

INTRODUCTION TO ELECTROCARDIOGRAPHY

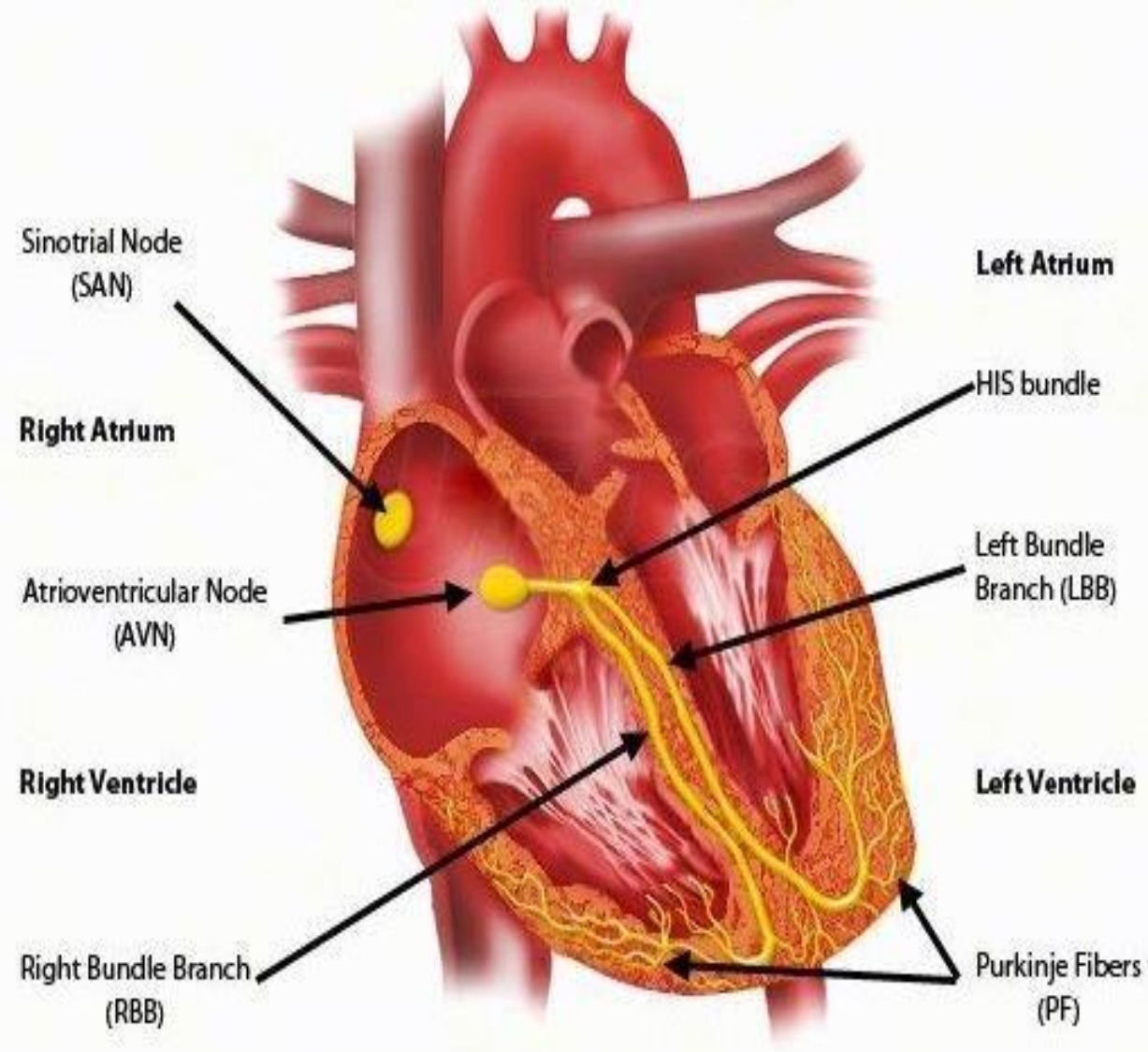
ECE 331 – INTRODUCTION TO BIOMEDICAL ENGINEERING

