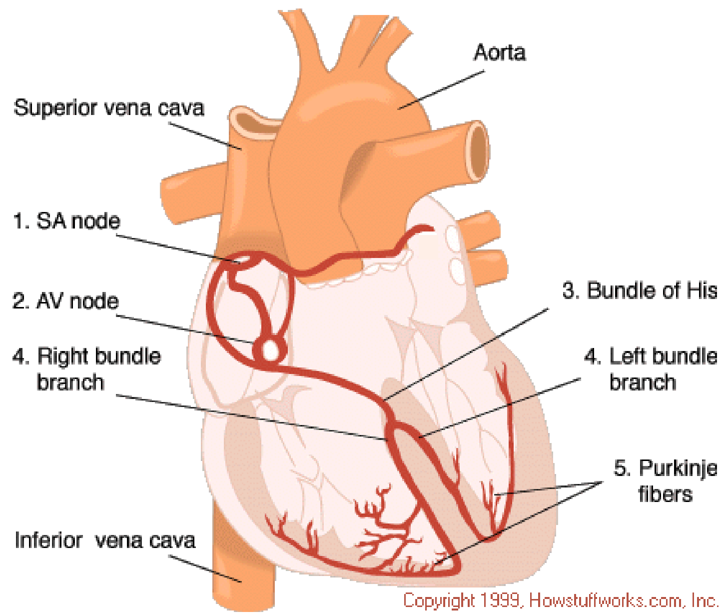
ELECTRO-CARDIOGRAPHY (ECG)

Introduction:

- In the human, the heartbeat is regulated by the ***sinoatrial (SA) node,*** located in the wall of the **right atrium**.

- After electrical activity spread to the atrial musculature, it is conducted to the **ventricular musculature** via specialized conducting pathways, including the

  - ***Atrioventricular*** *(AV) node*,
  - The ***bundle of His***,
  - The ***right*** and ***left bundle branches***
  - ***Purkinje fibers***



-When **depolarization** reaches cardiac muscle → **Contraction** (Called: Systole)

Followed by **Repolarization** ----------------------→ **Relaxation** (Called diastole)

Thus, the rhythmic change in electrical activity leads to the **mechanical pumping action** of the heart.

- The **electric field** generated by the electrical activity of the heart can be recorded anywhere on the body surface by **ECG**.

ECG

- Electrocardiograph is the instrument that monitors **electrical activity** of the heart.

- Used to: - Identify **abnormal electrical conduction**

  - Estimation of **heart rate**

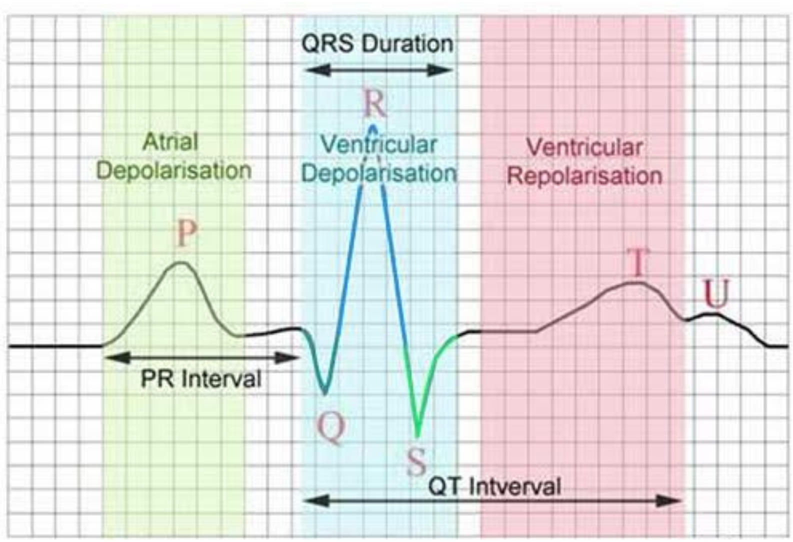
- The record produced by the electrocardiograph is called an **electrocardiogram**

