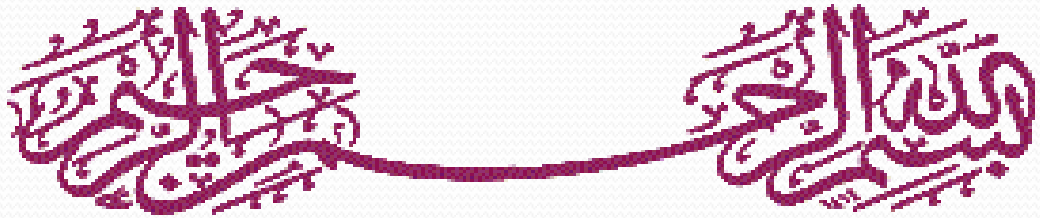


السلام عليكم ورحمة الله وبركاته

Cardiovascular System Block

The Electrocardiogram

(ECG)

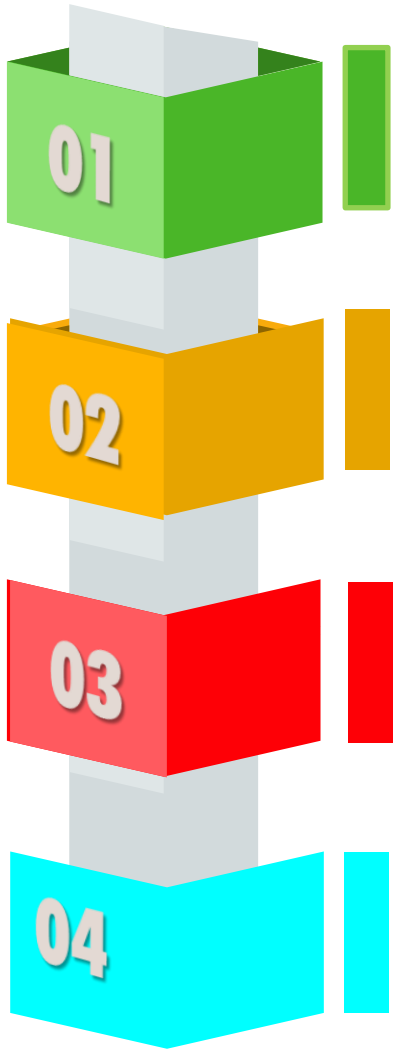
Dr. Hayam Gad

MBBS, MSc, PhD

Associate Professor Of Physiology

College of Medicine, KSU

Lecture Objectives



01 **Identify waves & intervals of the normal ECG trace and the physiological cause of each wave**

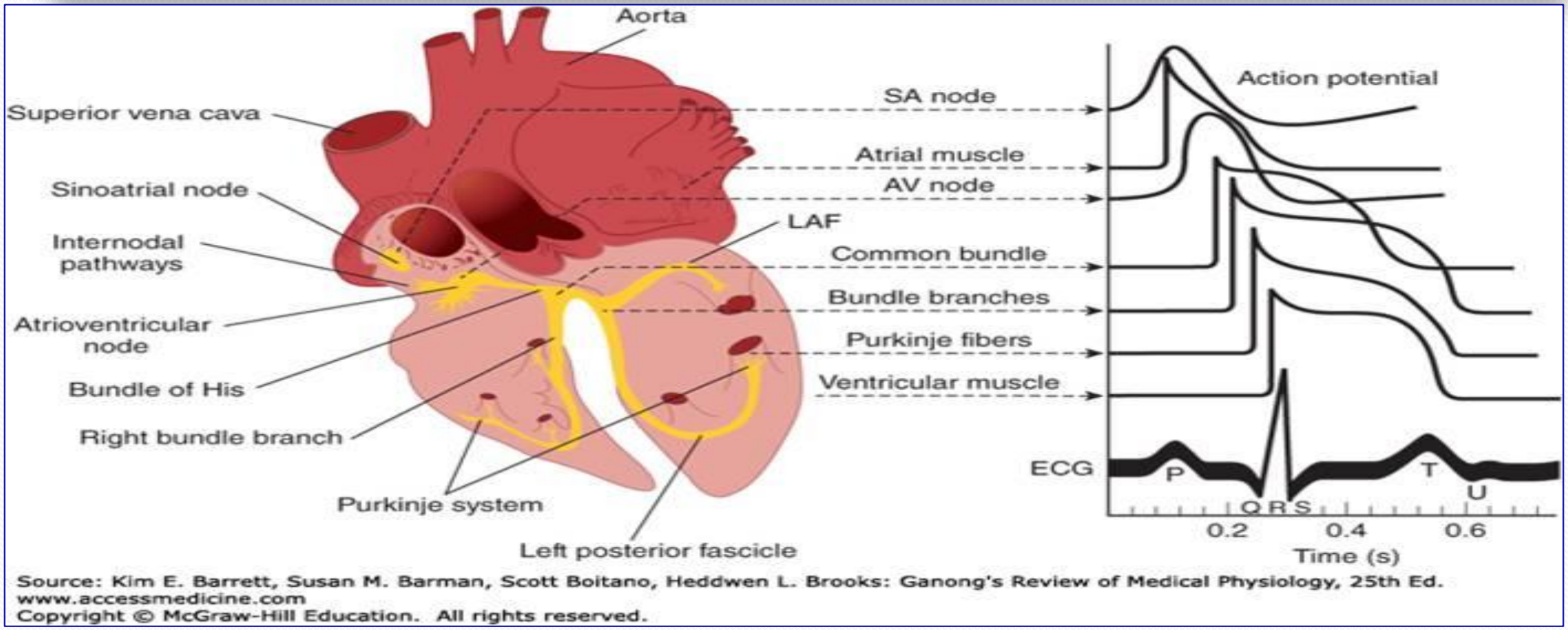
02 **Determine the bipolar, unipolar and chest leads**

03 **Know what is Einthoven's triangle and Einthoven's law**

04 **Describe the practical use of the ECG**

The Electrocardiogram (ECG)

It is the record of the electrical activity i.e. action potentials generated by the heart during cardiac cycle



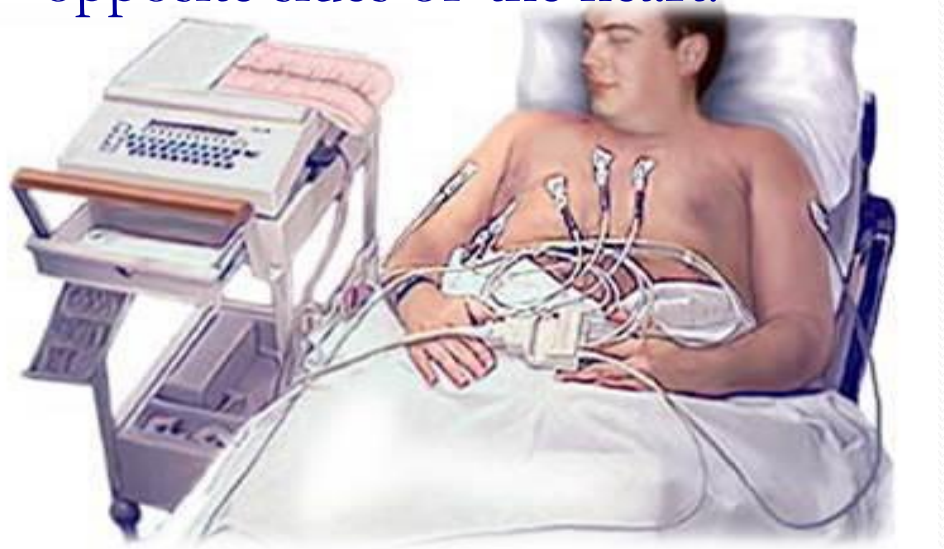
Source: Kim E. Barrett, Susan M. Barman, Scott Boitano, Heddwen L. Brooks: Ganong's Review of Medical Physiology, 25th Ed.
www.accessmedicine.com

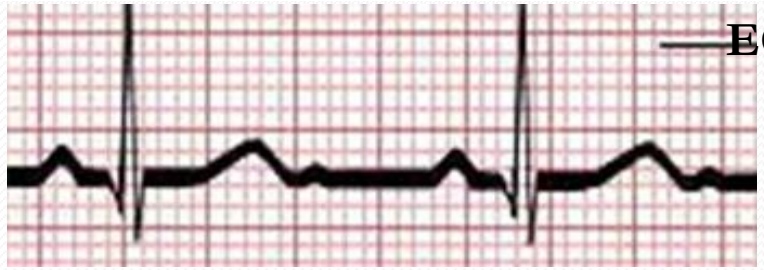
The Principle of ECG

- When the depolarization wave spread through heart, electrical currents pass into the surrounding tissue.
- Part of the current reaches the surface of the body (body fluids are good conductors).
- The electrical potentials generated by these currents can be recorded from electrodes placed on the skin opposite the heart.
- The record is the ECG.

How ECG can be recorded?

- ECG can be recorded by placing electrodes on body surface on opposite sides of the heart.





