



Cardiac electrophysiology: from cellular action potential to tracing analysis.

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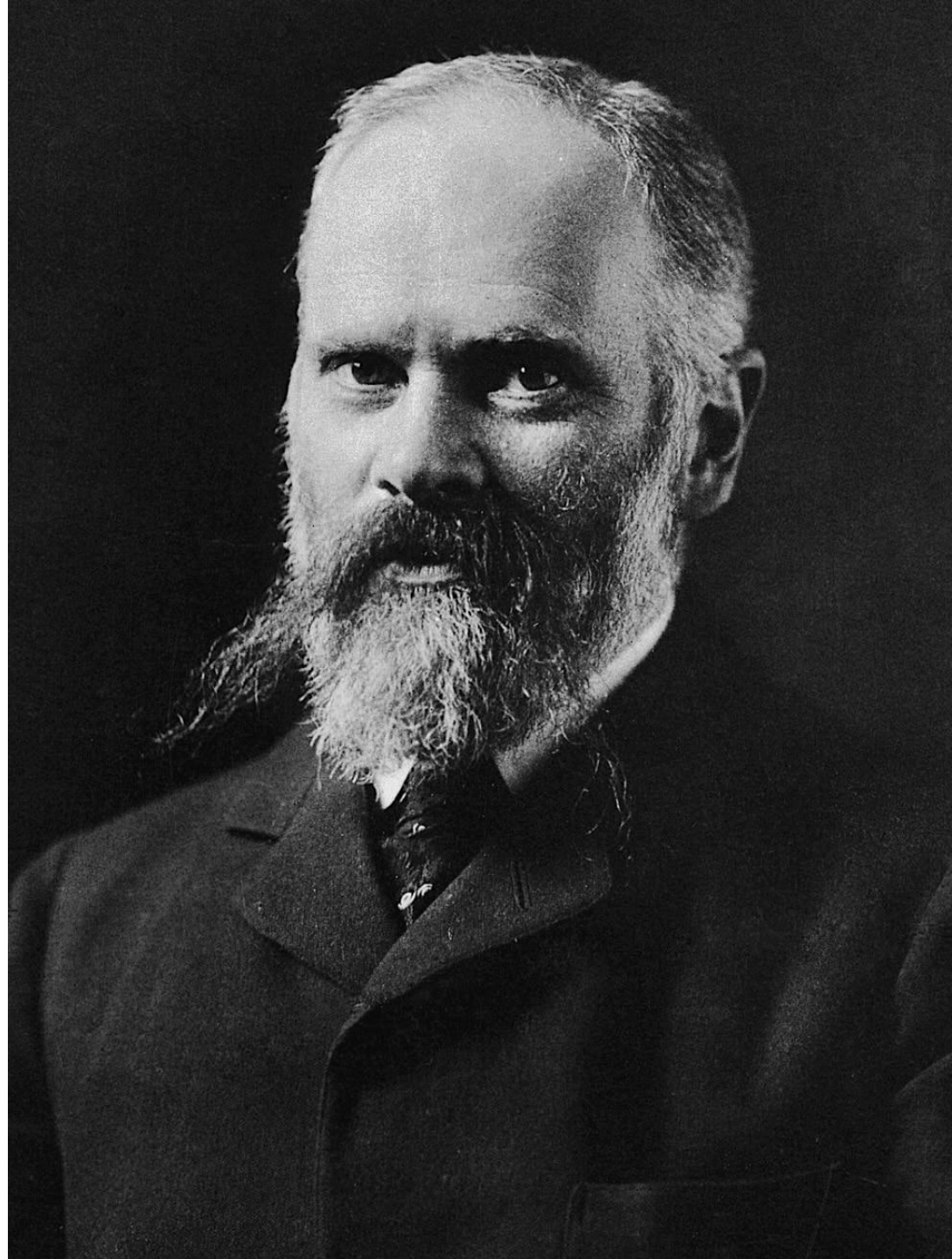
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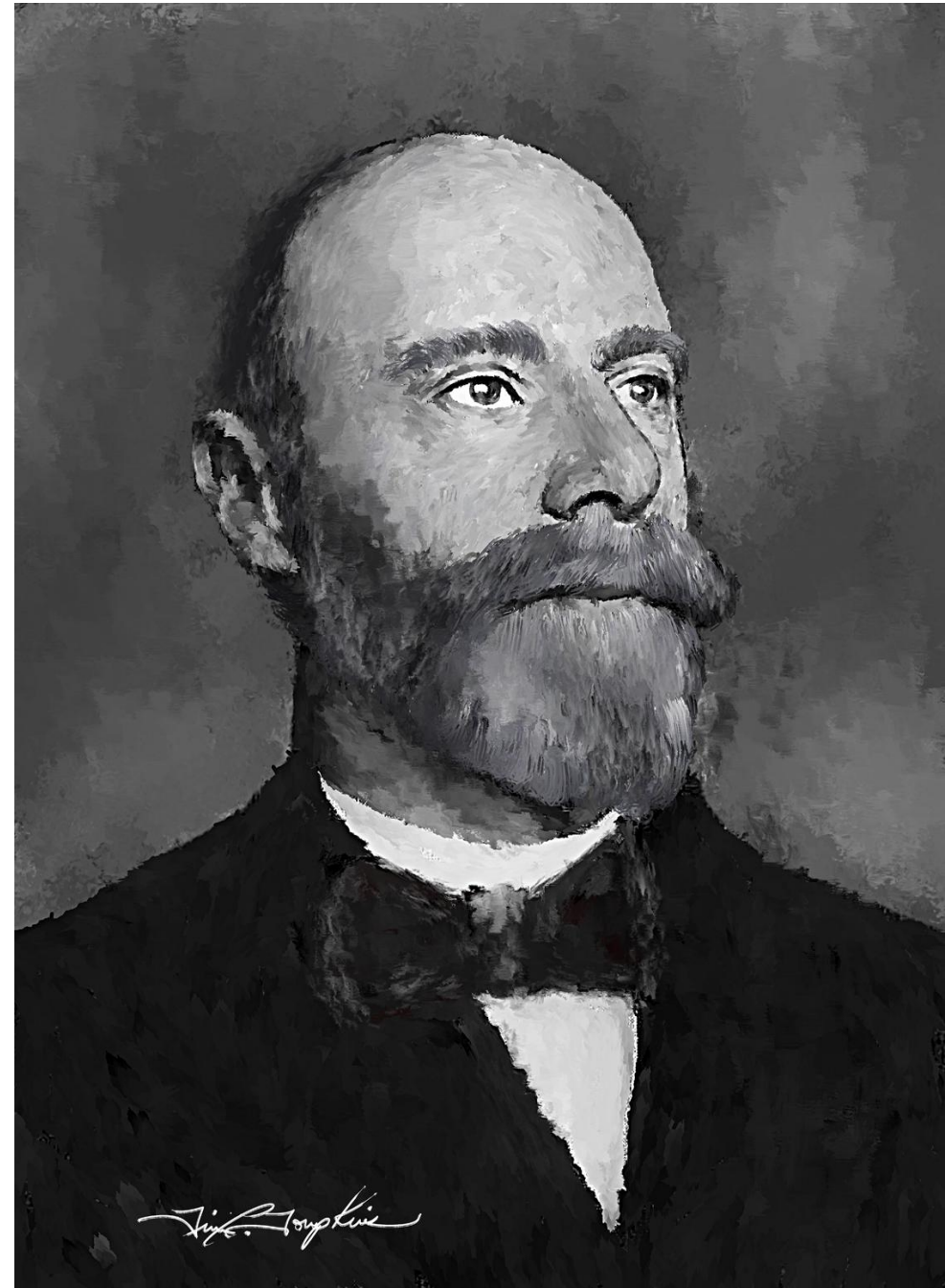
Learning objective