Tuesday, December 16, 2025

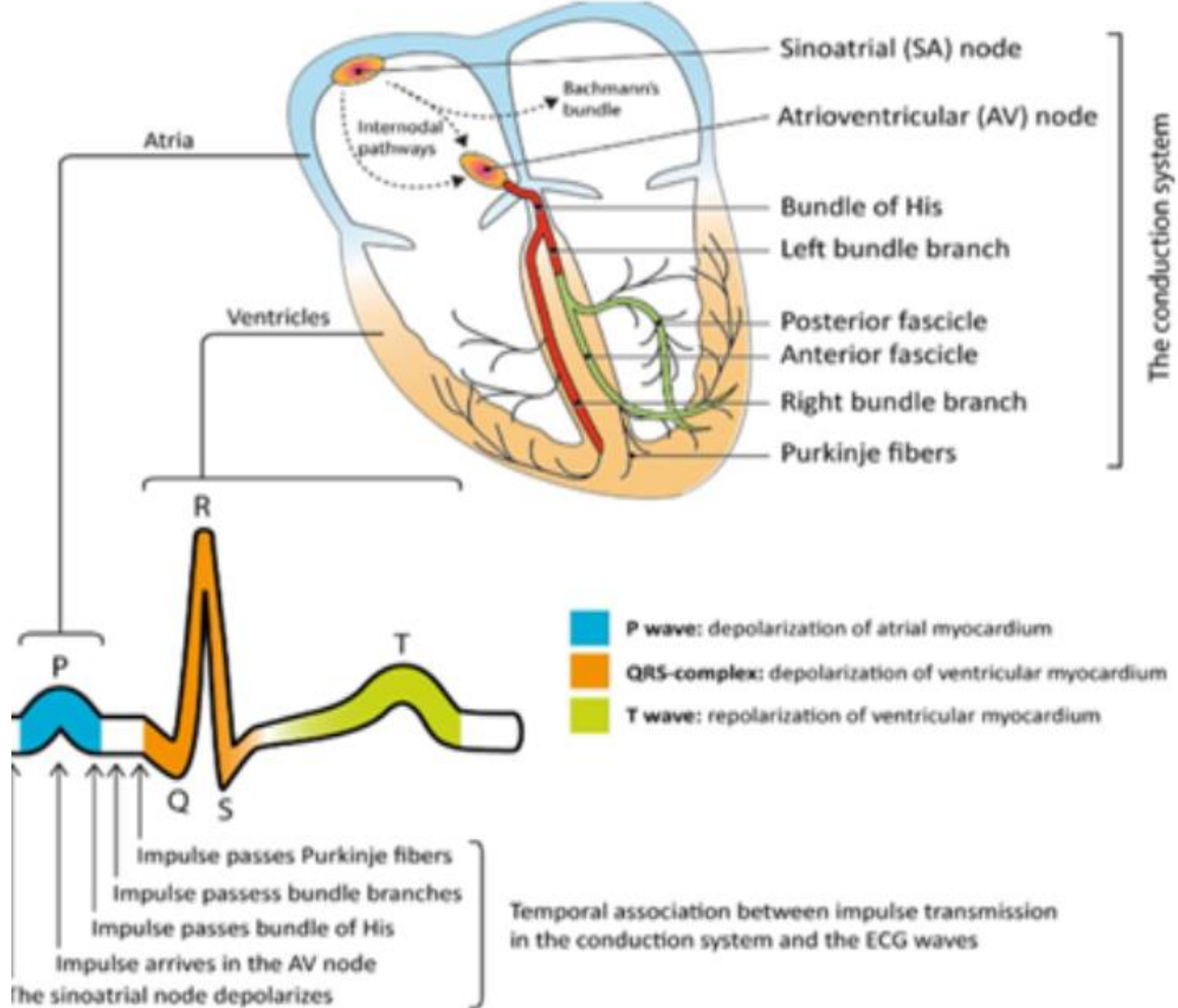
CATEGORIES OF HEART CELLS

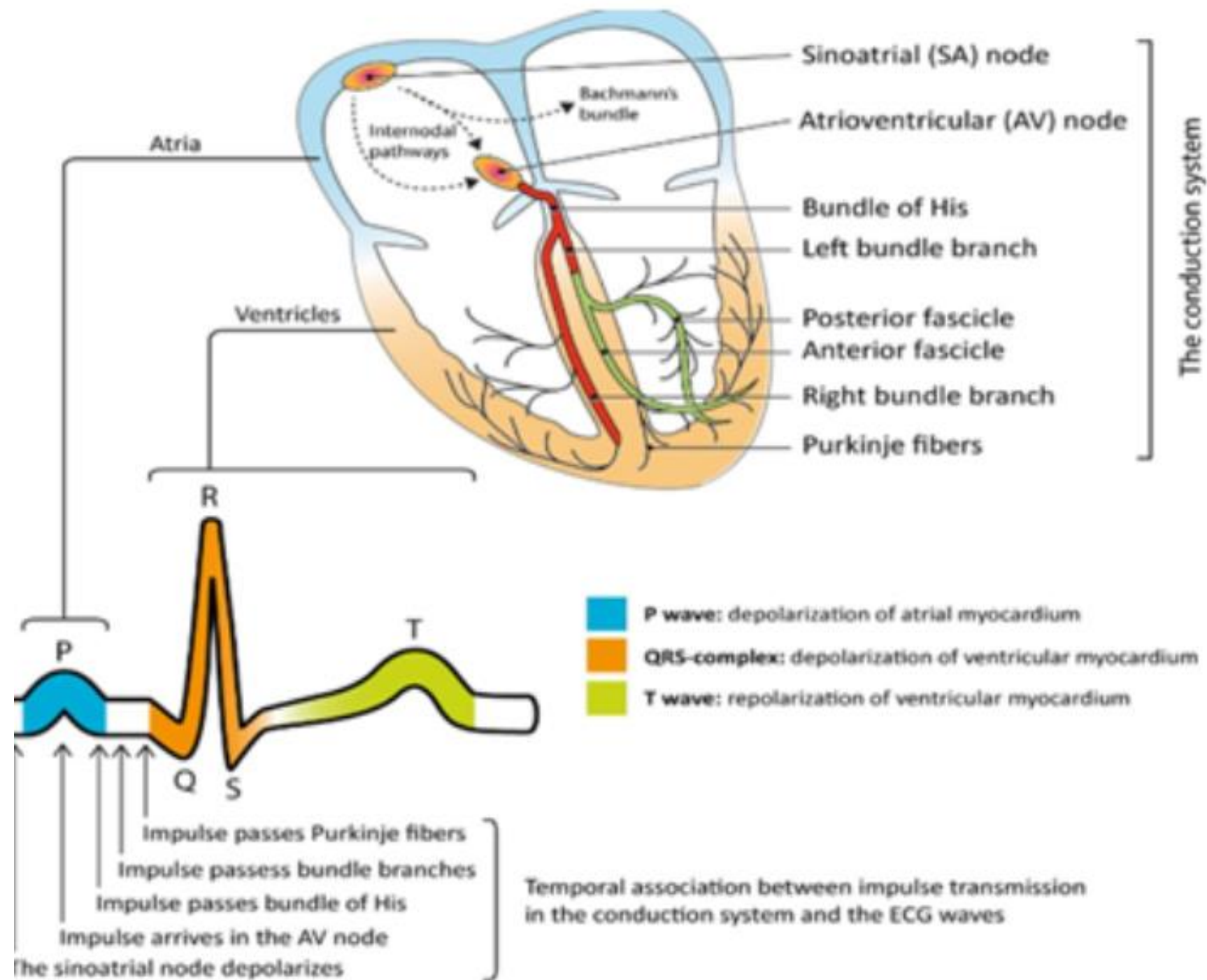
The heart consists of three types of cells:

- 1. Pacemaker cells:** under normal circumstances, the electrical power source of the heart
- 2. Electrical conducting cells:** the hard wiring of the heart
- 3. Myocardial cells:** the contractile machinery of the heart



RELATION BETWEEN THE HEART CONDUCTION SYSTEM & THE WAVES





HISTORY OF ELECTROCARDIOLOGY

- 1842-** Italian scientist **Carlo Matteucci (pronounced Mathew-uchi)** realizes that electricity is associated with the heartbeat
- 1876** – Irish scientist **Marey** analyzes the electric pattern of frog's heart
- 1895-** **William Einthoven (pronounced Eye-hoven)**, credited for the invention of ECG
- 1906-** using the string electrometer, **William Einthoven (pronounced Eye-hoven)**, diagnoses some heart problems.
- 1924** - the noble prize for physiology or medicine is given to **William Einthoven** for his work on ECG
- 1938** –**American Heart Association** and **Cardiac society of Great Britain** defined the position of chest leads
- 1942-** Goldberger increased Wilson's Unipolar lead voltage by 50% and made **augmented leads**.

WHAT IS ELECTROCARDIOGRAM (ECG)

- 1. Electrocardiogram (ECG)** is a test that measures the electrical signals that control heart rhythm.
- ECG provides information used to assess the following:
 - a) Heart's ability to generate electrical impulses.**
 - b) Heart's ability to conduct action potentials**
 - c) The ability of cardiac cells to respond to electrical impulses (excitability).**