ECG tracing

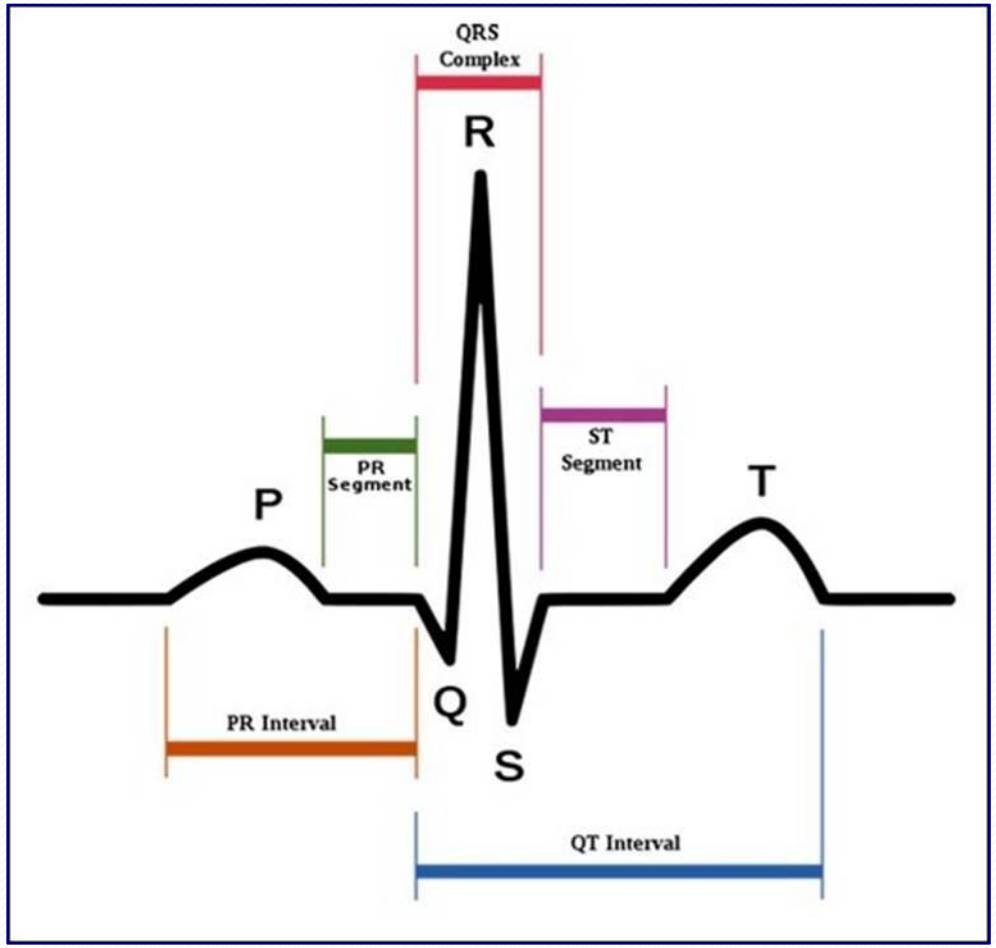
Methods for Recording ECG

Computer-based and electronic display

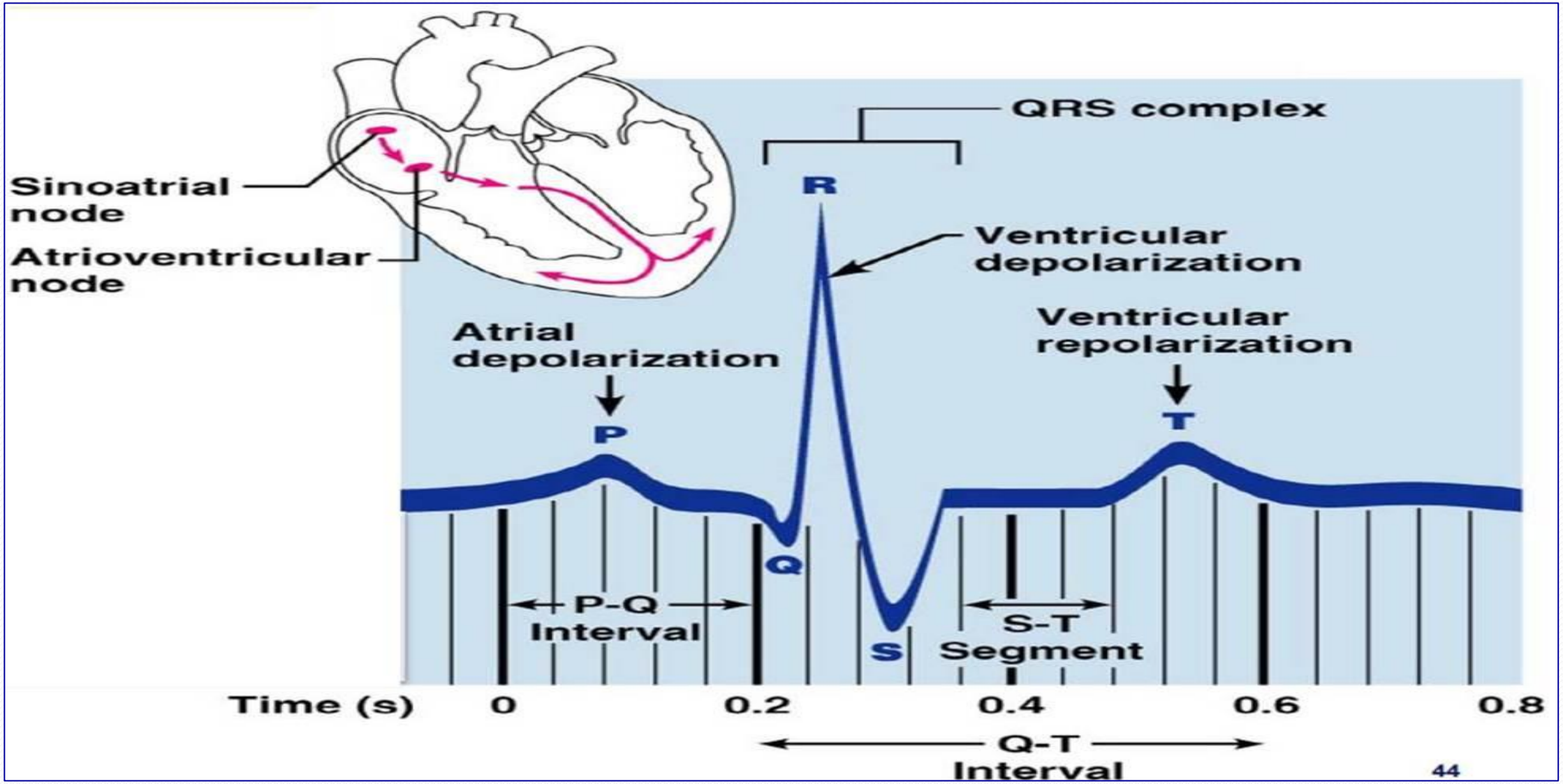
Pen recorder and a moving sheet

ECG Waveforms, Intervals & Segments

- **3 waves: (depolarize & repolarize)**
  - P- wave
  - QRS complex
  - T- wave
    - P, R & T- waves are positive
    - Q & S- waves are negative
- **3 time intervals: (include waves)**
  - P-R interval
  - Q-T interval
  - R-R interval
- **3 segments: (isoelectric, & doesn't include waves)**
  - ST segment
  - TP segment
  - PR segment

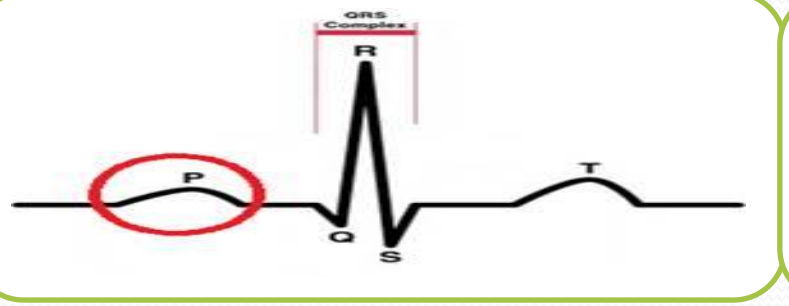


Record of the Electrical activity of the heart by ECG



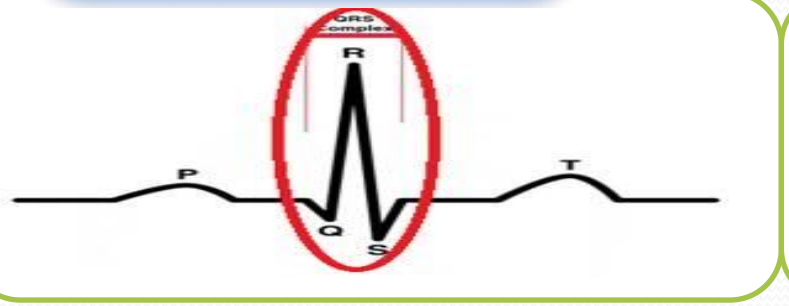
Analysis of Normal ECG

P-wave



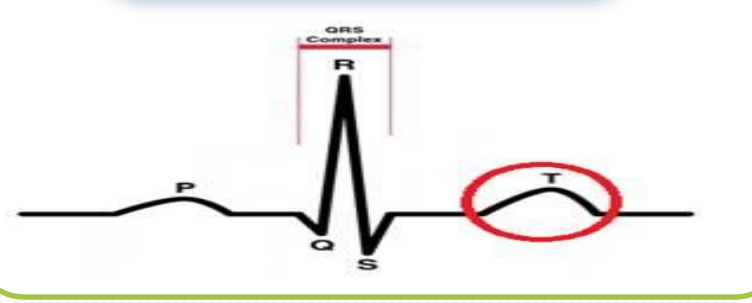
- Due to ***atrial depolarization***
- **P-wave** is recorded before the onset of atrial systole
- Atrial repolarization occurs at the same time with ventricular depolarization. But, since ventricular depolarization wave is giant, it masks the atrial repolarization wave

QRS complex



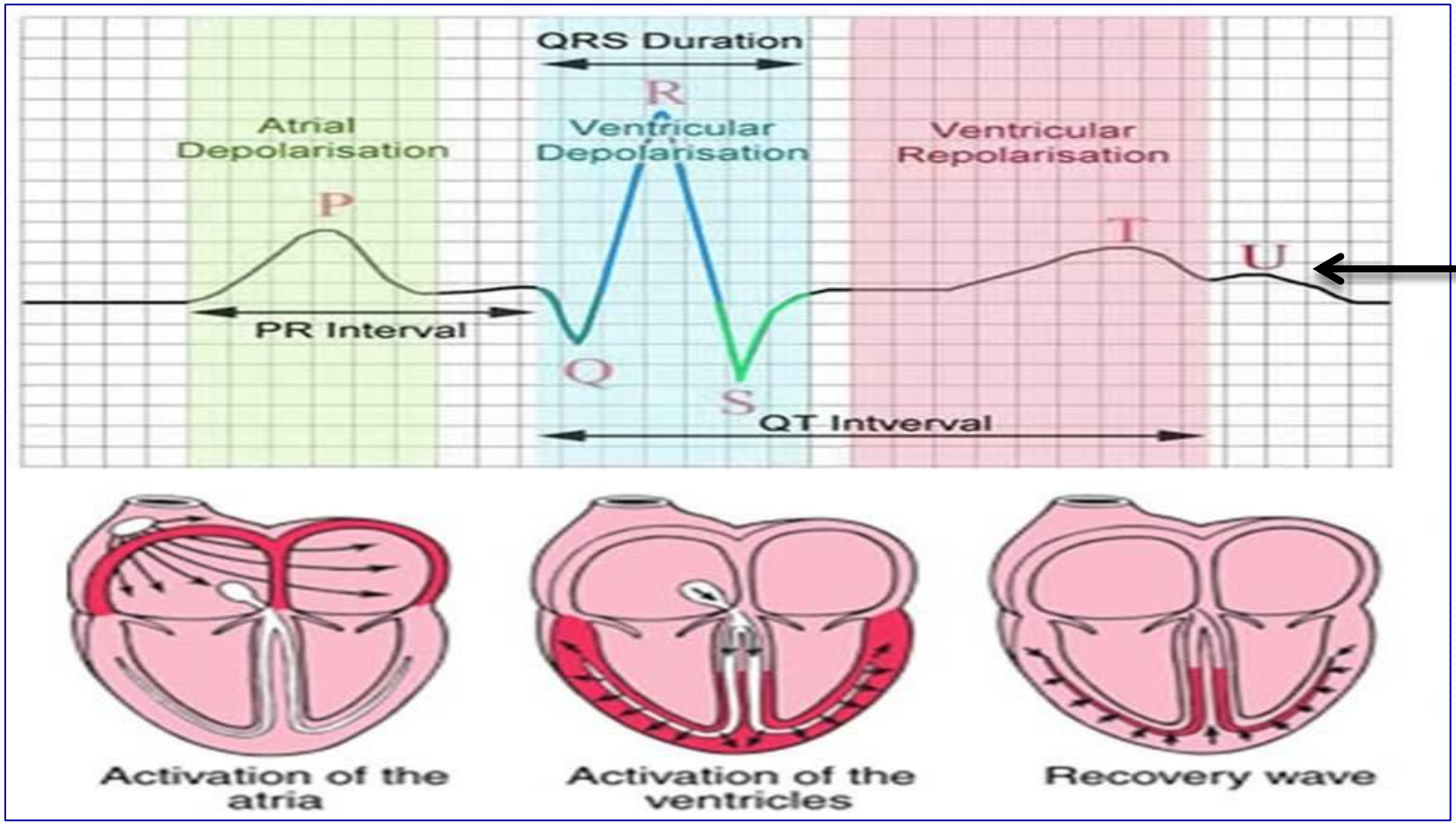
- Due to ***ventricular depolarization***
  - **Q-wave** due to depolarization of interventricular septum
  - **R-wave** due to depolarization of most ventricular wall
  - **S-wave** due to depolarization of base of the heart
- **QRS complex** is recorded before the onset of ventricular systole

T-wave



- Due to ***ventricular repolarization***
- **T-wave** is recorded before the onset of ventricular diastole

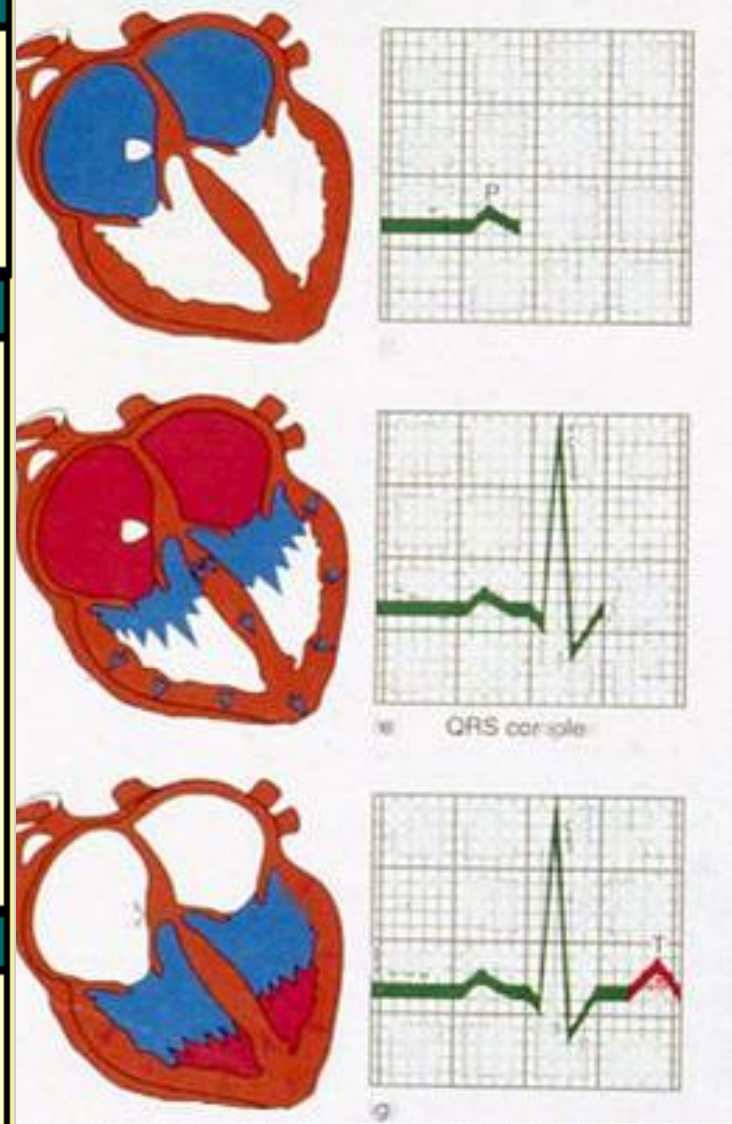
Normal ECG



N.B
Sometimes, 'U' wave is seen on ECG. It may not always be observed as a result of its small size.
'U' waves are thought to represent repolarization of the Purkinje fibers. However, the exact source of the "U" wave remains unclear.