- At the end of the session the audience will be able to,
 1. Define ECG
 2. List the waves of ECG
 3. Interpret the intervals of ECG
 4. Understand the voltage & time calibration of ECG
 5. Identify the leads of ECG
 6. Calculate Heart rate from ECG
 7. Correlate ECG abnormalities in clinical conditions like heart block, ischemia & infarction

- British physiologist **Augustus Waller**. In 1887, Waller recorded the very first human electrocardiogram using a capillary electrometer

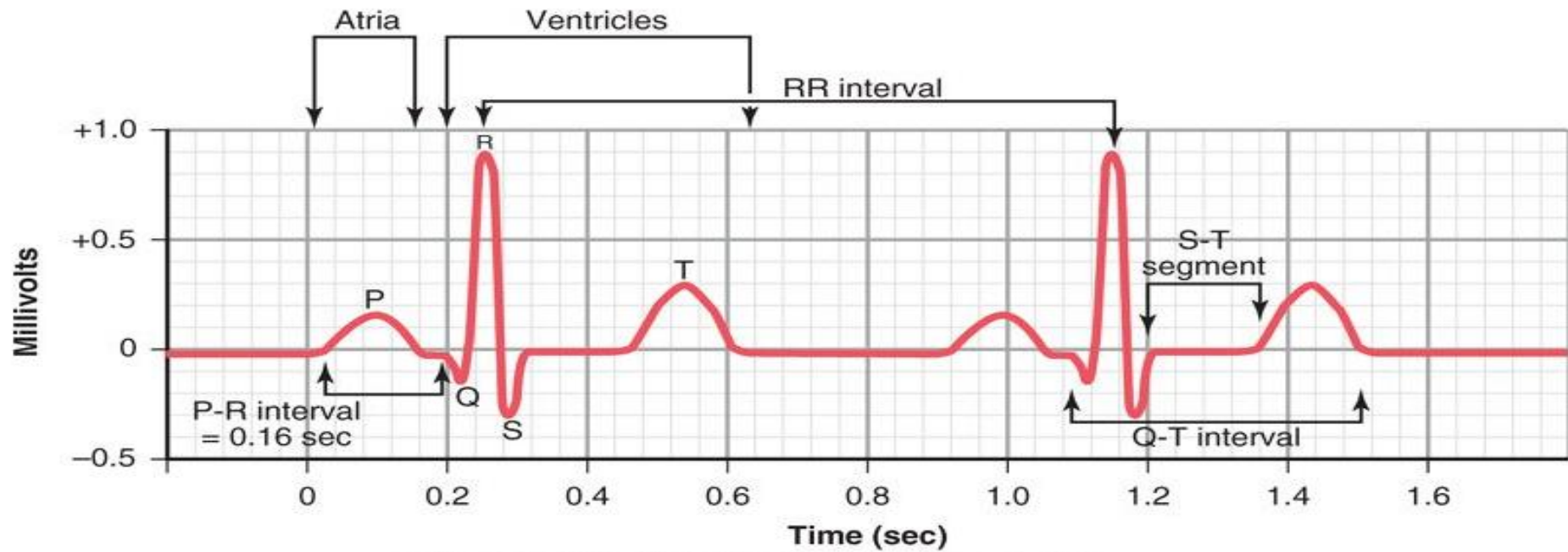


- Willem Einthoven, a Dutch doctor and physiologist, invented the first practical **electrocardiogram (ECG/EKG)** in 1903.
- A breakthrough that earned him the **Nobel Prize in Physiology or Medicine** in 1924

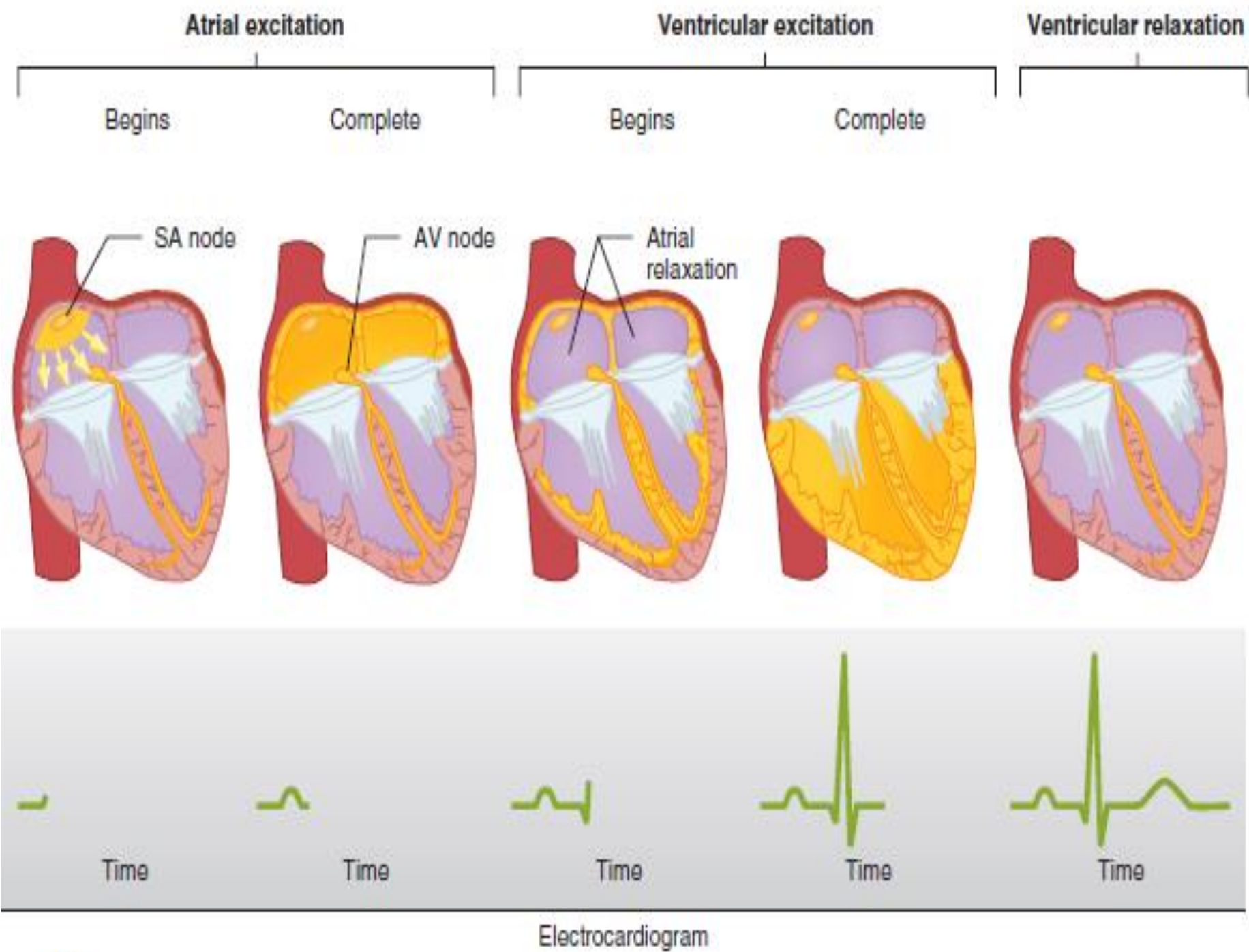


Electrocardiogram (ECG)

- Body fluids are good conductors. The action potentials of myocardial fibers can be recorded extracellularly, when any fluctuation in potential occurs.
- The record of potential fluctuations of the action potentials of myocardial fibres during the cardiac cycle is the electrocardiogram (ECG).
- **Characteristics of normal ECG**
The normal electrocardiogram is composed of **P wave**, **QRS complex** and **T wave**.