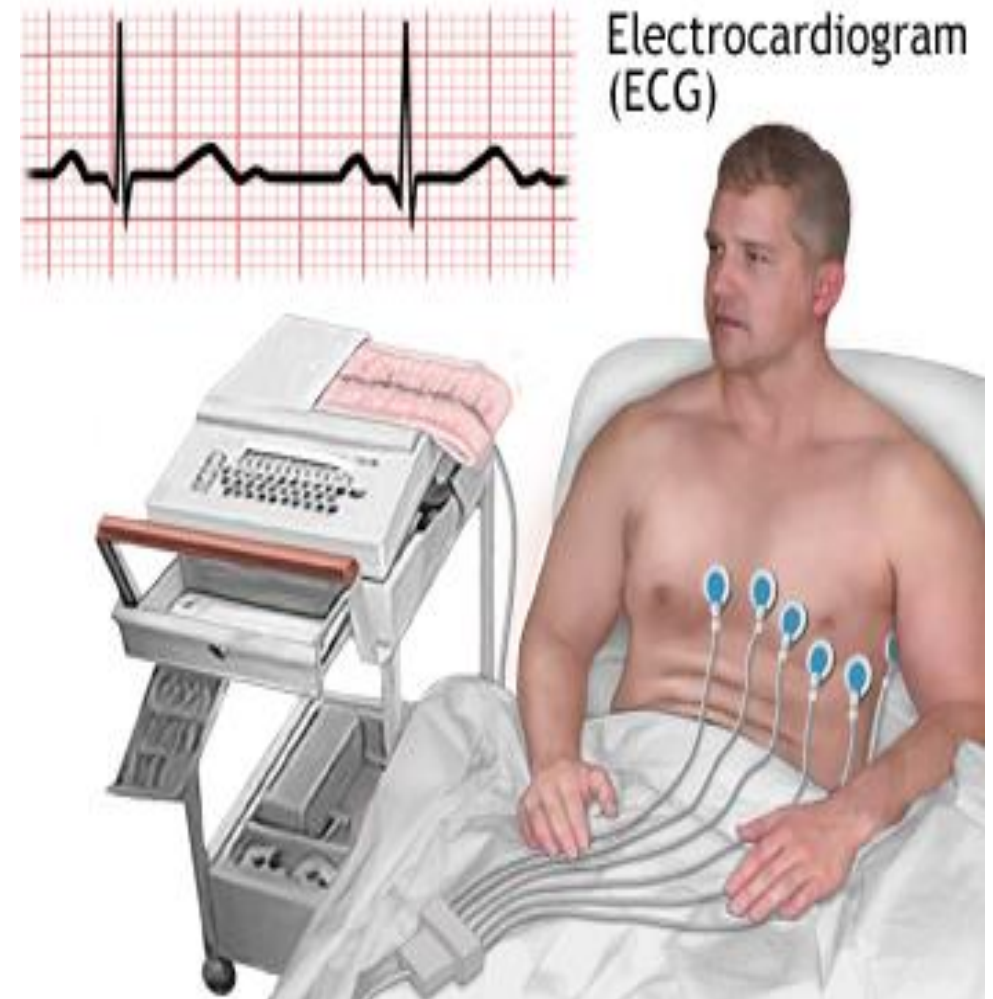


ECG OR EKG – WHAT IS THE DIFFERENCE?

- **ECG** stands for electrocardiogram
- **EKG** is the German spelling for elektrokardiographie, which is the word electrocardiogram translated into the German language.
- An **ECG (EKG)** is a test that measures the electrical activity of the heart.

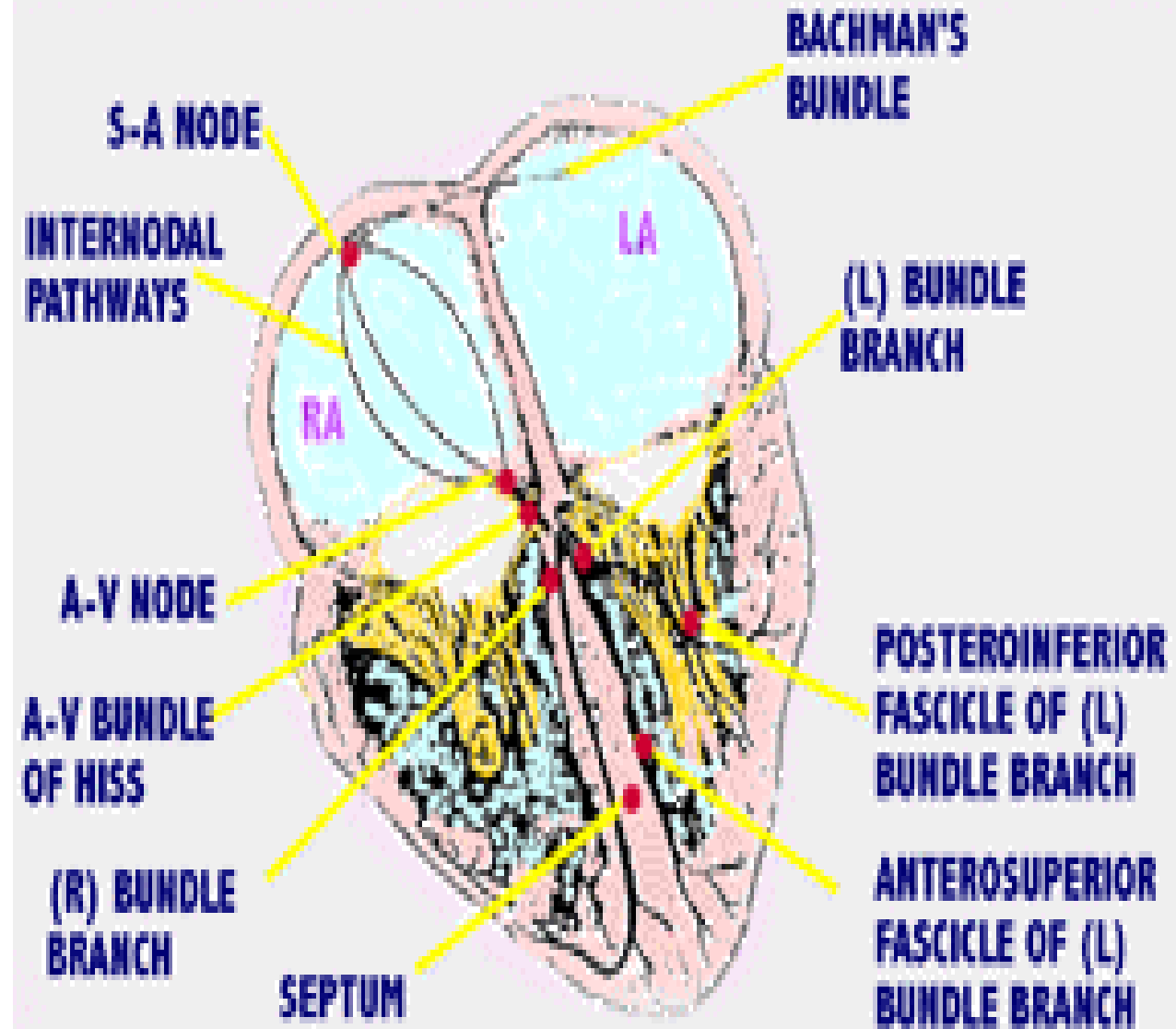
WHAT DOES ECG CHECK?