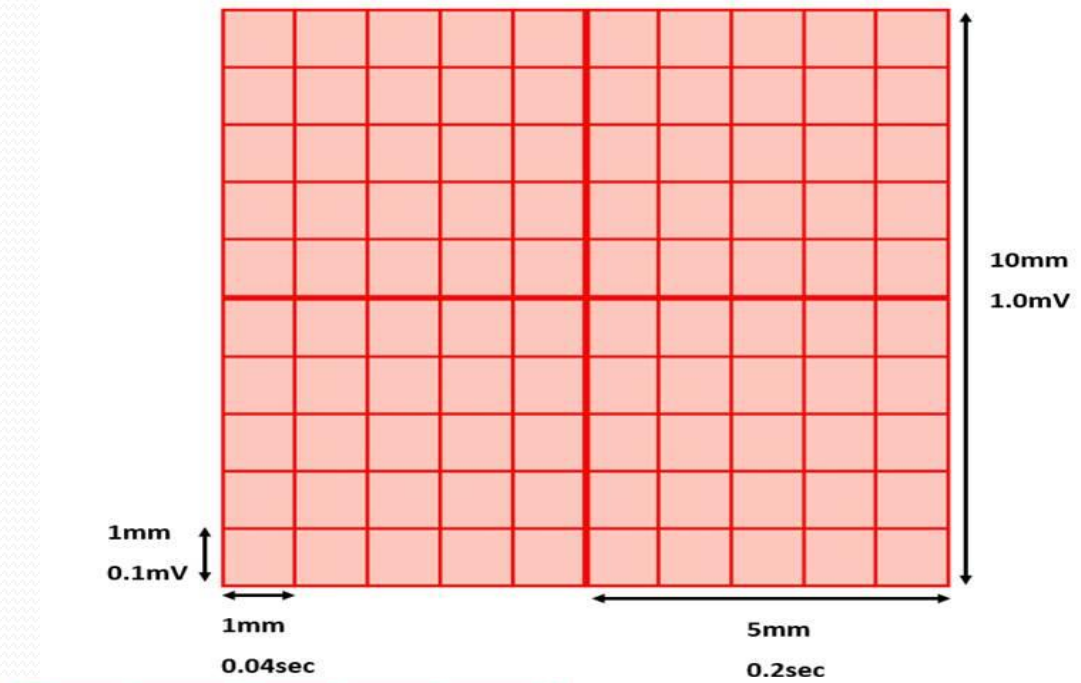
Causes of ECG Waves

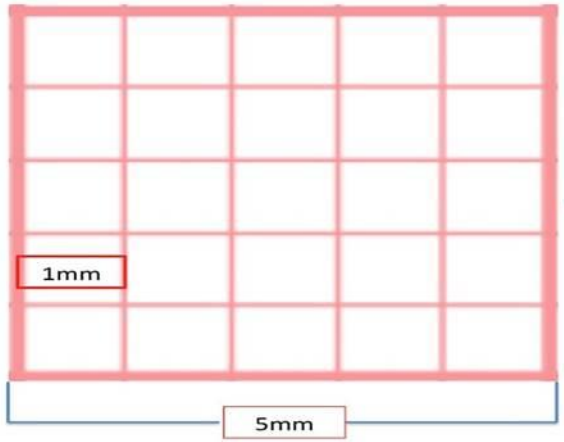
ECG Wave	Cause	Represent
P- wave	Atrial depolarization	◆ Time of electrical impulse from SA node to spread through atrial muscle ◆ Precedes atrial contraction by ≈ 0.02 sec
QRS- complex	Ventricular depolarization	◆ Measured from beginning of Q wave till end of S wave ◆ Consists of 3 waves: **Q wave: (-ve):** Produced by depolarization of interventricular septum **R wave: (+ve):** Produced by depolarization of ventricular wall **S wave: (-ve):** Produced by depolarization of the base of the heart ◆ Precedes ventricular contraction by ≈ 0.02 sec. ◆ Occurs after P-wave by ≈ 0.12-0.2 sec = PR interval
T- wave	Ventricular repolarization	◆ Occurs during latter part of systole, before the onset of diastole

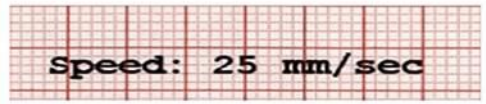


ECG Paper Calibration:Voltage and Time

- ECG is displayed on a graph paper as waves
- Speed: ECG machine runs at 25mm/sec.
- **Time (seconds) is calibrated on the horizontal lines** (X-axis):
  - 1mm square = 1mm= 0.04 second
  - 5 small lines = 0.2 second
  - 25 small lines = 1 second
- **Voltage(millivolt) is calibrated on the vertical lines** (Y-axis):
  - 1mm square= 0.1 mV
  - 10 small squares = 1 mV

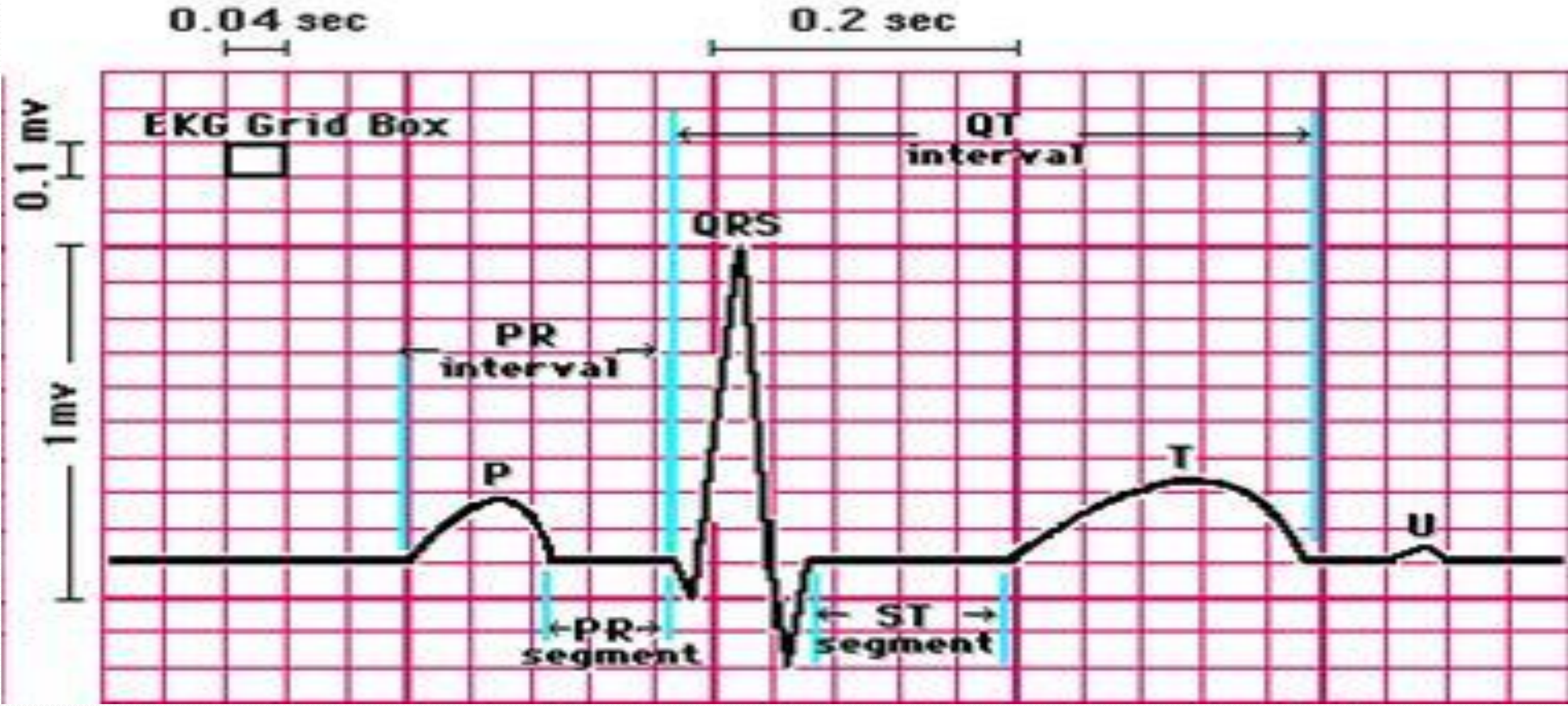






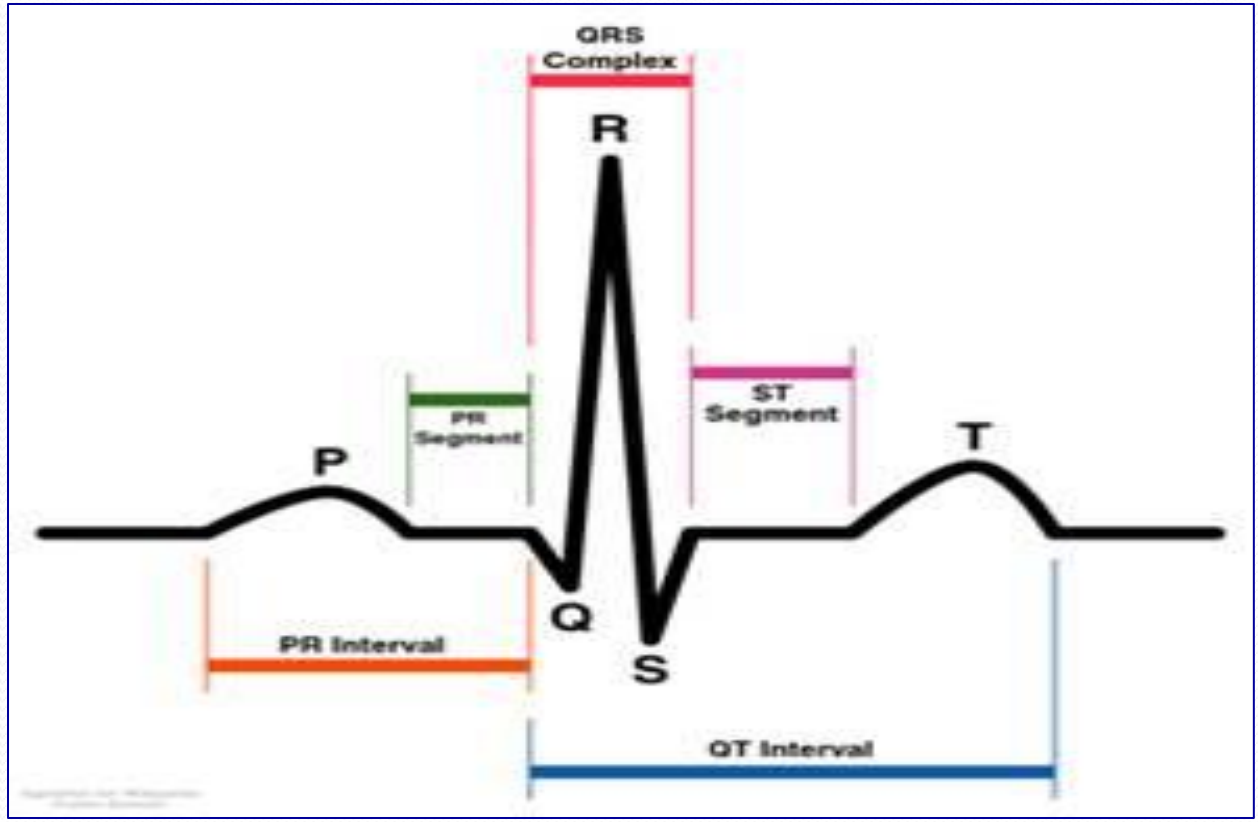
- 25mm = 1 second
- 5mm = 0.2 sec or 200msec
- 1mm = 0.04sec or 40msec