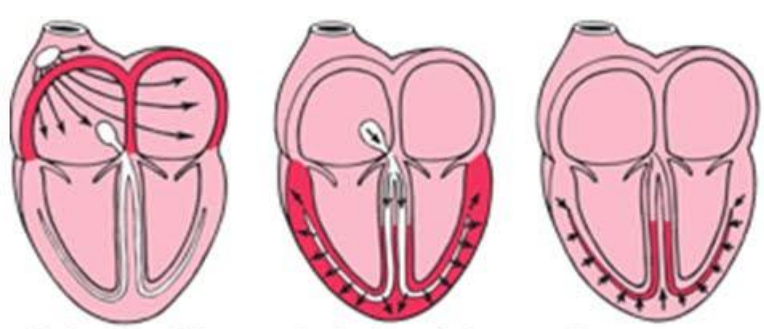
- The major components of **electrocardiogram** are:

  - **P wave → atrial depolarization**: spread of excitation from the SA node over the atrial musculature

  - **QRS wave →** rapid **ventricular depolarization** of the heart muscle that immediately precedes **ventricular systole**

  - **T wave → ventricular repolarization** of the muscle that occurs just before **ventricular diastole**



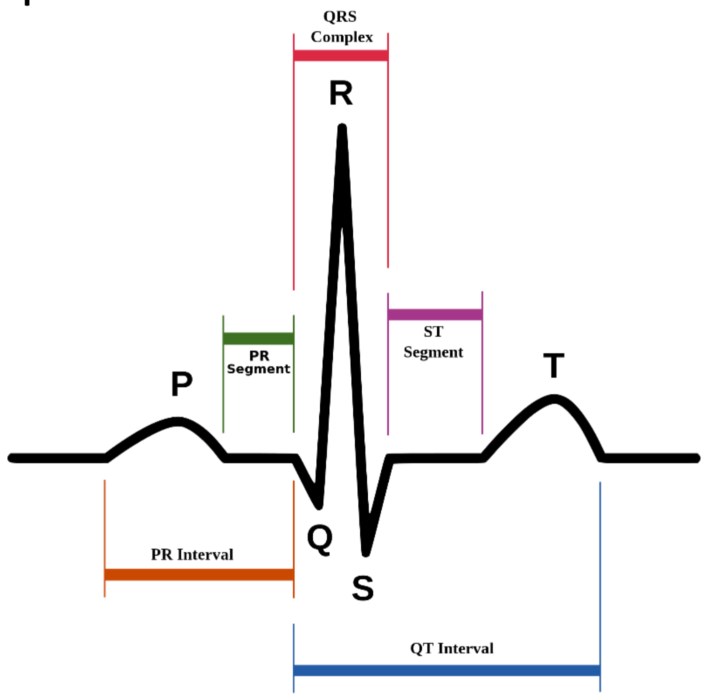


Activation of the atria | Activation of the ventricles | Recovery wave

Intervals and segments

Intervals or segments: The time spans between waves

- **P-R interval** → the time required for the **action potential** to travel through the **atria**, **AV node** and other fibers of the conductive system
- **S-T segment** → the time when the ventricular contractile fibers are depolarized during the plateau phase of the action potential
- **Q-T interval** → the time from the beginning of **ventricular depolarization** to the end of **ventricular repolarization**



- According to the above,

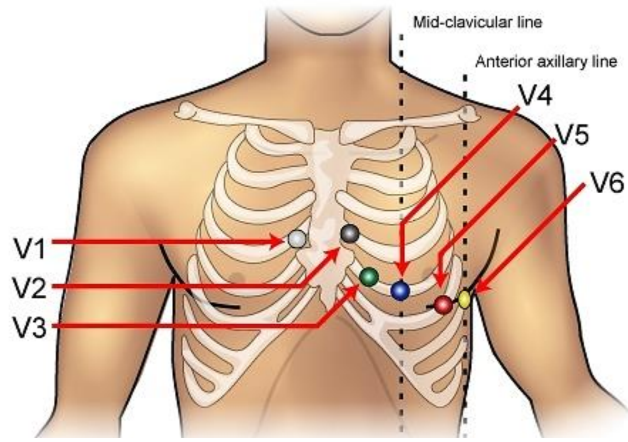
- **Atrial contraction** (or systole) is developed during the peak of the **P wave** and lasts until the onset of the **Q wave,**

- **Ventricular systole** takes place between the onsets of the **QRS complex** until the peak of the **T wave**.