- 1. Heart rate & rhythm:** Fast, slow, or irregular heartbeats (arrhythmias).
- 2. Heart damage:** Signs of a recent or ongoing heart attack, or damage from past ones.
- 3. Structural issues:** Enlargement of the heart or problems with heart valves.
- 4. Other conditions:** Electrolyte imbalances, lung diseases, or how heart medications are working.



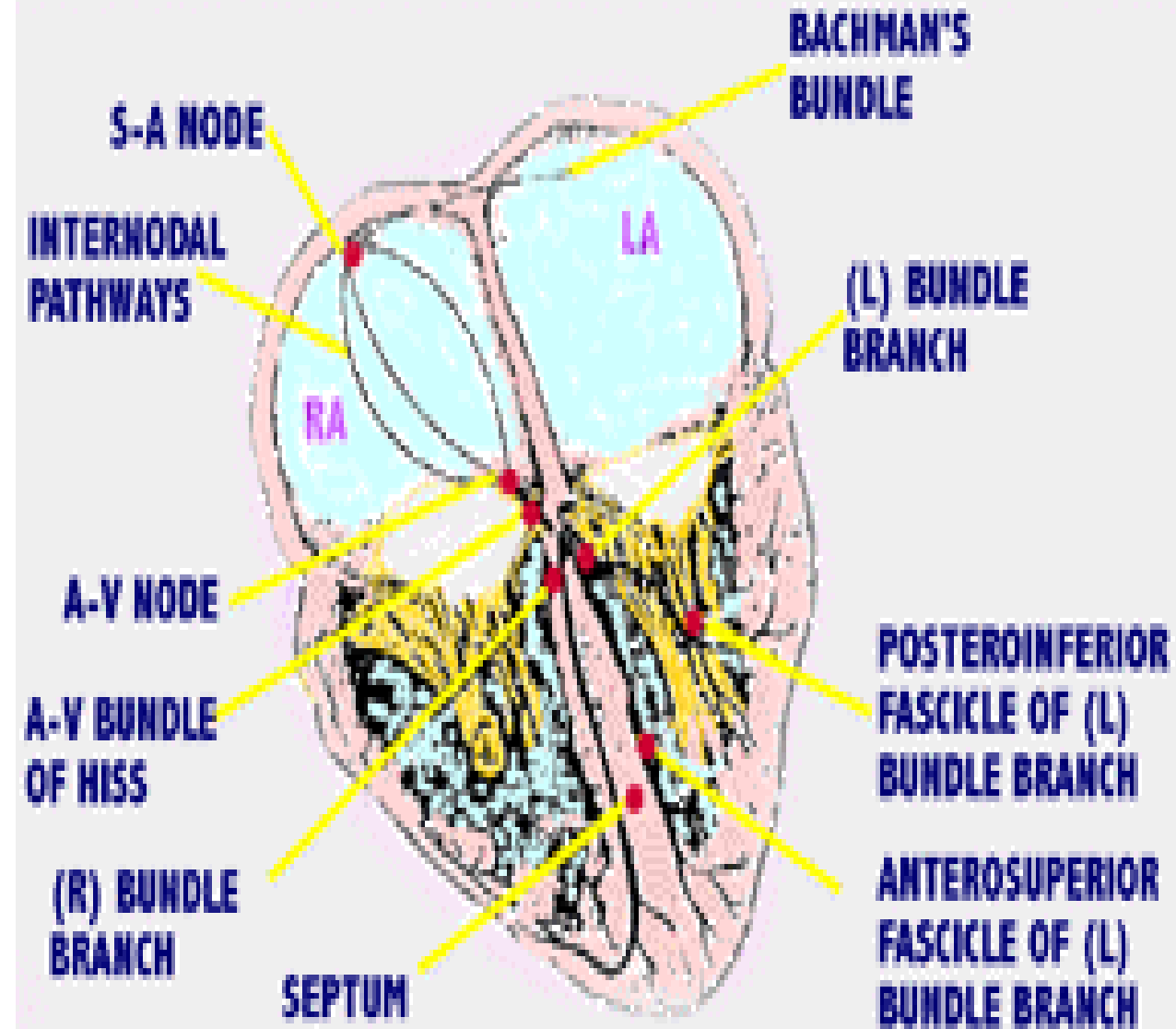
ANIMATION OF THE HEART ACTIVITY: S-A NODE