ECG Paper Calibration:Voltage and Time



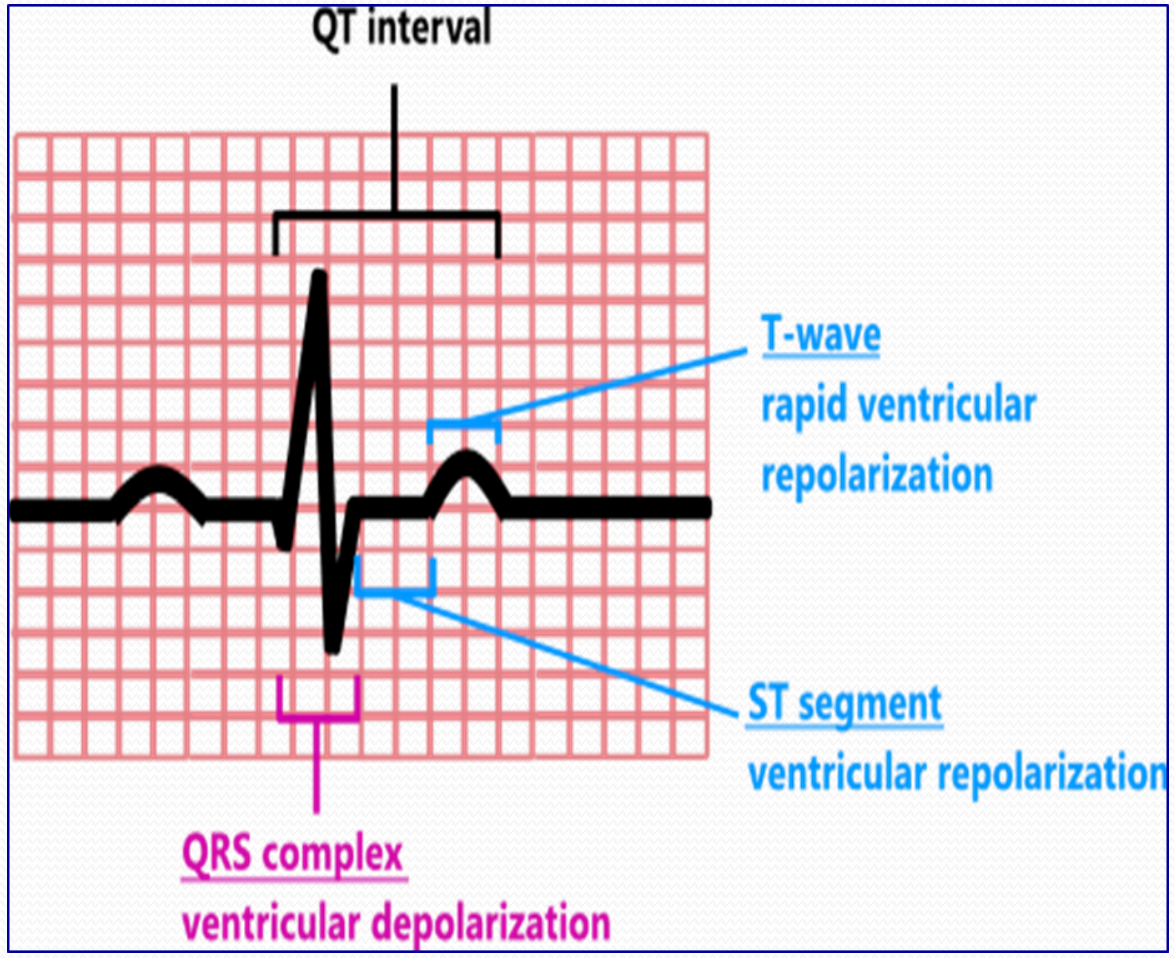
P-R interval

- Time period measured from start of P- wave to start of QRS complex; thus P-R interval includes P- wave & PR segment
- P-R interval is the time from the initial depolarization of atria to the initial depolarization of ventricles.
- P-R interval range = 0.12-0.2 sec.
- An increase in conduction velocity through AV node will decrease P-R interval (sympathetic stimulation) & vice versa.



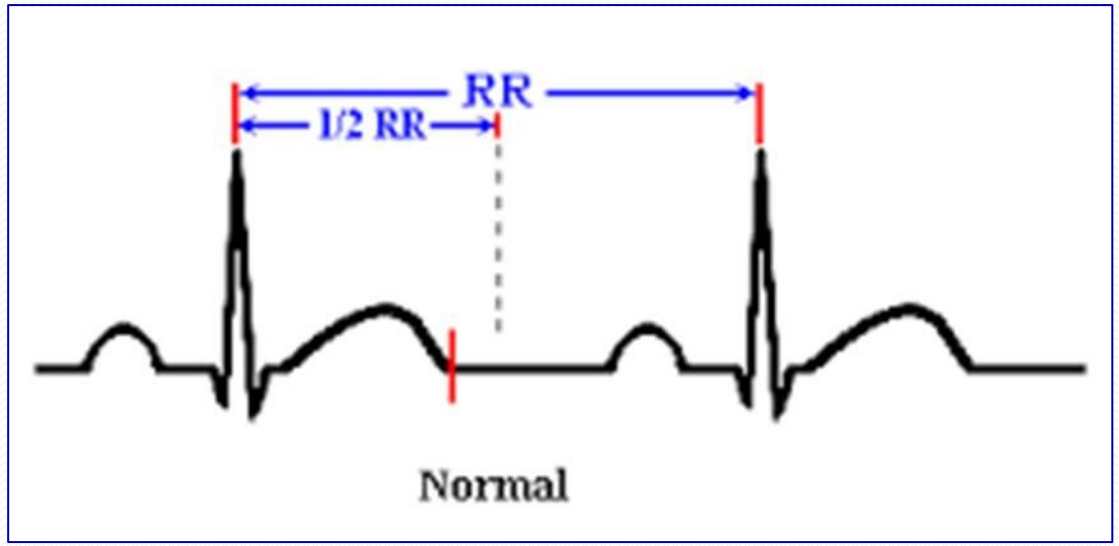
Q-T interval

- Q-T interval is the time from the beginning of the *Q wave* to the end of the *T wave*
- The QT interval represents total time taken by ventricle to depolarize & repolarize [contraction of ventricles]
- The Q-T interval includes the QRS complex, ST segment & T- wave.
- Q-T interval range = 0.35 – 0.45 sec.
- Approximate refractory period of ventricle.



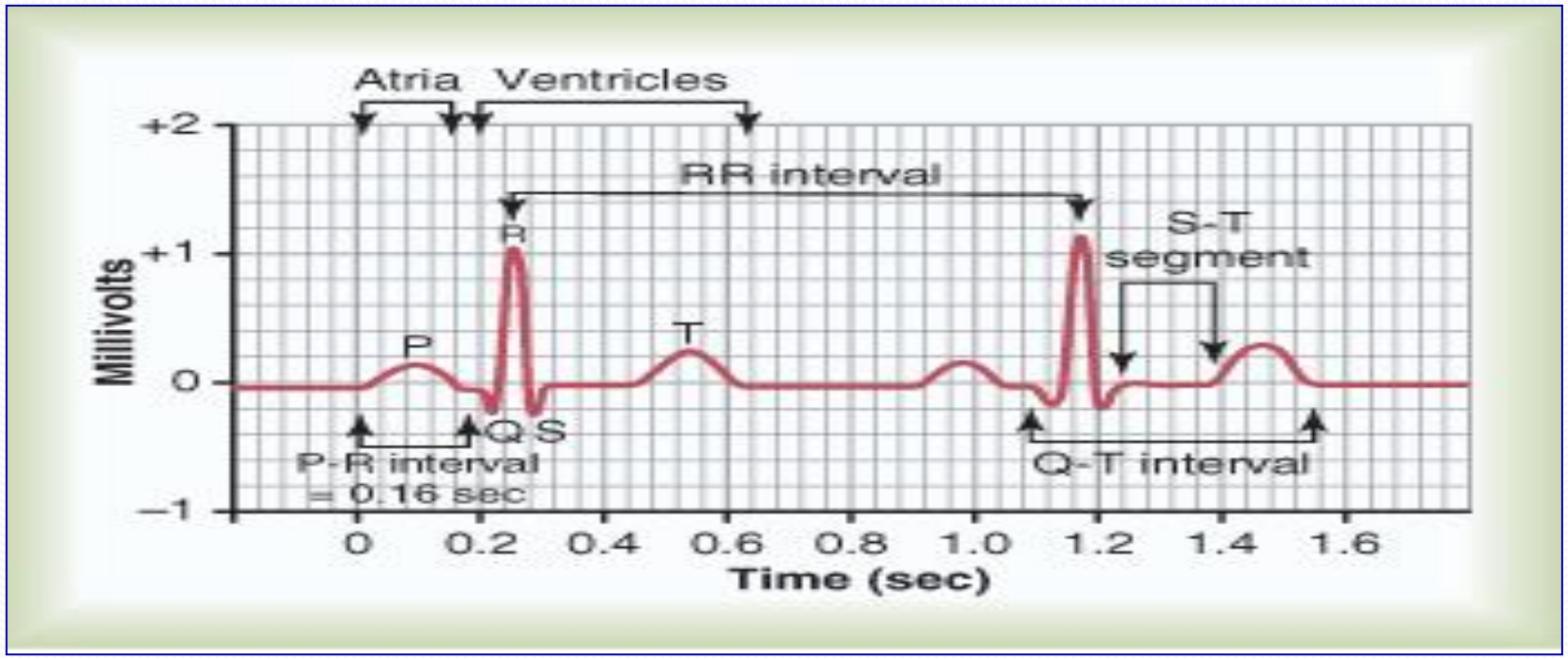
R-R interval

- The interval between two successive R- waves.
- It determines the heart rate & cardiac cycle length.
- Heart rate can be measured by counting the number of R-waves per minute.



Heart Rate

- The heart rate is the repetition of the time interval between two successive heart beats.
- If the interval between 2 beats is 1 second , the heart rate is 60 beats per minute.

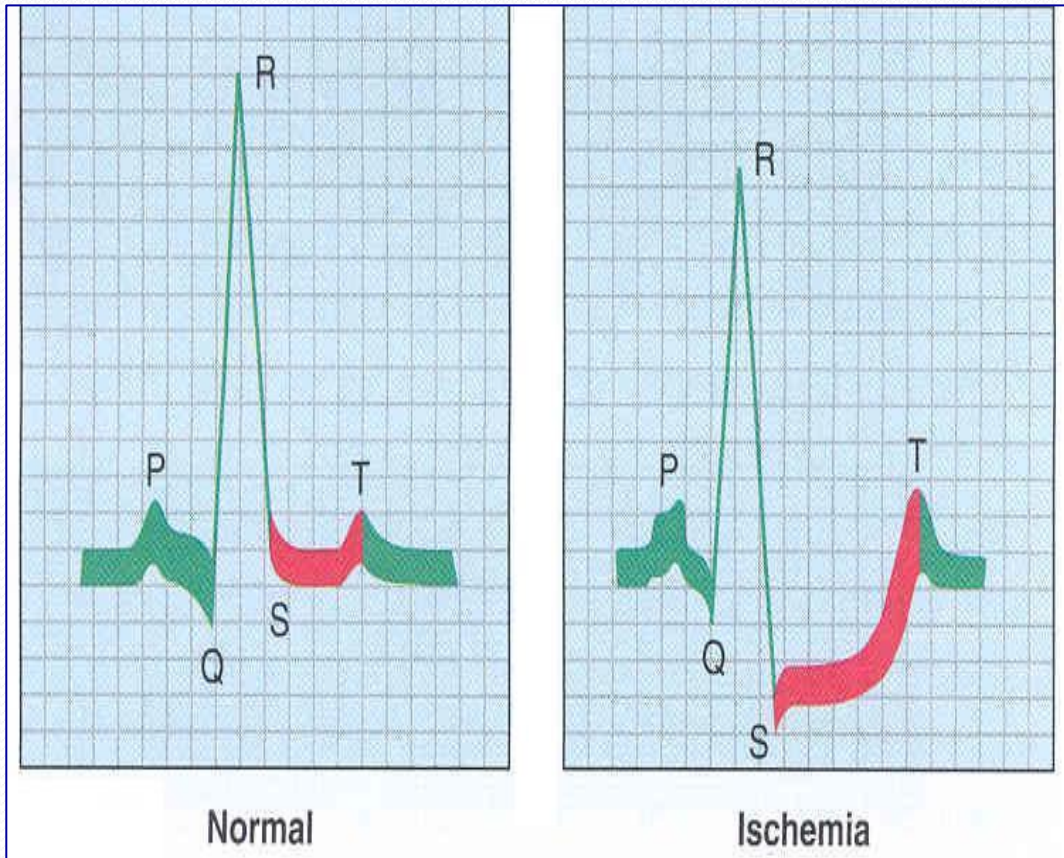


How to calculate HR from ECG

$$\text{Heart Rate} = \frac{300}{\text{No. large squares between two QRS complexes}}$$

S-T segment

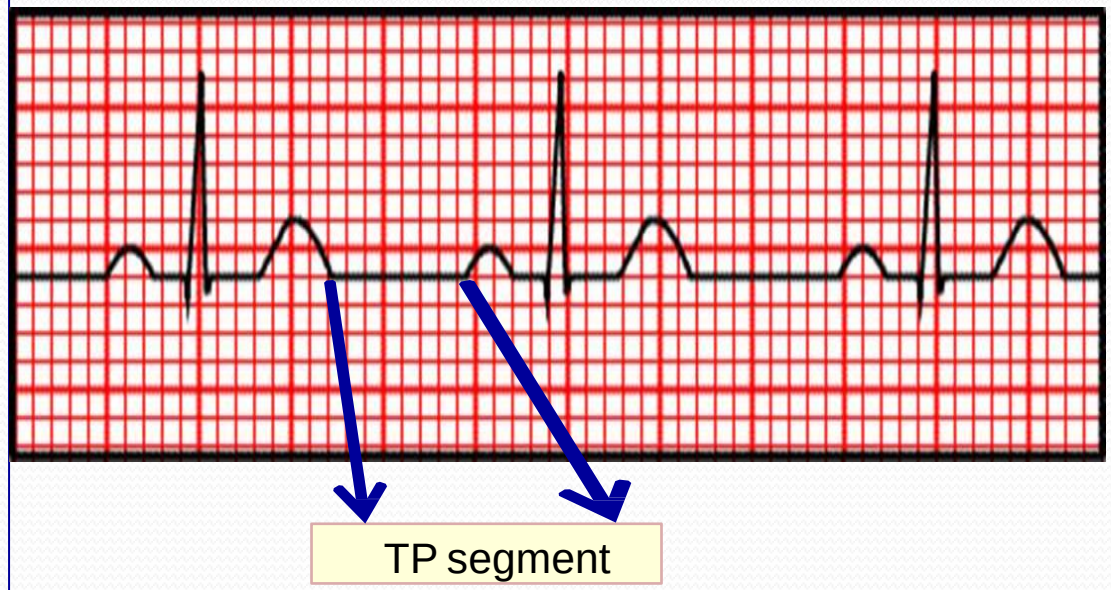
- It is segment of ECG from end of S wave to beginning of T wave.
- During this segment all ventricular muscles are completely depolarized, i.e. no potential difference between areas of myocardium at this stage.
- It roughly corresponds to the plateau phase of the ventricular action potential
- A normal S-T segment is on isoelectric line.
- If it is deviated up or down, it indicates diseased fibers.
- One ECG diagnostic change for acute myocardial infarction is ST segment elevation and inverted T wave.