- **P wave**
Caused by atrial depolarization.
Duration- 0.10 second.
- **QRS complex**
Caused by ventricular depolarization.
Duration- 0.08 to 0.11 second.
- **T wave**
Caused by ventricular repolarization.



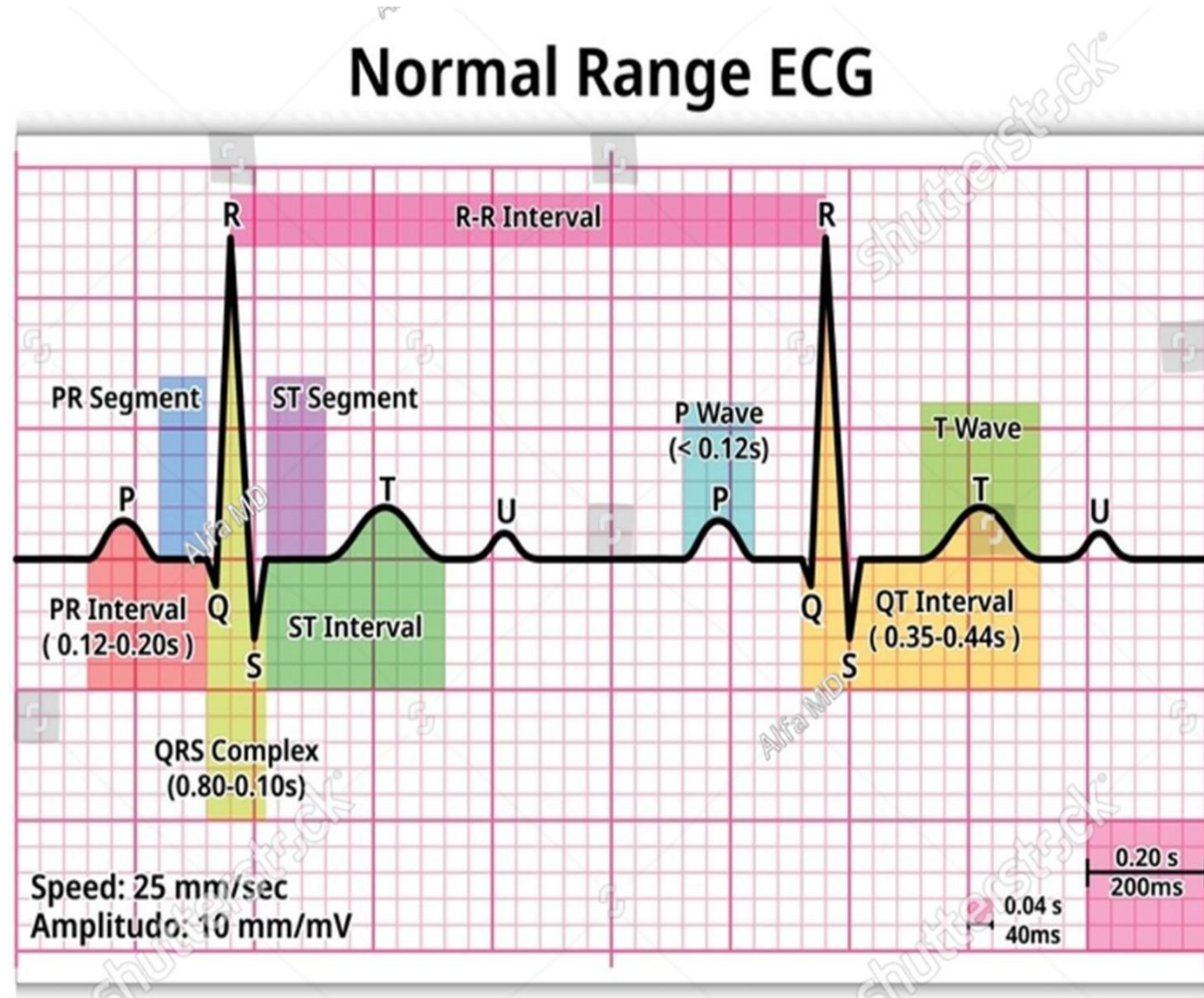
Intervals in ECG

PR interval- distance between the beginning of P wave to beginning of QRS complex.

PP interval- distance between two successive P waves.

RR interval- distance between two successive R waves.

QT interval-distance interval between the beginning of Q wave and the end of T wave.

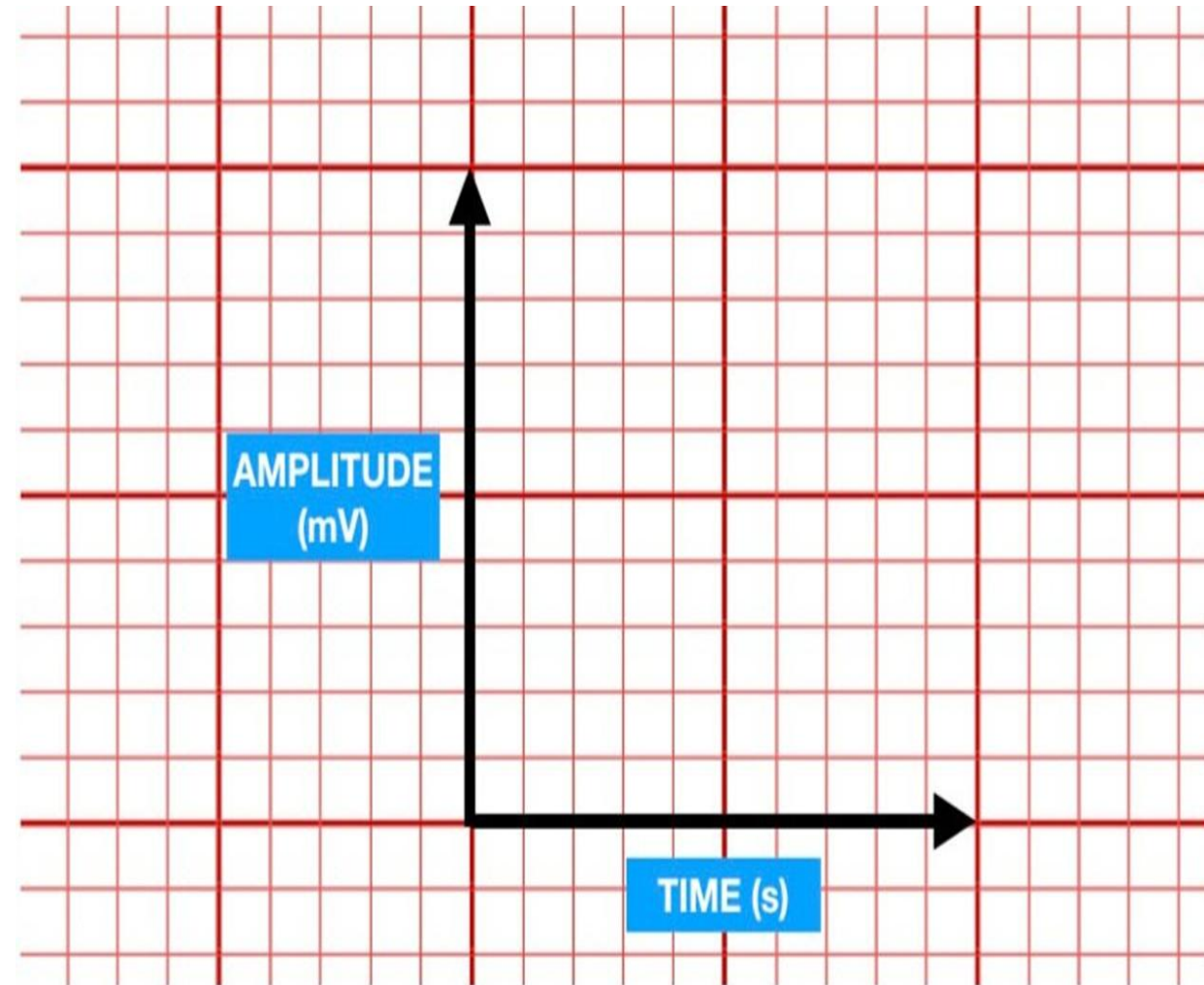


Voltage and time calibration of ECG

- ECG paper shows small and large squares, in each small square, thin horizontal and vertical lines present.
- Time measured horizontally and voltage measured vertically.