- 1. Sino Arterial Node (S-A Node)** is a cluster of cells located in the right atrium.
- 2. SAN** generates action potentials at regular intervals meaning the S-A Node directly controls heartrate.
- 3. Each action potential** generated by the S-A Node correlates to a single heartbeat.



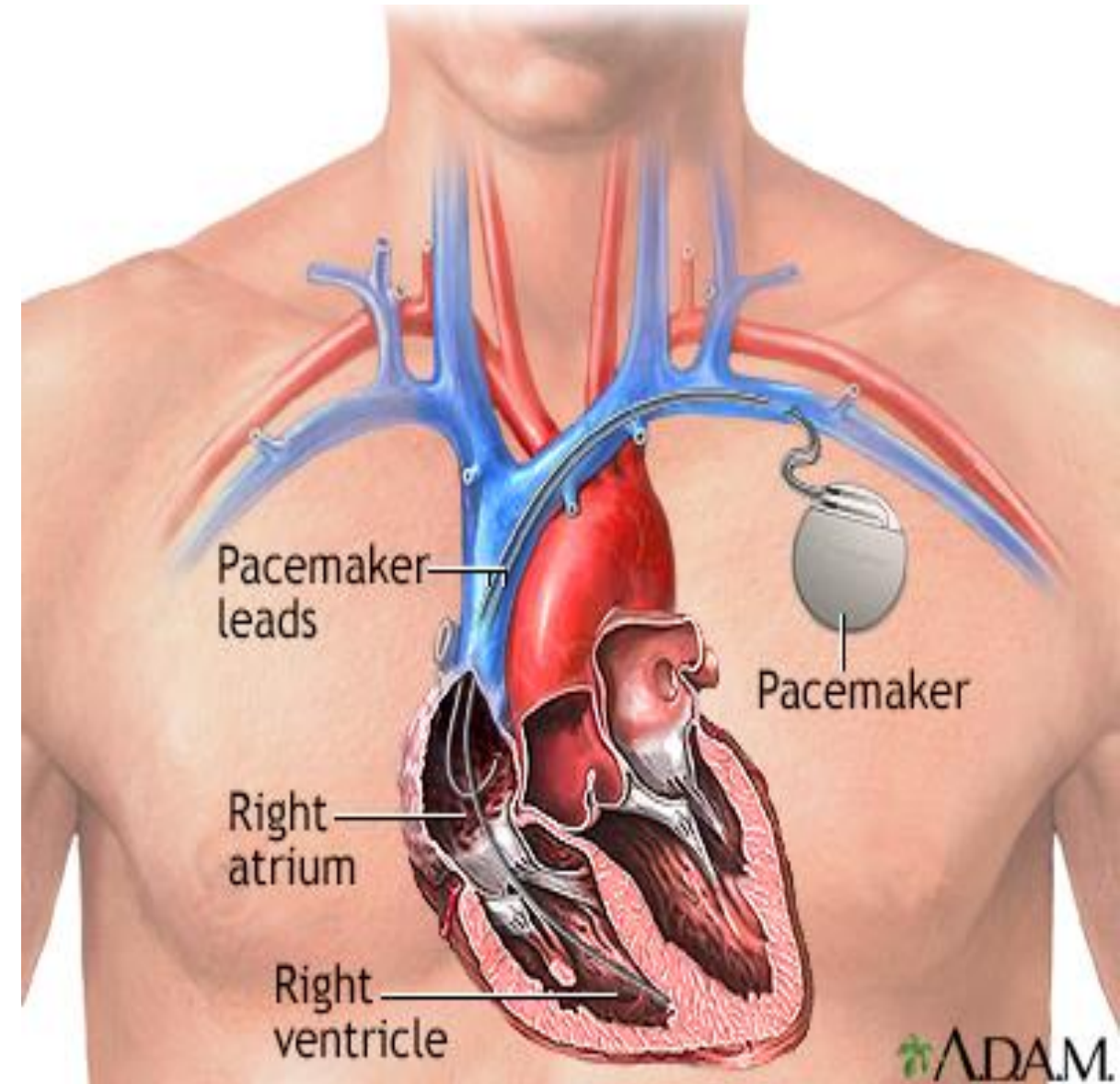
ANIMATION OF THE HEART ACTIVITY: AVN NODE