Procedure

In clinical ECG practice, **electrodes** are positioned on the **arms** and **legs** (**4 limb leads**) and at **six positions** on the **chest** (**6 chest leads**).

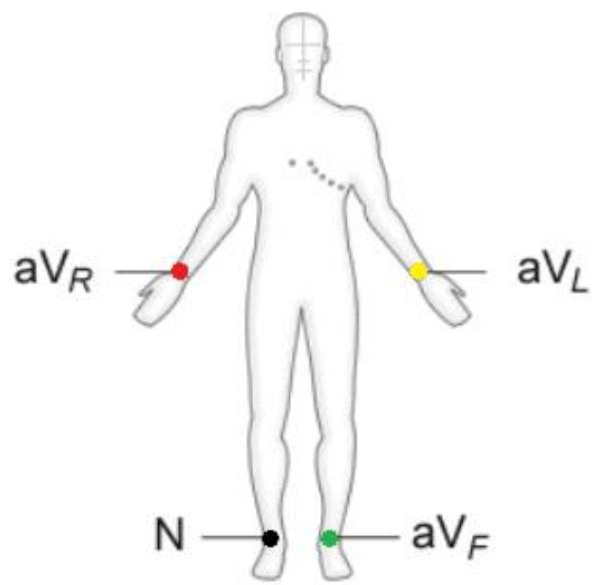
Positions of the leads



Chest leads

- **V1**: 4th intercostal space (right of sternum)
- **V2**: 4th intercostal space (left of sternum)
- **V3**: directly between V2 and V4
- **V4**: 5th intercostal space at **midclavicular line**
- **V5**: Level with **V4** at left **anterior axillary line**
- V6: Level with V5 at **left midaxillary line**

  (Directly under the midpoint of the armpit)



Limb leads

- **aV_R**: Right wrist (Red)
- **aV_L**: Left wrist (Yellow)
- **N**: Right foot (Black)
- **aV_F**: Left arm (Green)

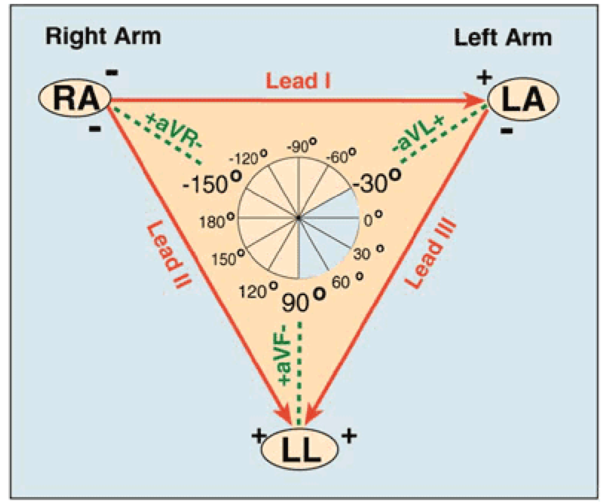
Potential difference is measured between pairs of electrodes that are connected to either the **negative** or the **positive** input of a differential amplifier, as shown in the following figure.

3 leads electrical directions will be produced according to the positions of the above leads:

Lead I has the **negative** electrode on the **right wrist** and the **positive** electrode on the **left wrist**

Lead II has a **negative electrode** on the right wrist and a **positive** on the left ankle

Lead III measures electrical activity between the **left wrist** (negative electrode) and the **left ankle** (positive electrode).