Isoelectric line

- It is the base line in ECG paper. Waves are measured either above (positive deflection) or below (negative deflection).



One small square

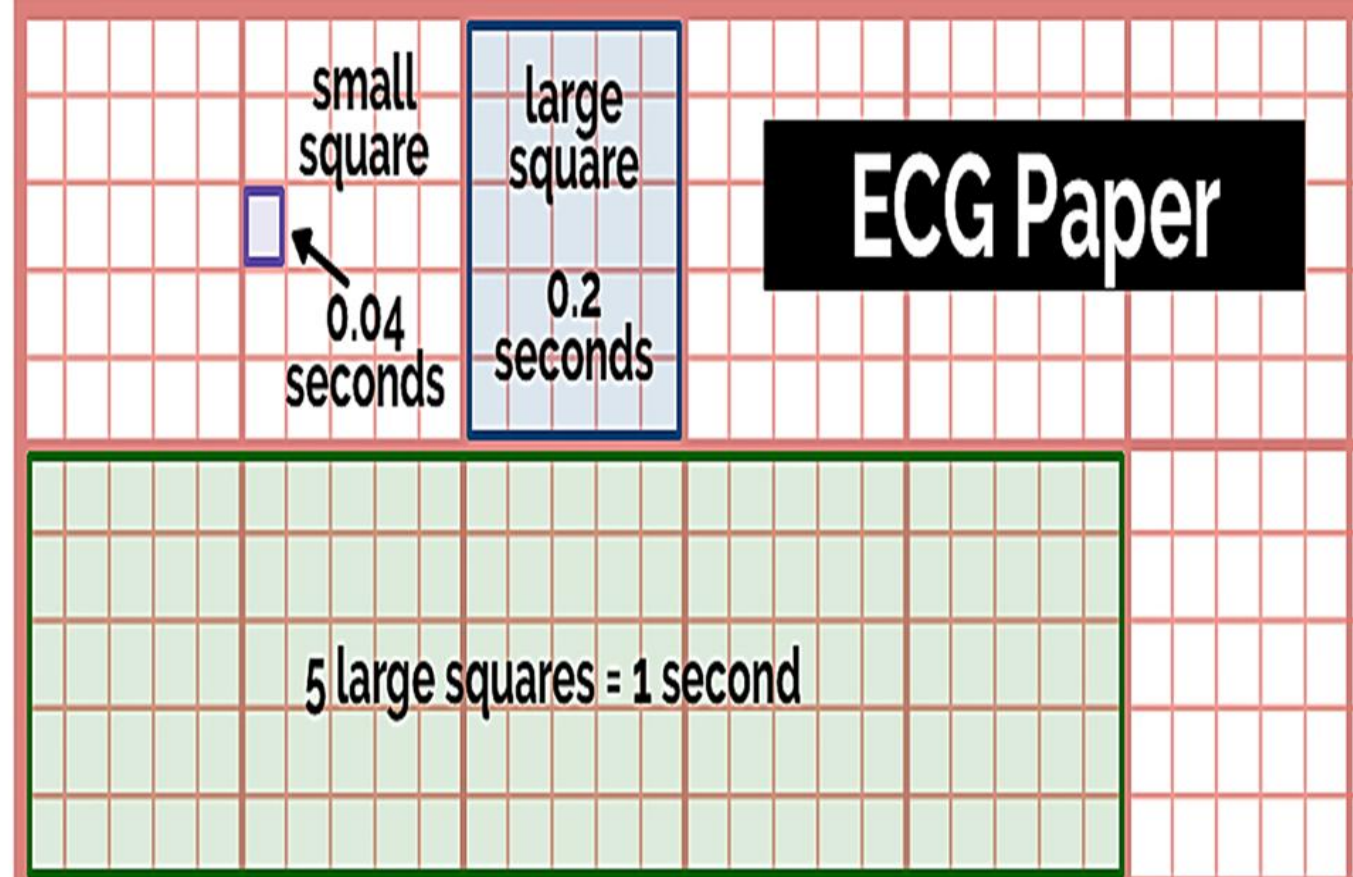
- Height=1mm
- Horizontal (in time) =0.04 second

One big square (5 small squares)

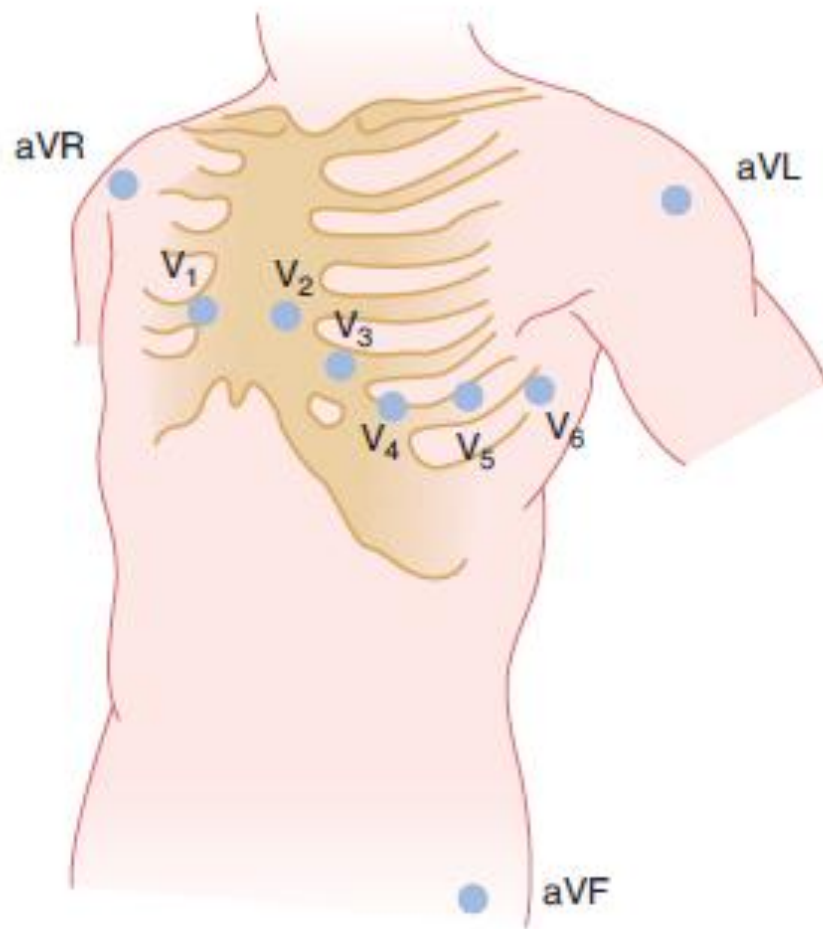
- Height=5mm
- Horizontal (in time)= $0.04 \times 5 \text{ sec} = 0.2 \text{ sec}$

So, 0.2 second= 5mm

- 1 second= $5 / 0.2 = 25 \text{ mm}$
- So, recording speed is 25mm/sec



Electrocardiographic Leads



- Three Bipolar Limb Leads, LI, L II, LIII
- There are six unipolar chest leads named precordial leads, they are V1–V6.
- And three augmented unipolar limb leads. They are VR (right arm), VL (left arm), and VF (left foot).