1. **Atrio Ventricular Node (AVN)** acts to **delay the wave of depolarisation** sweeping through the heart before it enters the ventricles.
2. **This allows the atria to contract before the ventricles.**
3. The wave of depolarisation then spreads through the **Bundle of His** down into the **Purkinje fibres** of the heart



PACEMAKER ABILITY OF THE HEART

- **Pacemaker ability of the heart** is what makes cardiac muscles so unique.
- **Pacemaker ability allows heart transplants to occur** without the need to give the heart additional nervous connection when entering a donor body.
- If the heart loses all pacemaker ability, then it will not be able to beat in the correct time or with the correct synchronization. In short, the patient will die.
- Fortunately, external pacemakers can be inserted into the heart takeover the role of the failed SAN.
- This is achieved through surgery, with two wires being inserted into the chambers of the heart.



CLINICAL CONDITIONS REQUIRING ECG?

1. ECG should be recorded when a patient has:
 - a) Chest pain,
 - b) Palpitations,
 - c) Breathlessness or dizziness,
 - d) Syncope (fainting or passing out) or an unexplained collapse.
 - e) Stroke
2. ECG machines can be found in:
 1. Clinics
 2. Hospital Wards
 3. Operating rooms
 4. Ambulances.
3. **Some personal devices, such as smartwatches, can do simple ECGs.**