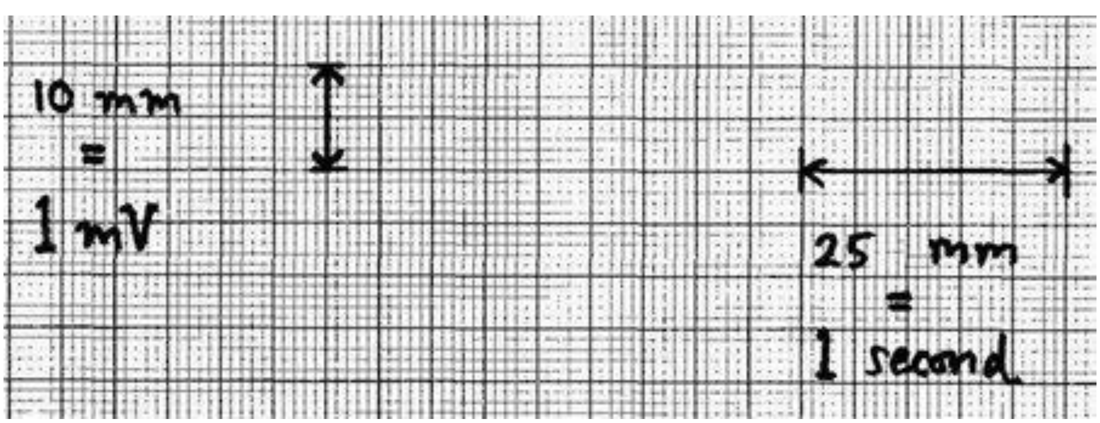
Measuring and reading the results

The amplitude, or voltage, of the recorded electrical signal is expressed on an ECG in the vertical dimension and is measured in millivolts (mV).

On standard ECG paper 1mV is represented by a deflection of 10 mm, and a speed of 25 mm per second

ECG paper is marked with a grid of **small** and **large** squares.

Each **small square** represents **40 milliseconds** (ms) in time along the horizontal axis and each **larger square** contains **5 small squares**, thus representing **200 ms**, (5 large squares = 1 second → each 30 large squares= 6 seconds)



Readings the results

1- Identify abnormal electrical condition (Indication of ischemic heart disease)

- **Regular shape** of the peaks and regular intervals→ **Normal sinus rhythms**:

- **T wave inversion** → angina (as shown in figure)

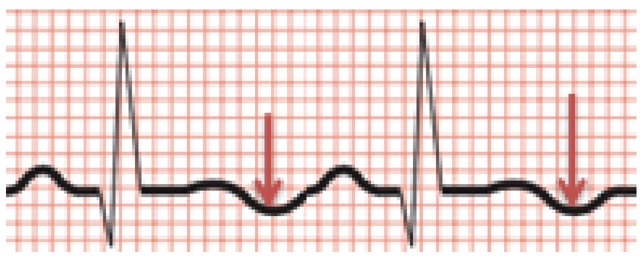
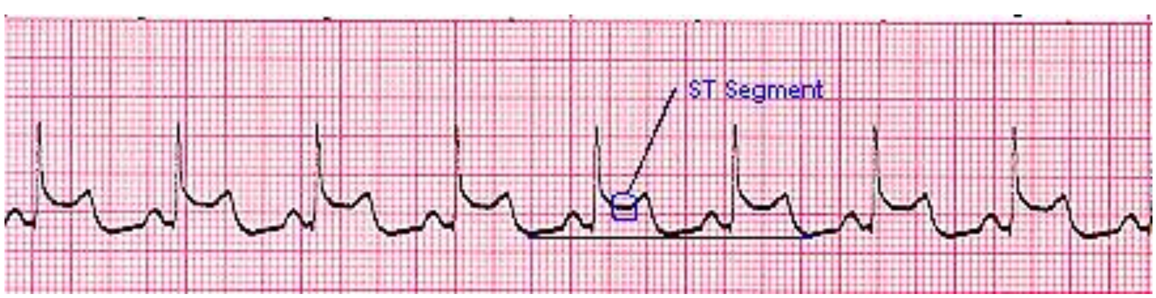


Figure: Example of T wave inversion in unstable angina

- **ST segment depression** → angina (as shown in figure)

Figure: Example of ST segment depression in unstable angina

- **ST segment elevation** → myocardial infraction (MI)



- **Wide QRS complex** → myocardial infraction (MI)