Three Bipolar Limb Leads

- **Lead I**

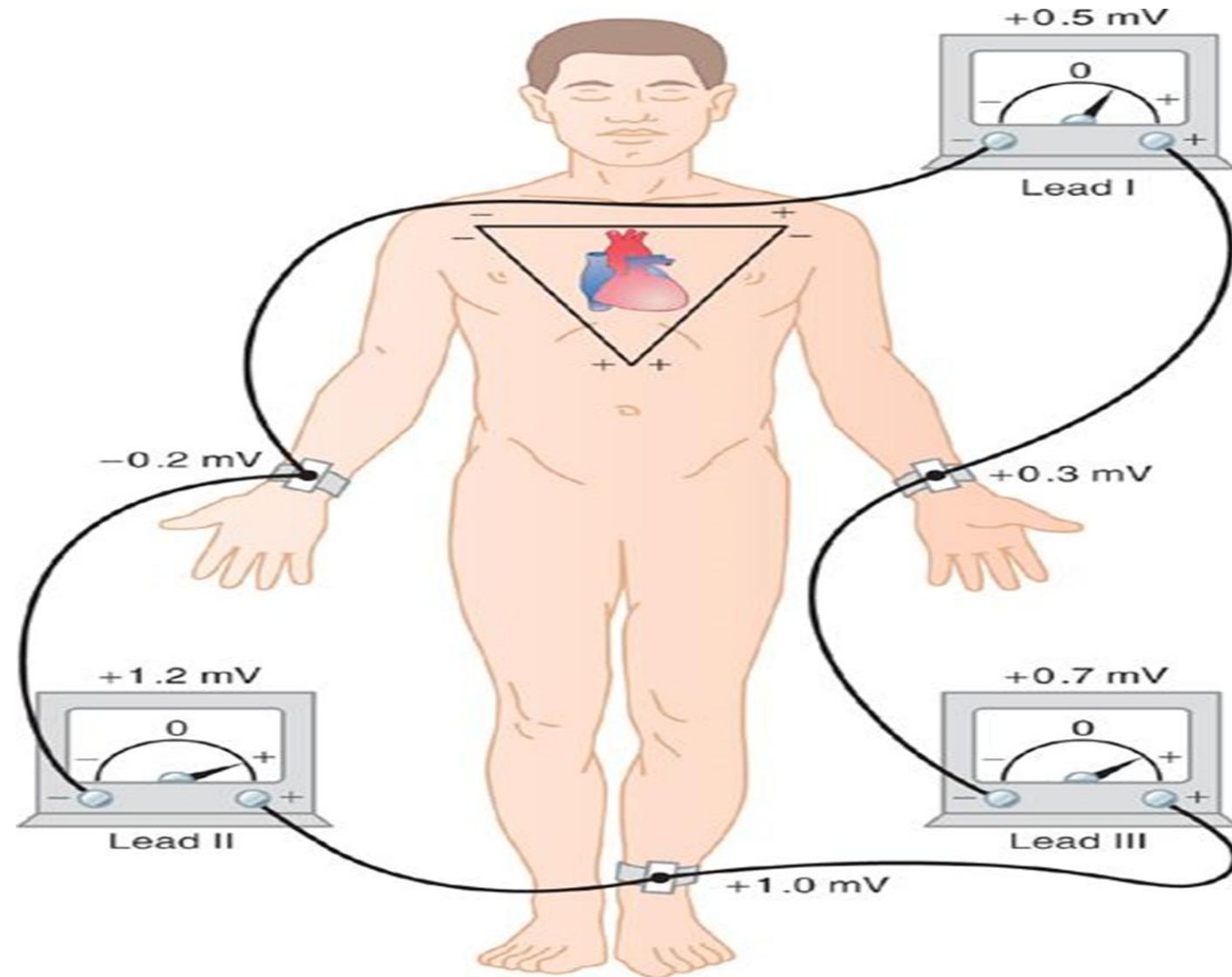
negative terminal connected to the right arm and the positive terminal to the left arm.

- **Lead II**

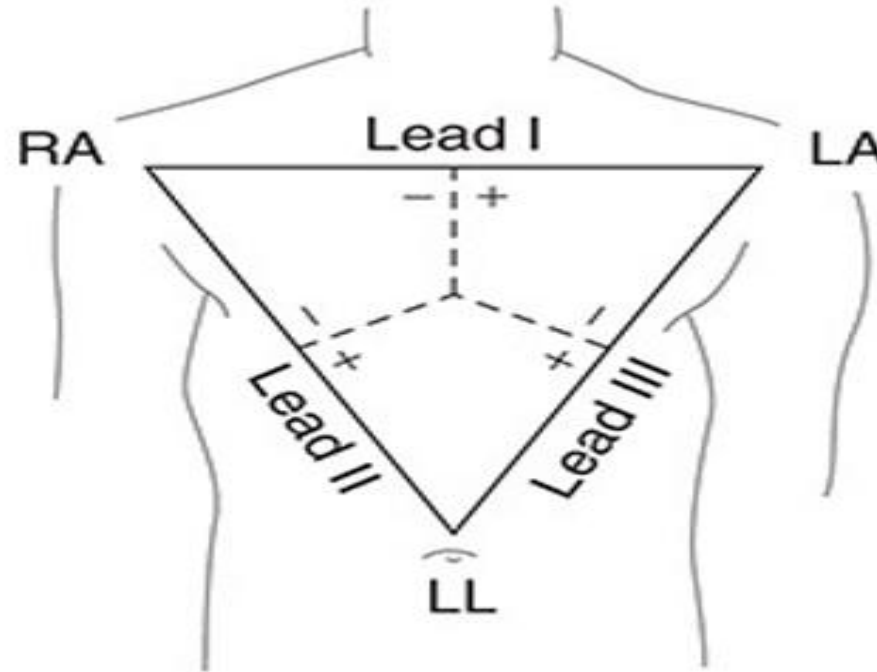
negative terminal connected to the right arm and the positive terminal to the left leg.

- **Lead III**

the negative terminal connected to the left arm and the positive terminal to the left leg



- **Einthoven's Triangle** is drawn around the area of the heart. This triangle illustrates that the two arms and left leg form apices of a triangle surrounding the heart



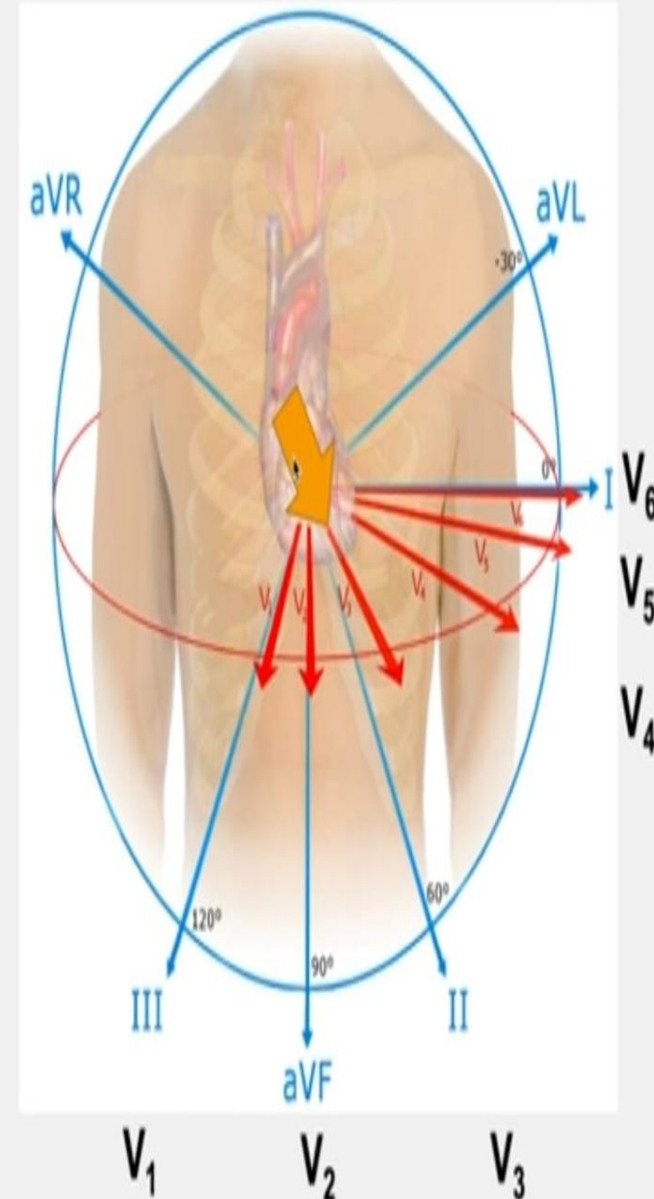
- Einthoven's law states that if the ECGs are recorded simultaneously with the three limb leads, the sum of the potentials recorded in leads I and III will equal the potential in lead II:
- **Lead I potential + Lead III potential = Lead II potential**