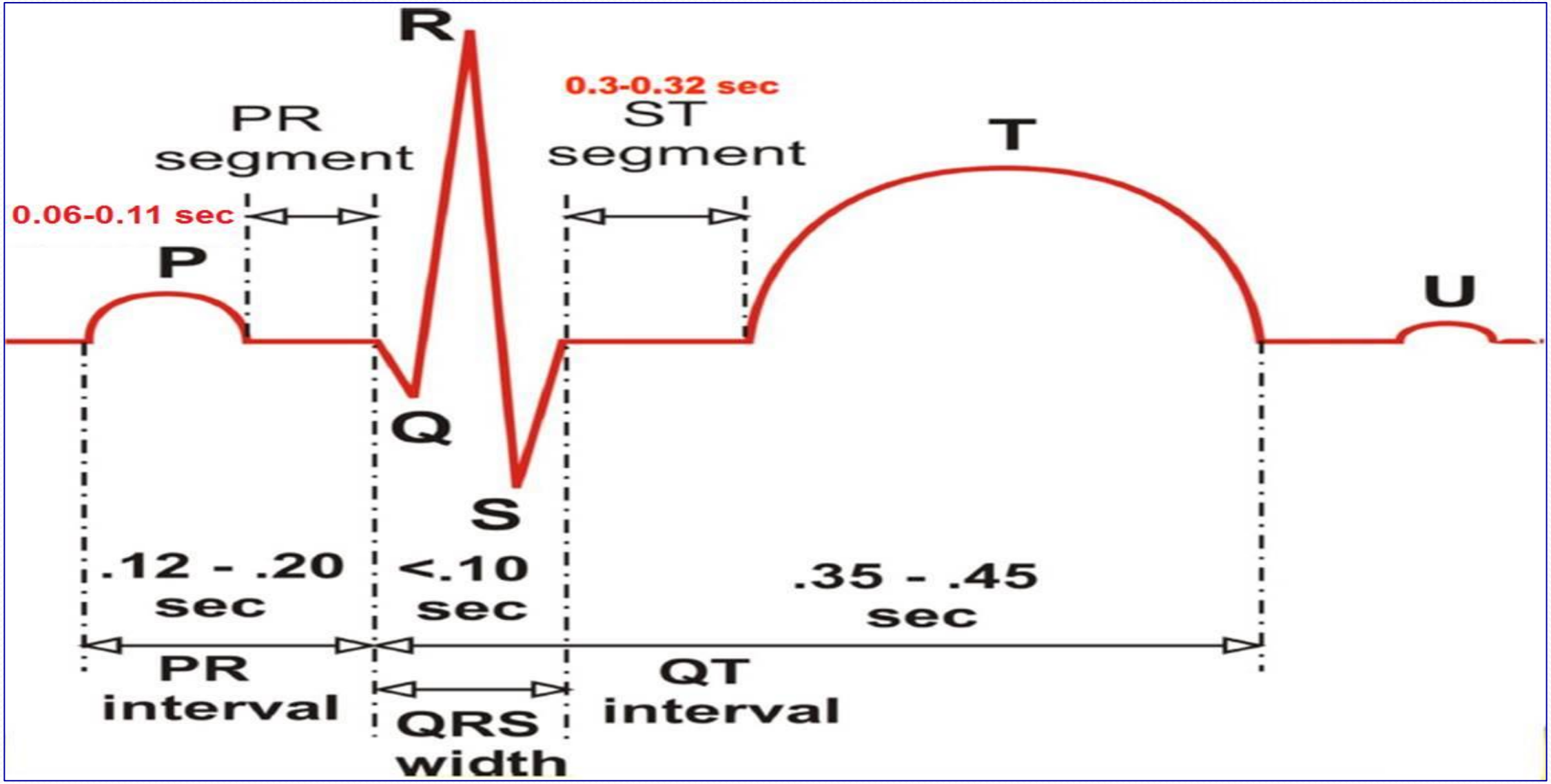
Depression of the S-T segment as a result of myocardial ischemia

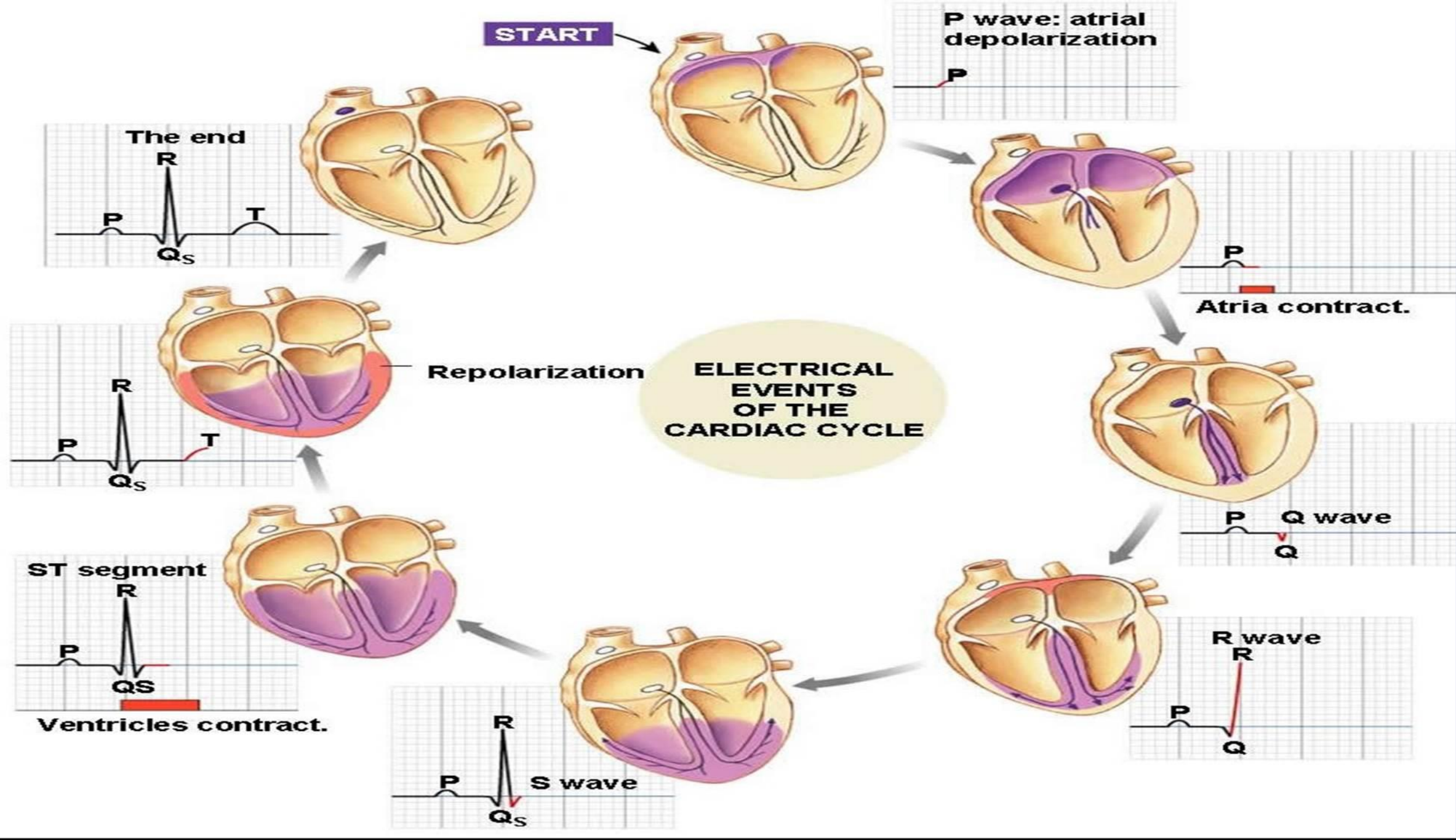
T-P segment

- Calculated from end of T- wave to beginning of P- wave.
- Time interval from ventricular repolarization till next atrial depolarization.
- It represents ventricular filling



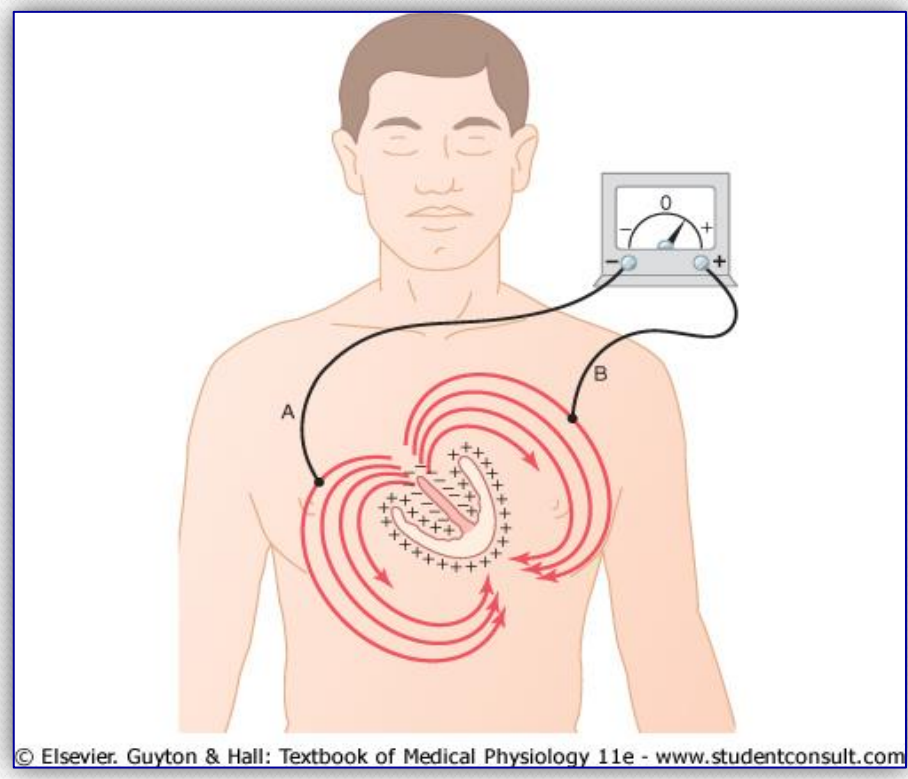
Duration of ECG Waves & Intervals




START
P wave: atrial depolarization
P
Atria contract.
P
Q wave
Q
R wave
R
P
Q
S wave
R
P
QS
ST segment
R
P
QS
Ventricles contract.
Repolarization
R
P
T
QS
The end
R
P
T
QS
ELECTRICAL EVENTS OF THE CARDIAC CYCLE

Flow of Electrical current in the Heart

- In normal ventricles, current flows from the *electronegative* inner surface of the heart to the *electropositive* outer surface (from the ***base*** of the heart to the ***apex***).
- An electrode placed near the base of the heart is electronegative, and near the apex is electropositive
- The first area that depolarizes is the *ventricular septum*