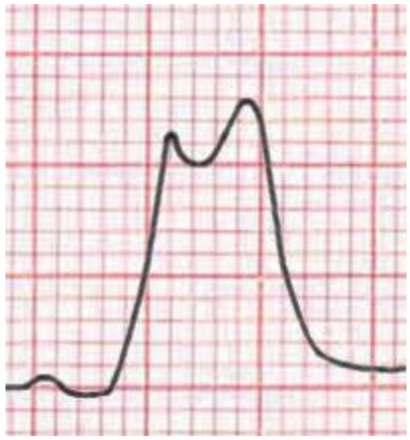


Figure: Example of QRS complex widening in acute MI

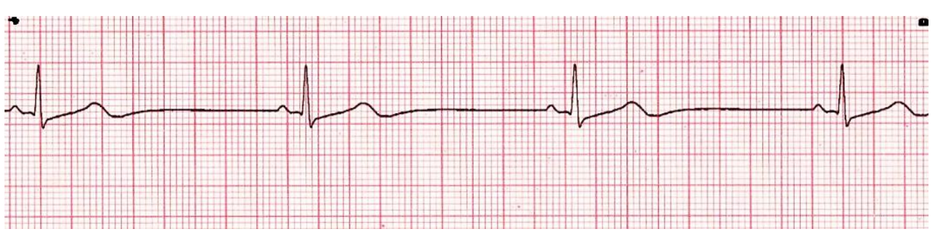
2. Estimation of Heart rate

As shown before, each **30 large square** = **6 seconds**

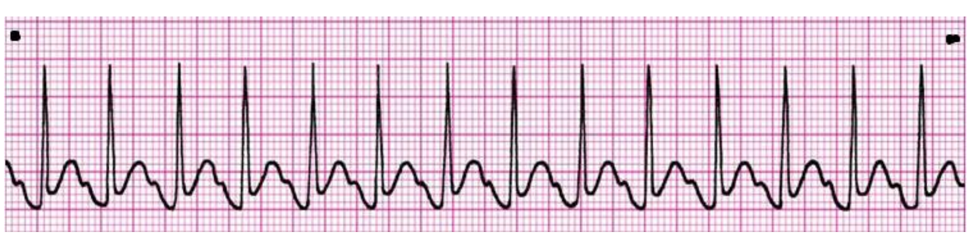
Thus, Heart rate (beat/min) = No. of QRS complex in **30 large squares** × 10

Example 1: Heart rate= **7** QRS complex × 10 = **70 beats/min** → Normal

Example 2: Heart rate = **4** QRS complex × 10 = **40 beats/min** → Bradycardia



Example 3: Heart rate = **14** QRS complex × 10 = **140 beats/min** → Tachycardia



Note: Irregular heartbeats can be also identified by ECG, which can be shown as irregular QRS complex distribution along the ECG paper.

Example: as shown in the figure below which is a case of sinus arrhythmia

Figure: Sinus arrhythmia

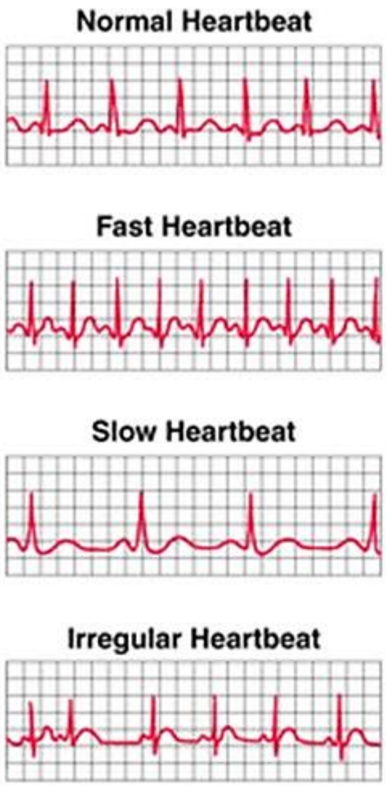


Figure: This figure shows normal, fast, slow and irregular heart beats taken by an ECG machine.