Augmented Limb Leads

- In this type of recording, two of the limbs are connected through electrical resistances to the negative terminal of the electrocardiograph, and the third limb is connected to the positive terminal.
- When the positive terminal is on the right arm, the lead is known as the **aVR** lead;
- when on the left arm, it is known as the **aVL** lead;
- and when on the left leg, it is known as the **aVF** lead.

- **V1** : Fourth intercostal space at (1 inch) away from the right sternal border.
- **V2** : Fourth intercostal space at (1 inch) away from the left sternal border.
- **V3** : At the midpoint between V2 and V4
- **V4** : Fifth intercostal space at left mid-clavicular line.
- **V5** : At a point where the anterior axillary line intersects perpendicularly the horizontal line extended from v4
- **V6** : At a point where mid-axillary line intersects perpendicularly the same horizontal line extended from v4

Precordial Leads





Methods for calculating heart rate

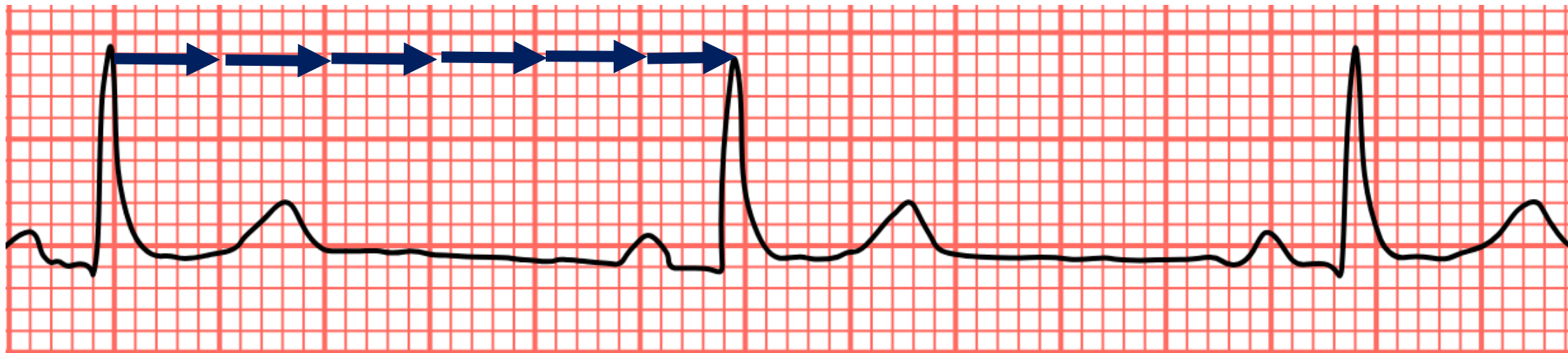
There are two methods for **calculating the heart rate**:

1. **R-R interval** (for **regular** rhythms)
2. **QRS complexes** (for **irregular** rhythms)

Cardiac Arrhythmias & their Electrocardiographic interpretation

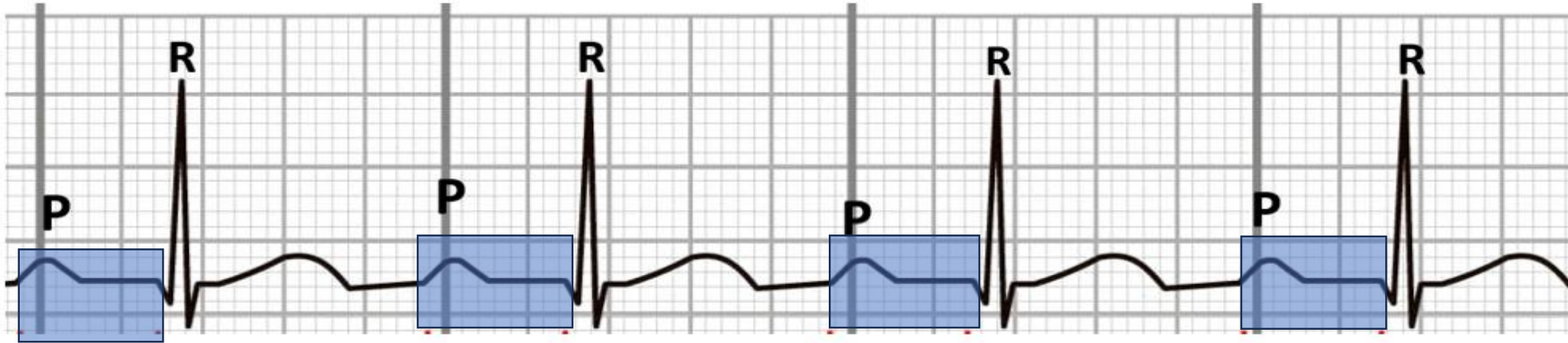


HR= $300 \div 2$
150 beats/min
Tachycardia



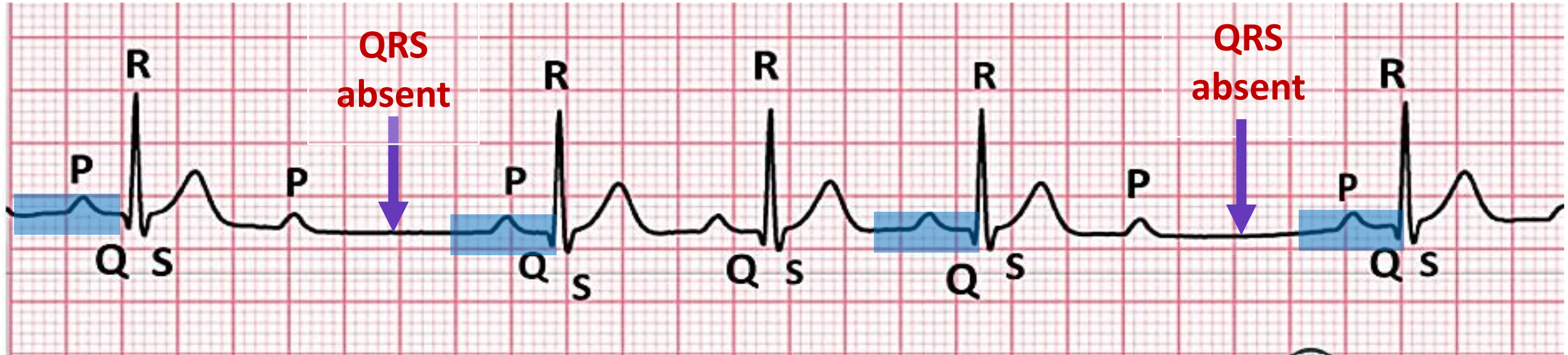
Heart rate = $300 \div 6$
HR $\approx$ 50 beats/min
Bradycardia

