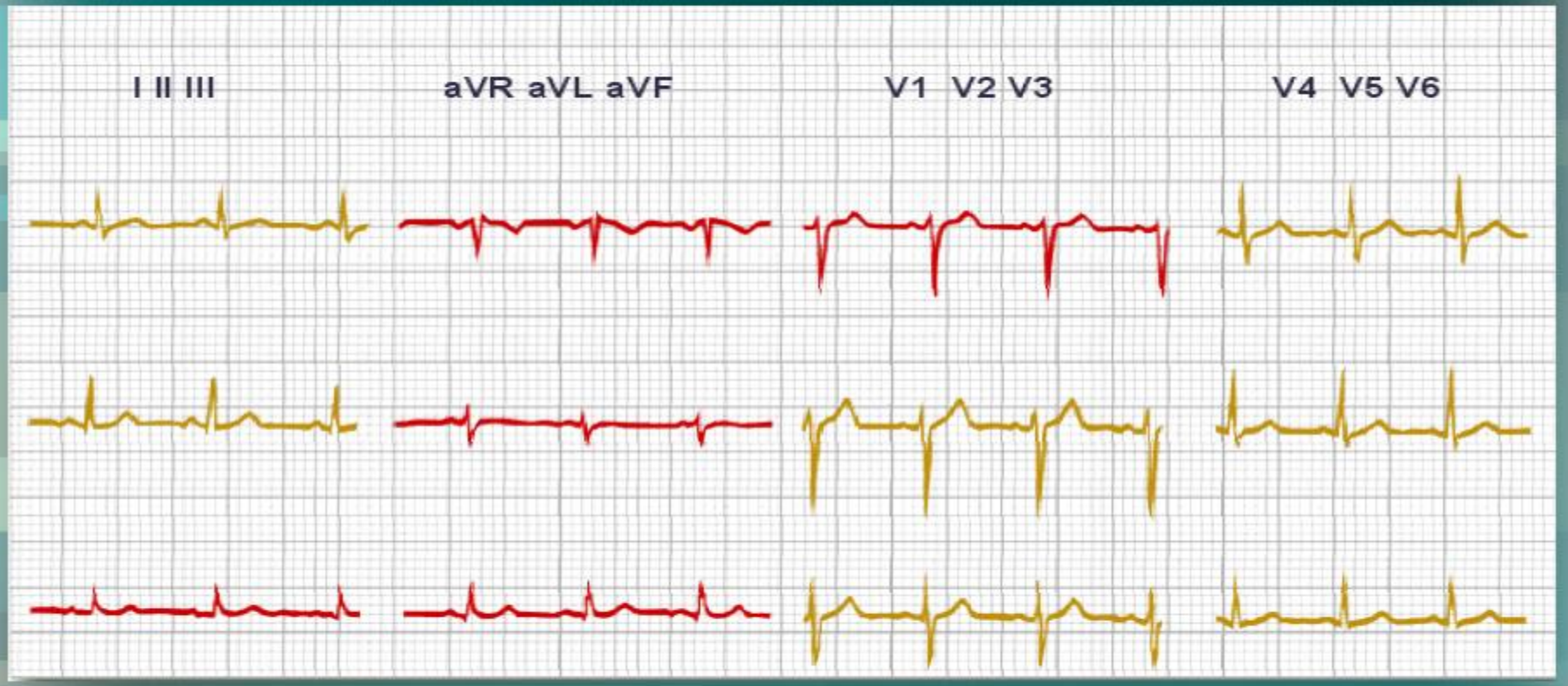
RULE 7

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

RULE 8

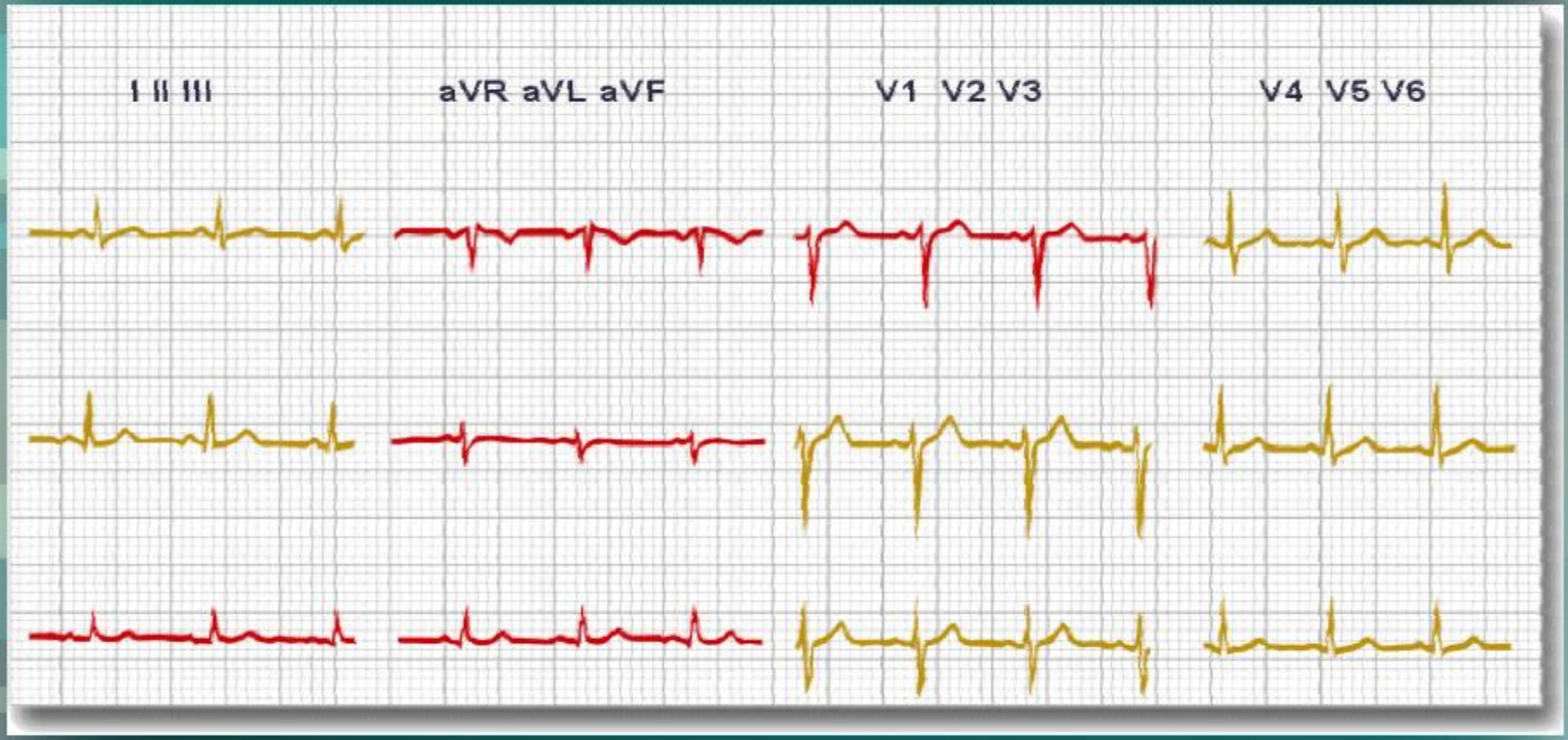
The P waves should be upright in I, II, and V2 to V6

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

Thank you!