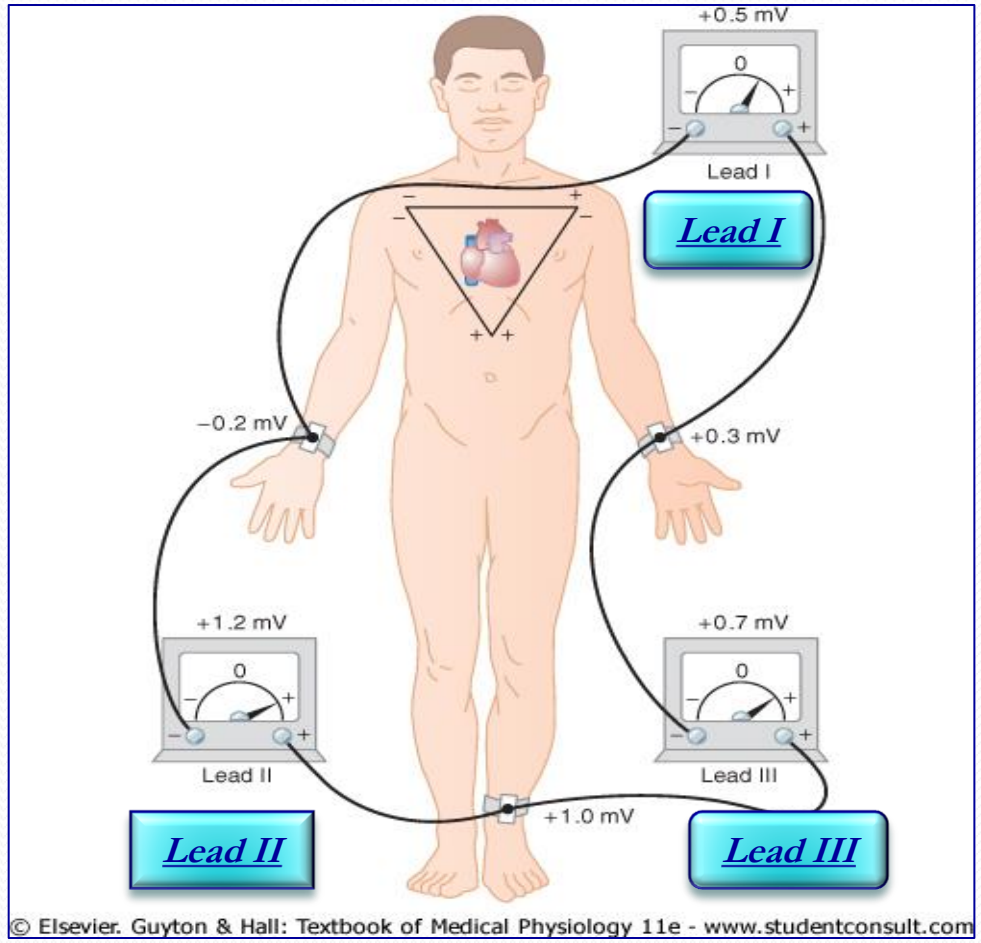
The ECG Leads

- An ECG lead is a pair of electrodes and their wires to make a complete circuit. They are applied to particular parts of the body.
- ECG leads are:-
  - The Bipolar Limb Leads: (I, II, III)
  - Augmented Unipolar Limb Leads (aVR, aVL, aVF)
  - Chest Leads: (V1, V2, V3, V4, V5, V6)

The Bipolar (Standard) Limb Leads

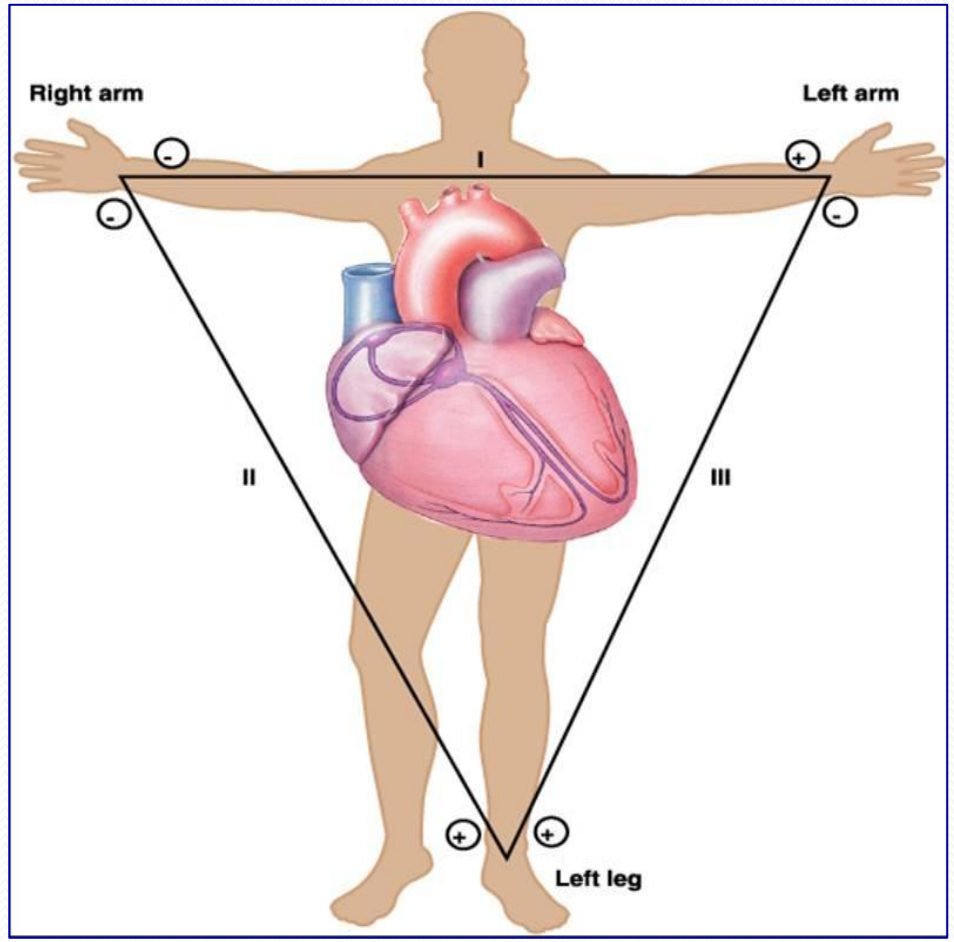
Bipolar: means that two electrodes are used for recording the ECG. They are:-

- **Lead I:**
  - *Connects right arm (-ve) & left arm (+ve)*
- **Lead II:**
  - *Connects right arm (-ve) & left leg (+ve)*
- **Lead III:**
  - *Connects left arm (-ve) & left leg (+ve)*



Einthoven's Triangle

- The standard limb leads can be represented by Einthoven triangle. The heart is considered to lie in center (the triangle is drawn around the area of the heart).
- The two apices at the upper part of the triangle represent the points at which the two arms connect electrically
- The lower apex is the point at which the left leg connects



Einthoven's Law

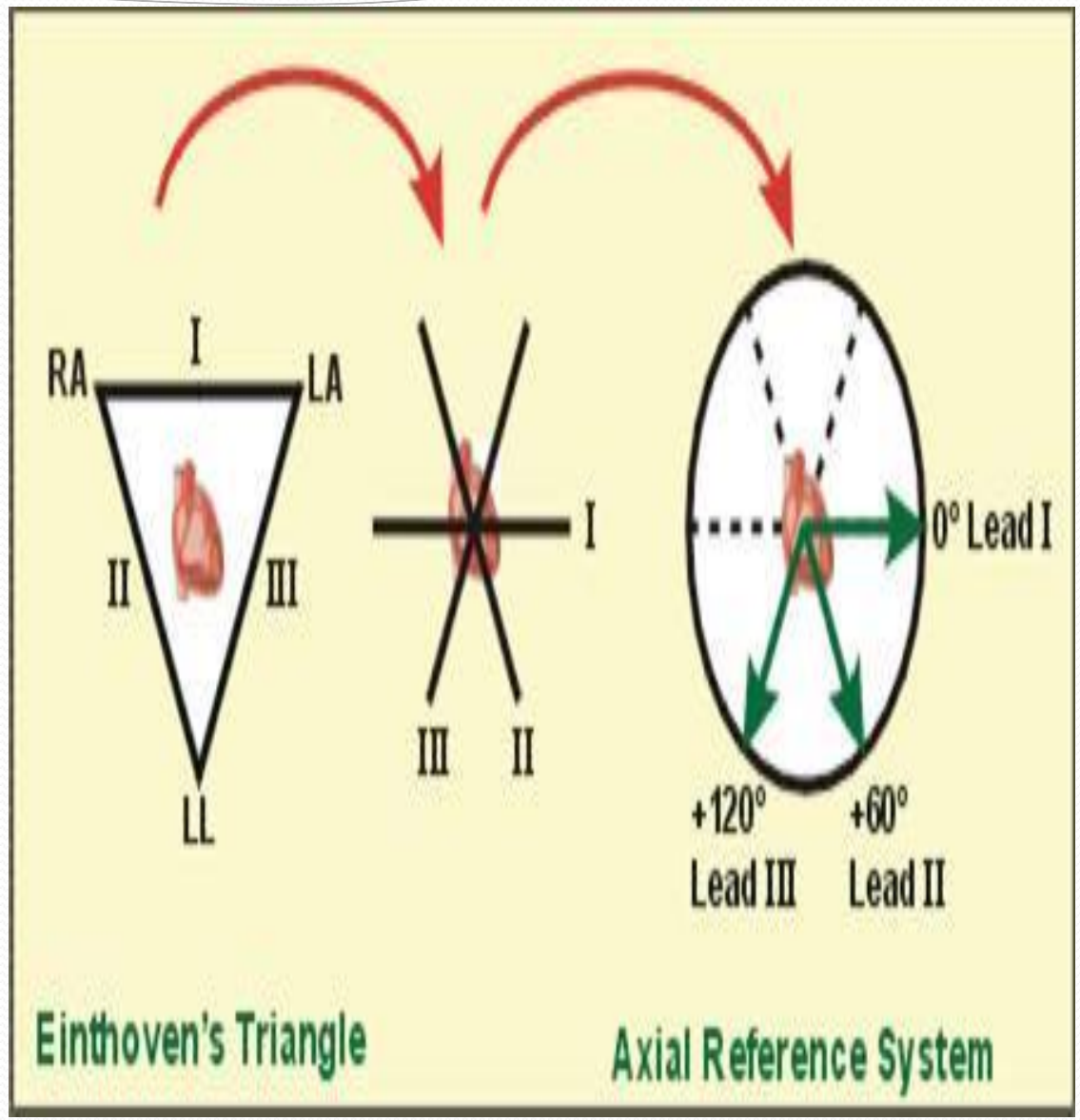
- **Einthoven's Law**: if the electrical potential of any two of the three bipolar limb leads are known, the third one can be determined mathematically by summing the first two (note the +ve and -ve signs)

Einthoven's law

The sum of the voltage in Lead I + Lead III= Lead II

Hexagonal reference system

- The direction of axis of 3 standard limb leads can be represented by 3 intersecting lines:-
  - The axis of lead I is 0 degree
  - The axis of lead II is 60 degree
  - The axis of lead III is 120 degree.

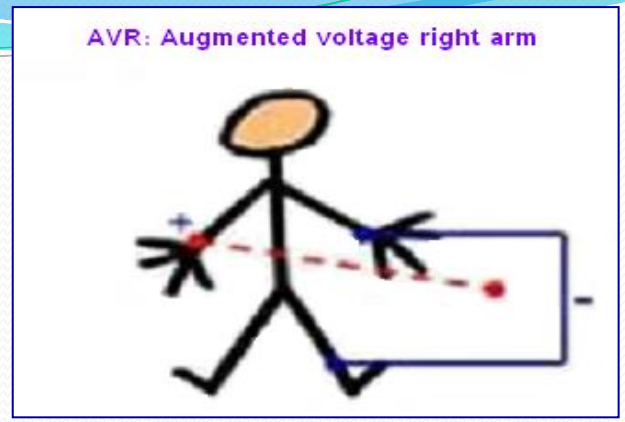


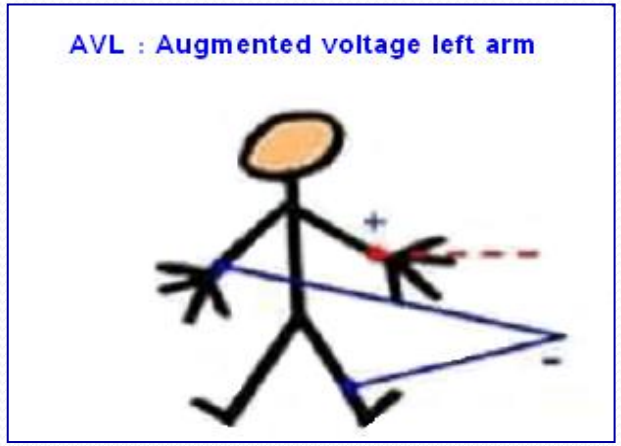
Augmented Unipolar Leads

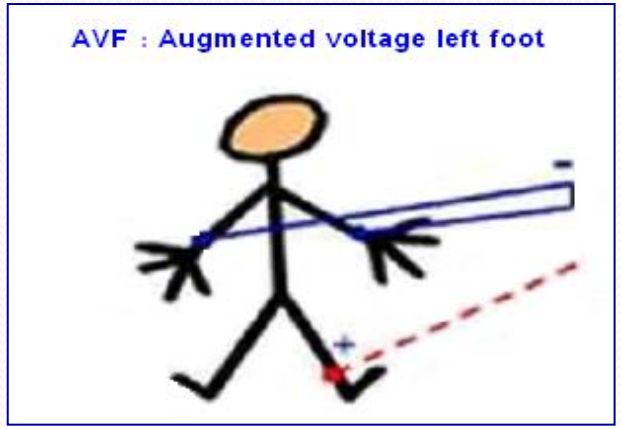
- ECG record is by using an active or exploring electrode connected to an indifferent electrode at zero potential.
- One limb is connected to the positive terminal of the ECG.
- The other two limbs are connected to the negative terminal of the ECG.
- These are aVR, aVL, aVF
- All are similar to the standard limb leads
- aVR lead is inverted

Augmented Unipolar Leads…..Cont.