1st Degree Heart Block



Prolonged PR interval

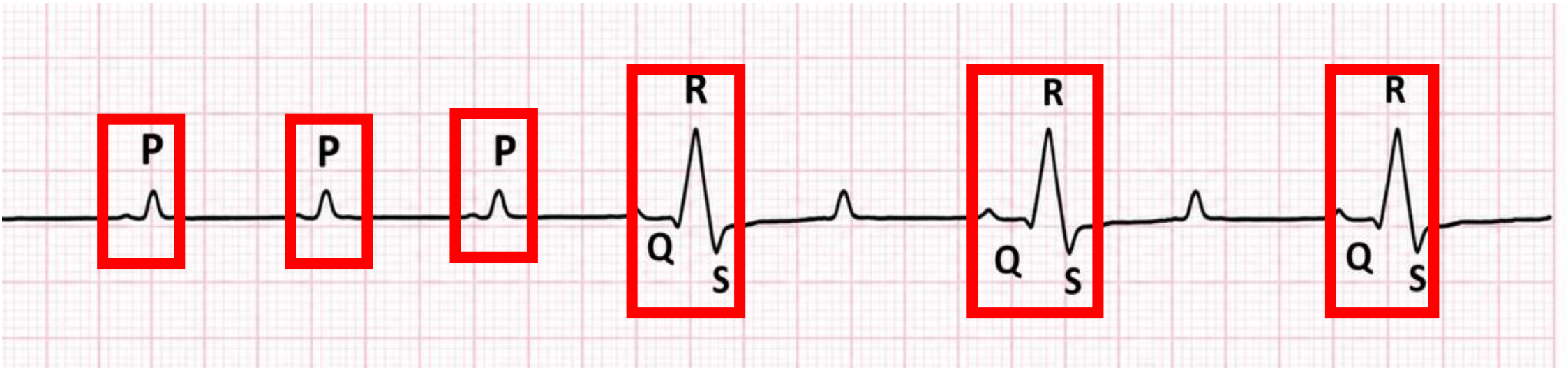
2nd Degree Heart Block



PR interval progressively
increases

QRS is dropped

3rd Degree Heart Block

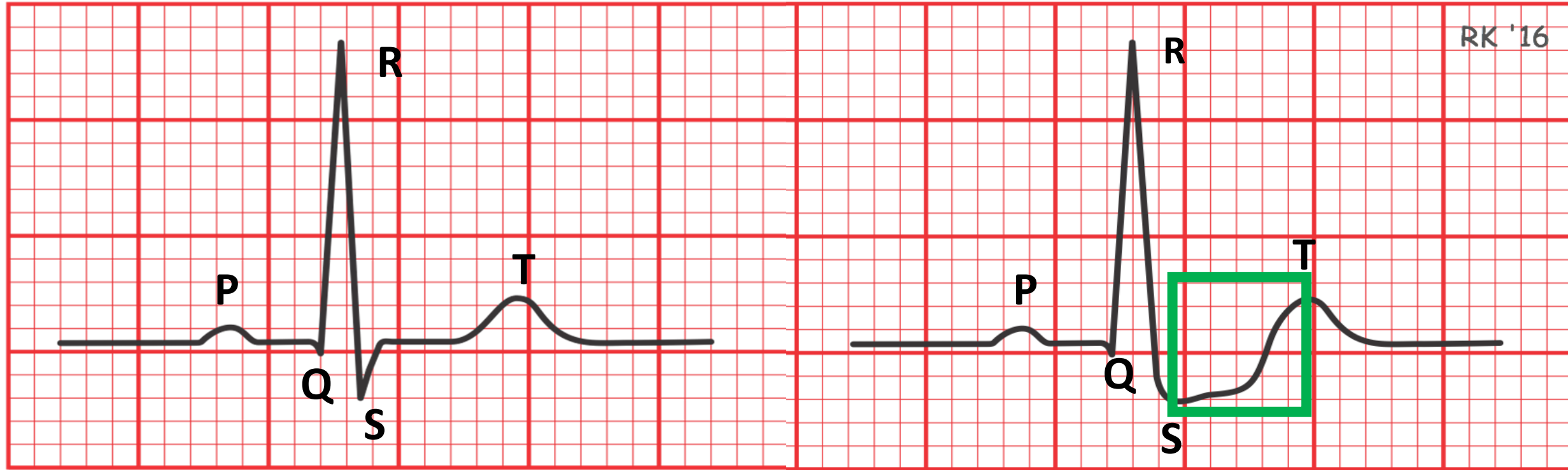


No relationship between P waves
and QRS complexes.

Atria and ventricles beat
independently

Electrocardiographic Appearances under Certain Cardiac Disorders or emergencies

ECG Changes in Ischemia



ST Depression

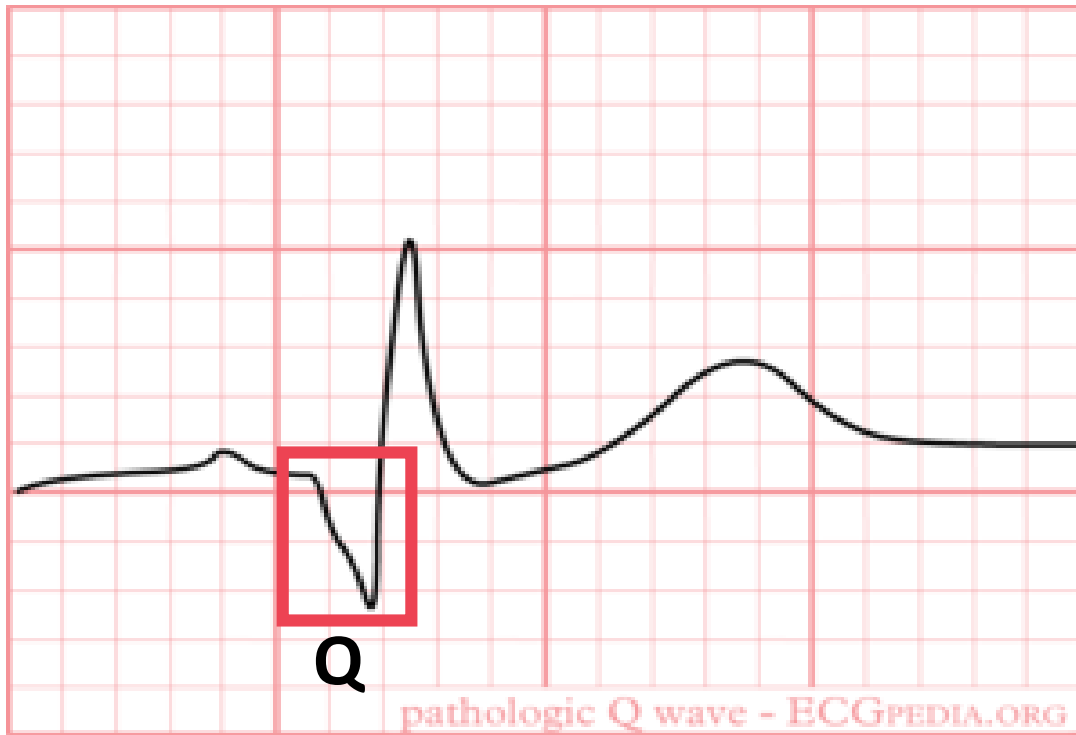
ECG Changes in Ischemia



T Inversion

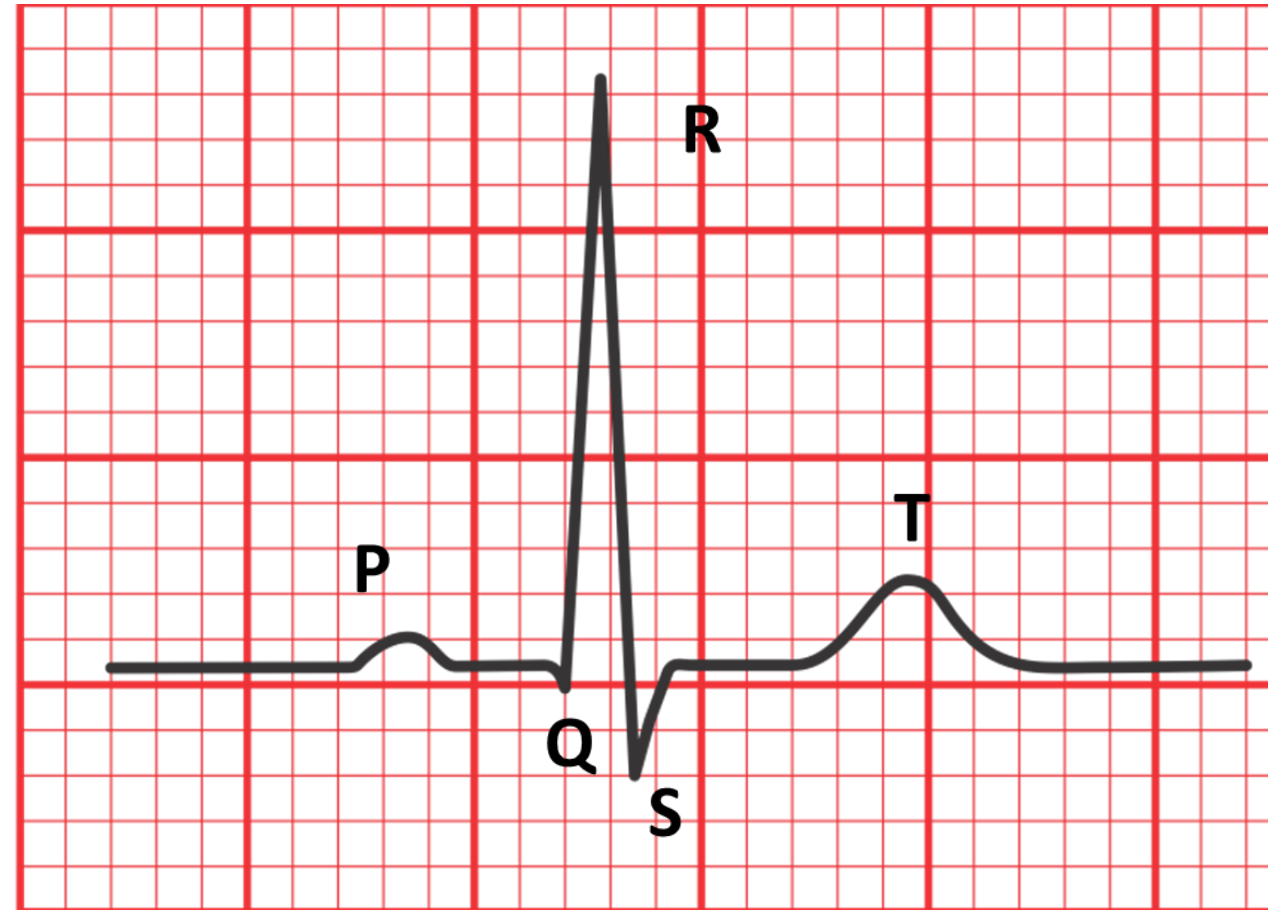
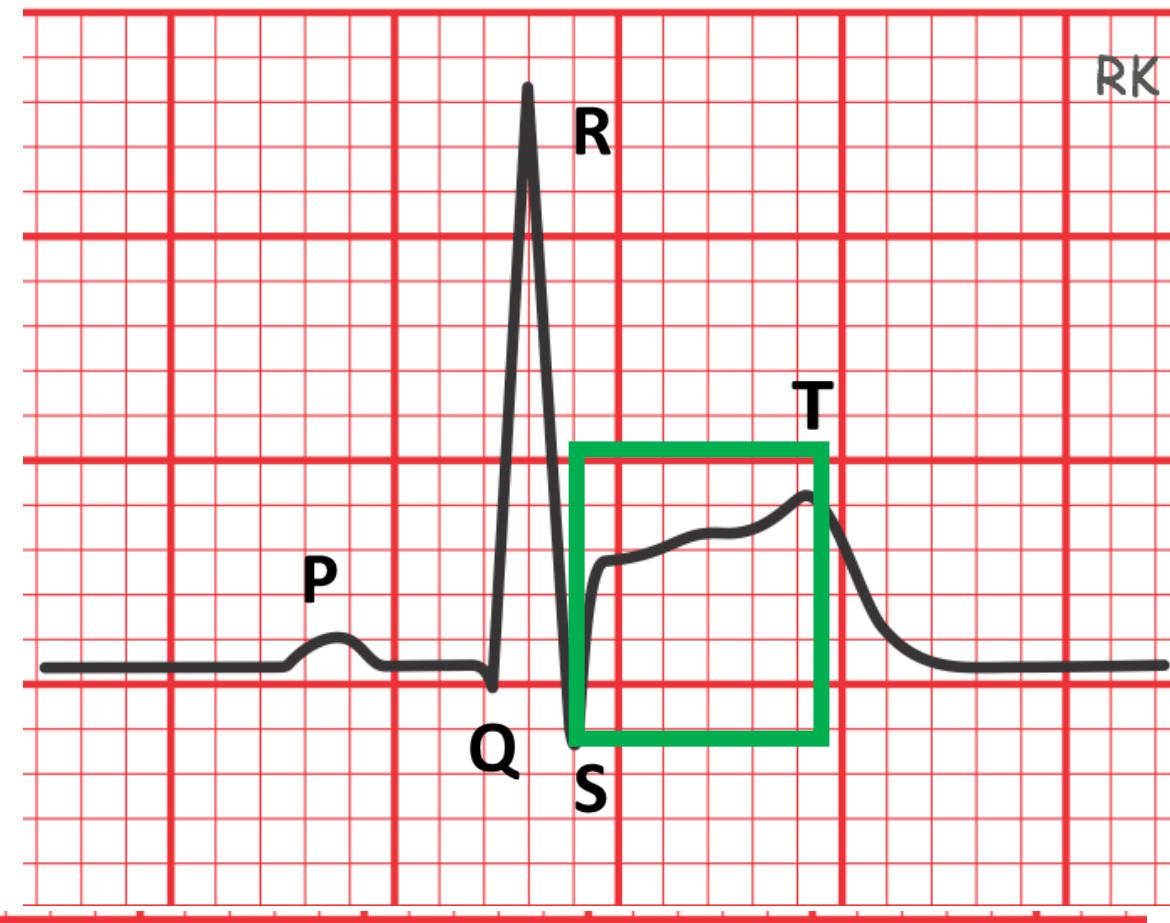
ECG Changes in MI

- Duration > 0.03s
- Depth - > 2mm



Pathological Q Wave

ECG Changes in MI



ST elevation

References

1. Hall, J.E., 2016. *Guyton and Hall textbook of medical physiology* (Vol. 13, No. 1, p. 2017). Philadelphia: Elsevier.
2. Barrett, K.E., Boitano, S., Barman, S.M. and Brooks, H.L., 2010. *Ganong's review of medical physiology*. The McGraw-Hill Companies, Inc..
3. Abdullah, A.B.M., 2025. *ECG in medical practice*. Jaypee Brothers Medical Publishers.

Thank You!