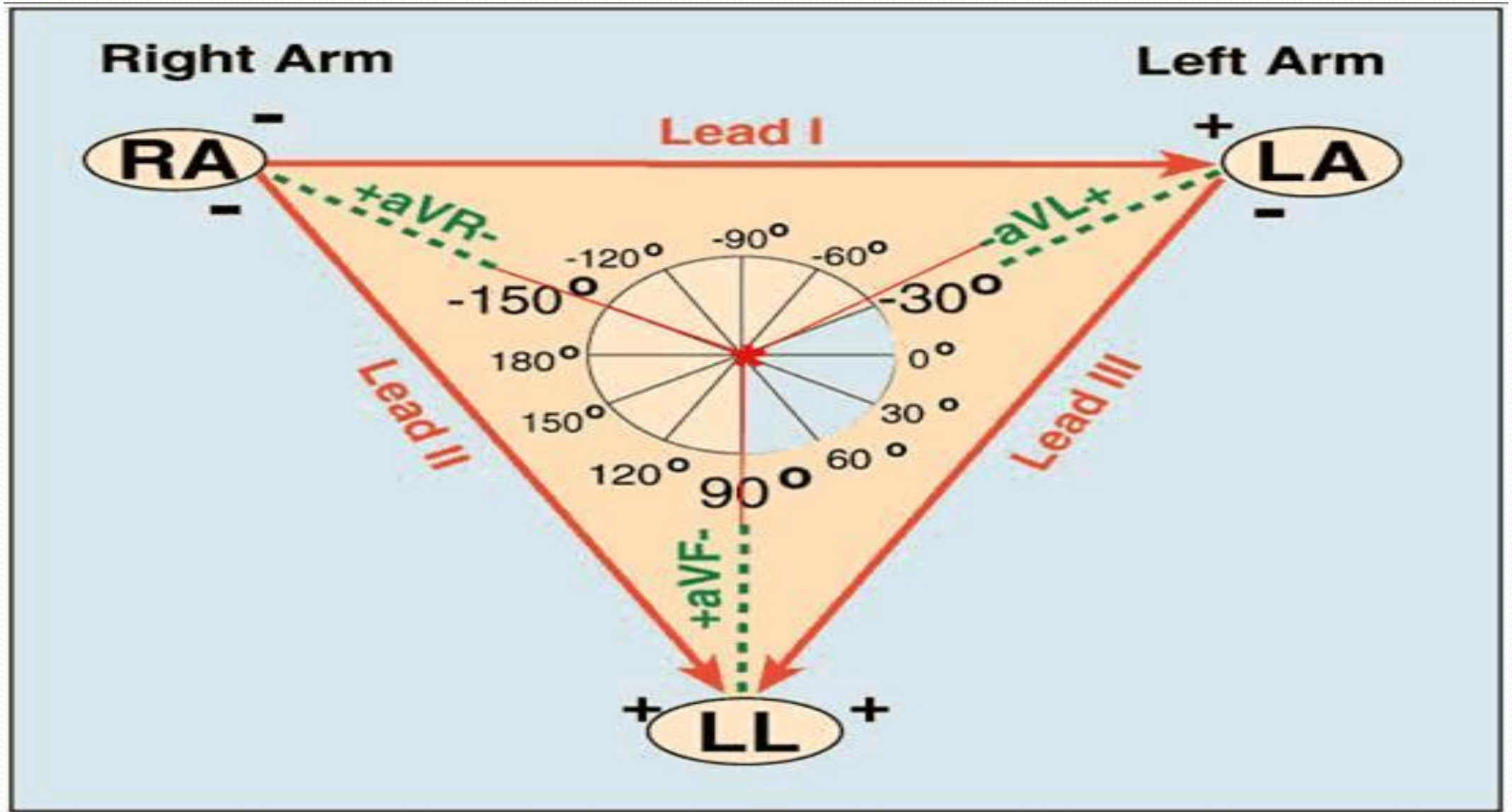
- They labeled according to limb to which the exploring (positive) terminal of machine is connected.
- When the positive terminal is connected to ***right arm*** and other electrode is connected to other 2 limbs = **aVR**.
- When the positive terminal is connected to ***left arm*** and other electrode is connected to other 2 limbs = **aVL**.
- When the positive terminal is connected to ***left foot*** and other electrode is connected to other 2 limbs = **aVF**.
- Letter (a) means augmentation i.e. ↑ magnitude of recording 1.5 times.



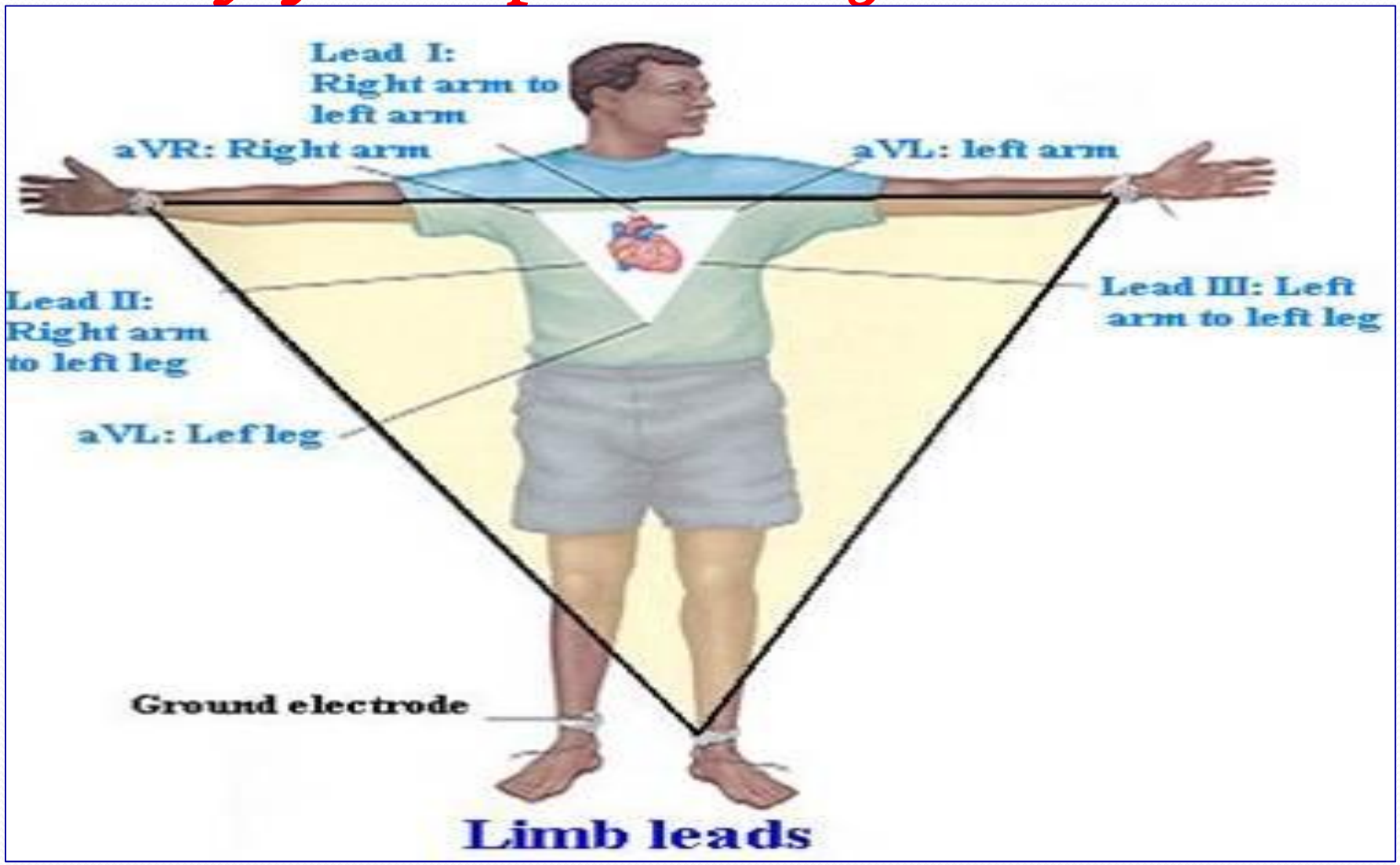




Summary of The Bipolar & Augmented limb Leads

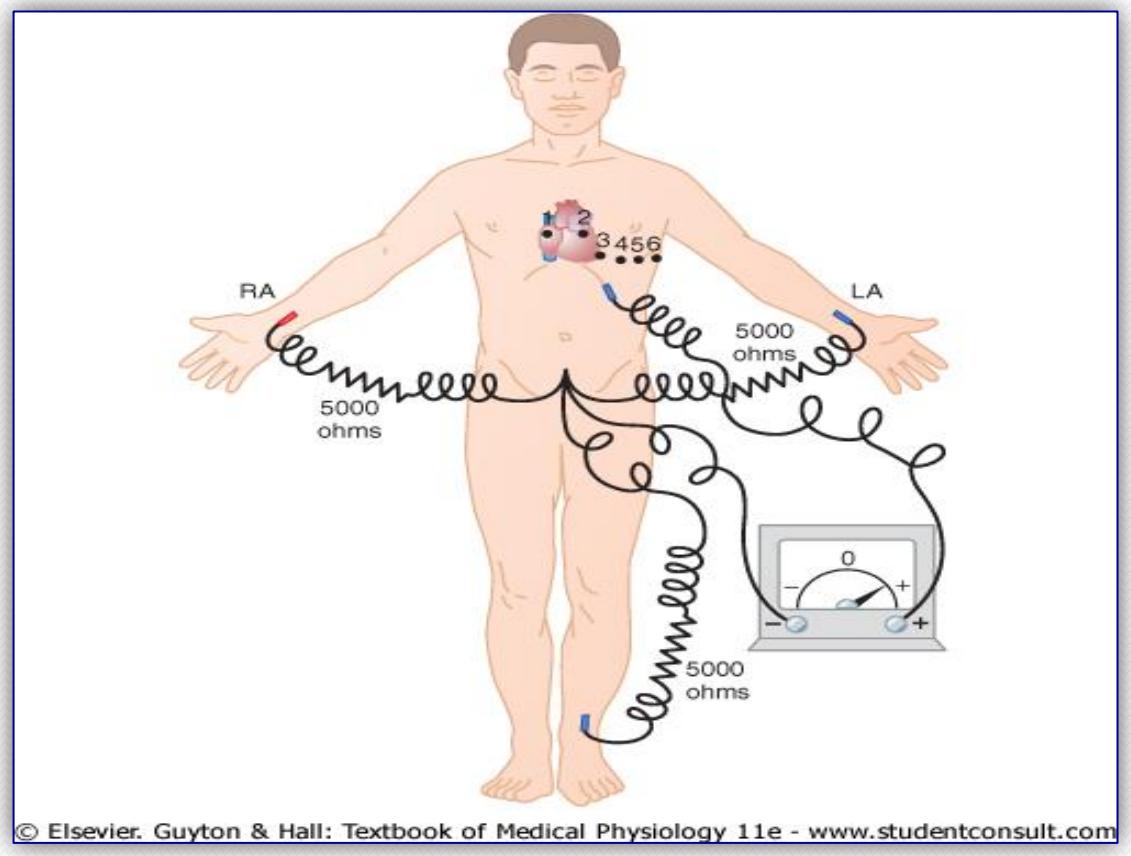


Summary of The Bipolar & Augmented limb Leads



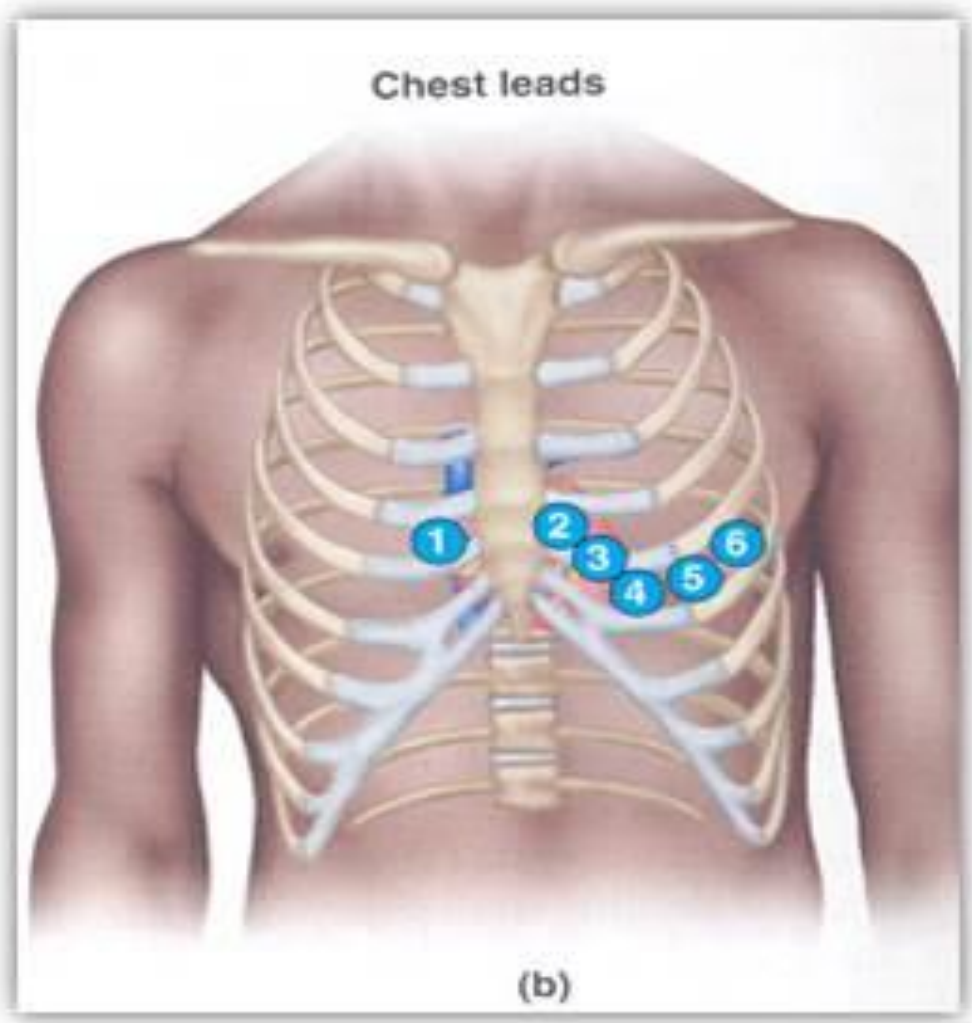
Chest Leads

- Exploring (positive) electrode is placed on chest
- The indifferent (negative) electrode is connected to the 3 limbs:- the right arm, left arm, and left leg.
- They include leads V I-6.



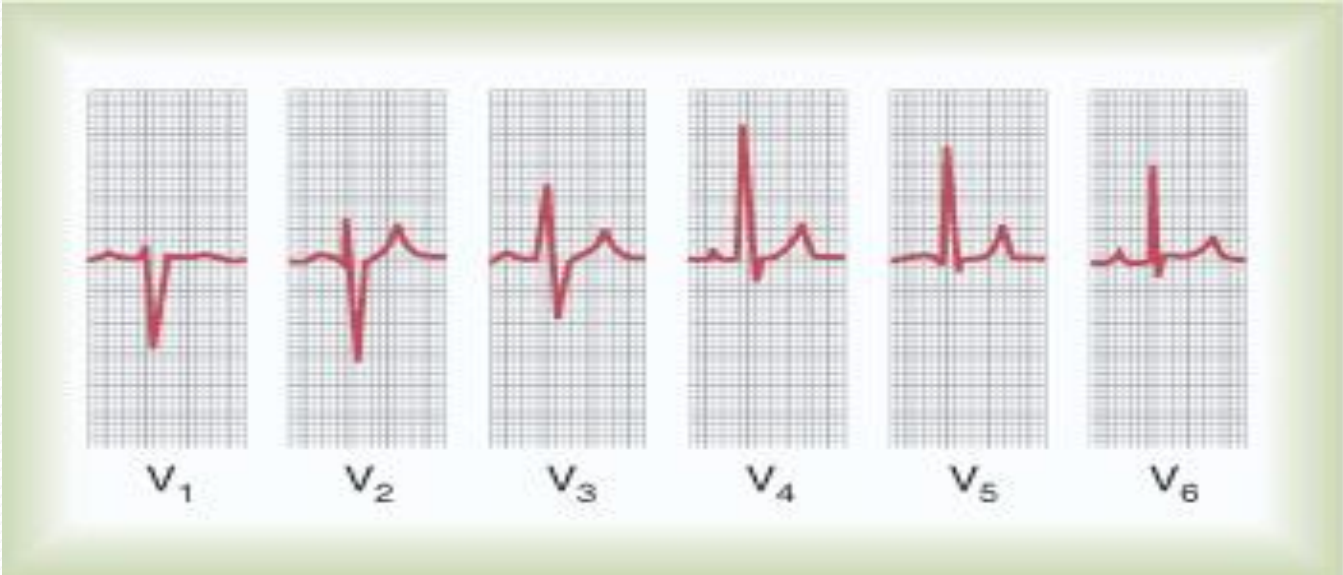
Chest Leads….Cont.

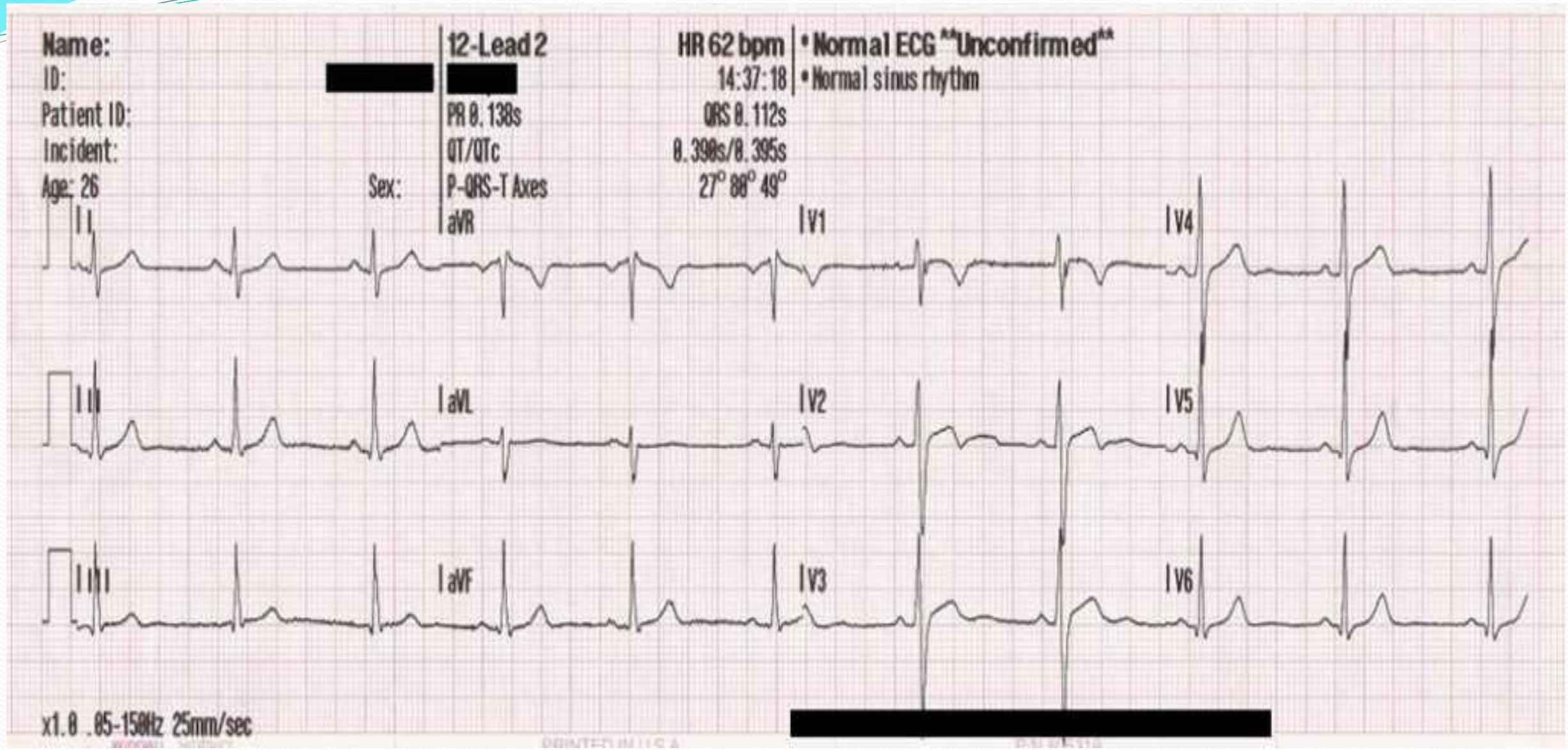
- **V1:-** At right 4th intercostal space near sternum.
- **V2:-** At ***left 4th*** intercostal space near sternum.
- **V3:-** Midway between V2 & V4.
- **V4 :-** At ***left 5th*** intercostal space at ***midclavicular*** line.
- **V5 :-** At ***left 5th*** intercostal space at ***anterior axillary*** line.
- **V6 :-** At ***left 5th*** intercostal space at ***midaxillary*** line.



Chest Leads…..Cont.

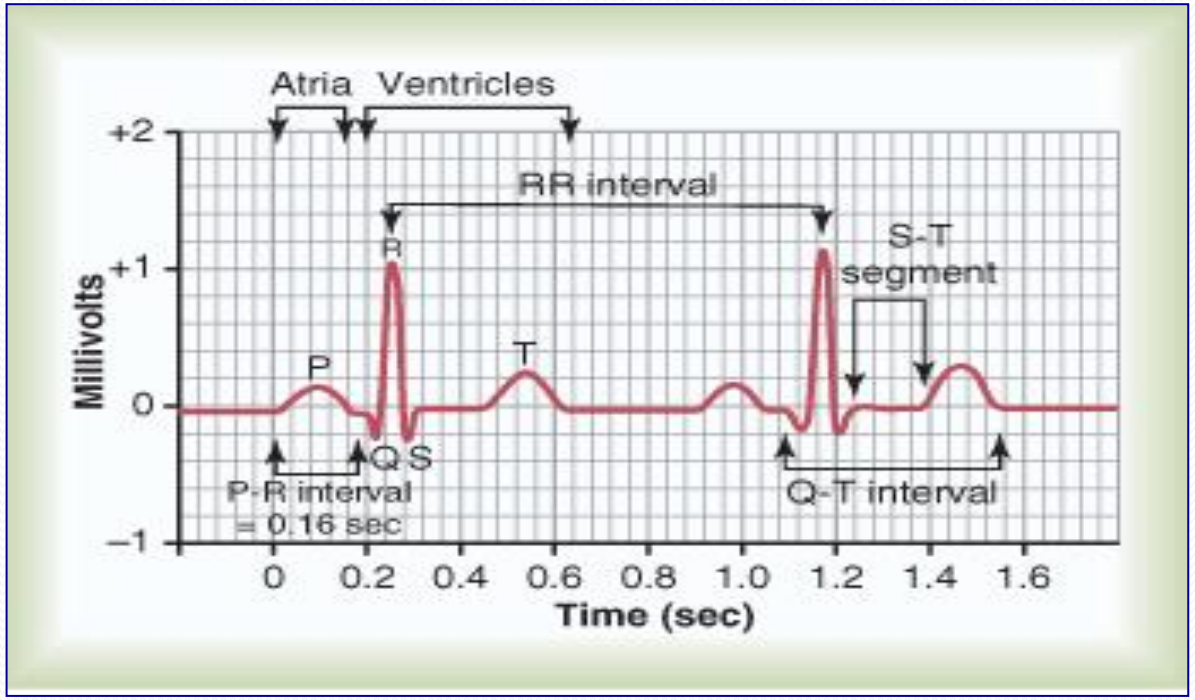
- **V1 & V2:** QRS are mainly negative because the chest leads are nearer to the base of the heart (electronegative).
- **V3, V4, V5 & V6** are mainly positive because the chest electrode are nearer to the apex (electropositive).




Name:
ID:
Patient ID:
Incident:
Age: 26
Sex:
12-Lead 2
PR 0.138s
QT/QTc
P-QRS-T Axes
aVR
HR 62 bpm
14:37:18
QRS 0.112s
0.398s/0.395s
27° 88° 49°
• Normal ECG **Unconfirmed**
• Normal sinus rhythm
I
II
III
aVL
aVF
V1
V2
V3
V4
V5
V6
x1.0 .05-150Hz 25mm/sec

Practical use of the ECG

- Heart rate
- Normal intervals
- Rhythm
  - Regular
  - Single p-wave precedes every QRS complex
  - P-R interval is constant and within normal range
- Cardiac Axis



For further readings and diagrams:

Textbook of Medical Physiology by Guyton & Hall

Chapter 11 (The Normal Electrocardiogram)