WHEN **ECG** TEST IS NEEDED



**Weakness,
or Fatigue**



Dizziness



Chest pain



**Irregular
Heartbeat**

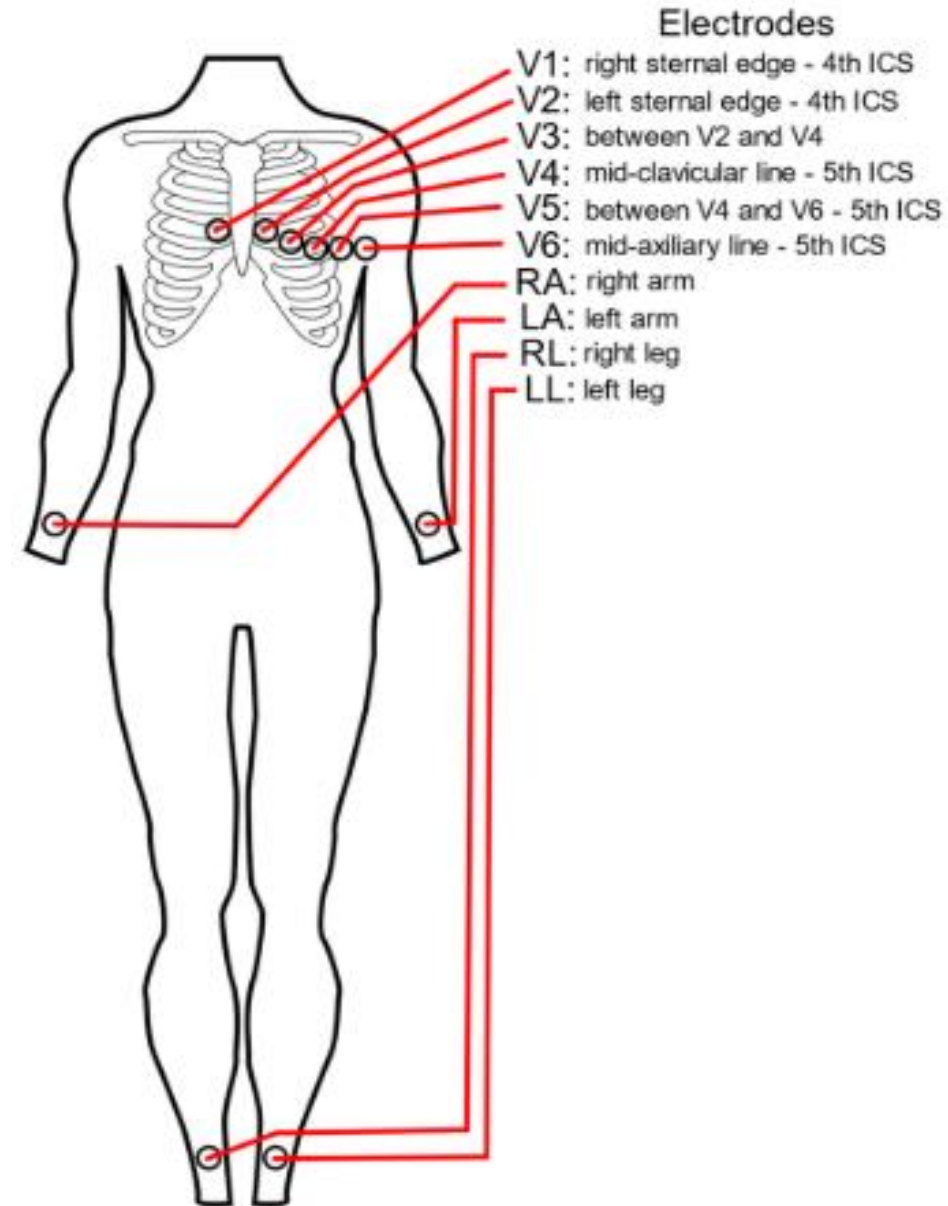


**Shortness
of Breath**



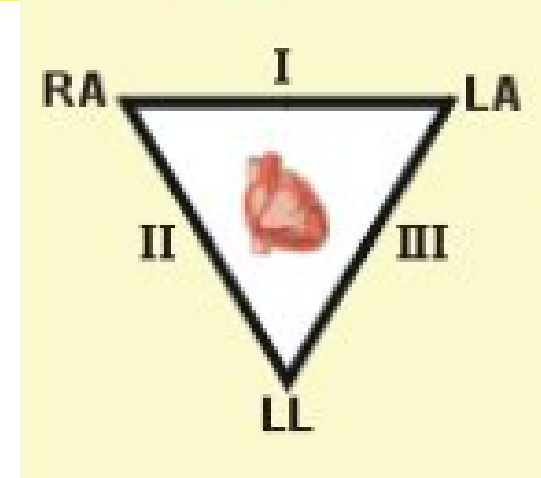
ECG LEADS

- 1. Electrodes are placed on the chest and limbs** of the patient to record different views of the heart's electrical activity.
- 2. Each view of the heart is described as a 'lead'.** The word 'lead' does not refer to the electrodes.
- 3.** Graphically, each lead has a corresponding axis, each axis has an orientation.
- 4.** There are three lead systems that make up the standard ECG:
 - a) Standard Limb Leads (Bipolar):** I, II & III
 - b) Augmented Limb Leads (Unipolar):** aVR, aVL & aVF
 - c) Precordial Leads:** V1- V6

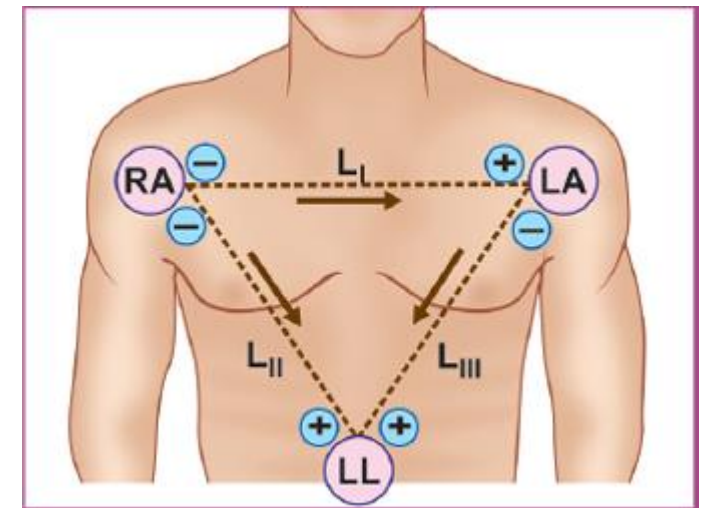


STANDARD LIMB LEAD

- 1. Standard Limb Lead** are bipolar leads, exploring the activity of the heart **in coronal plane based on Einthoven Triangle**.
- The lead system uses **three active electrodes and a grounding electrode**.
- The electrodes are named with the first letter of the words indicating their positions and are usually colour-coded:
 - 1. Right upper limb –R** (right)- red
 - 2. Left upper limb- L** (left)-yellow
 - 3. Left lower limb- F**(foot)- green
- The ground limb-** on the right lower limb and is usually black.



(a) Einthoven Triangle

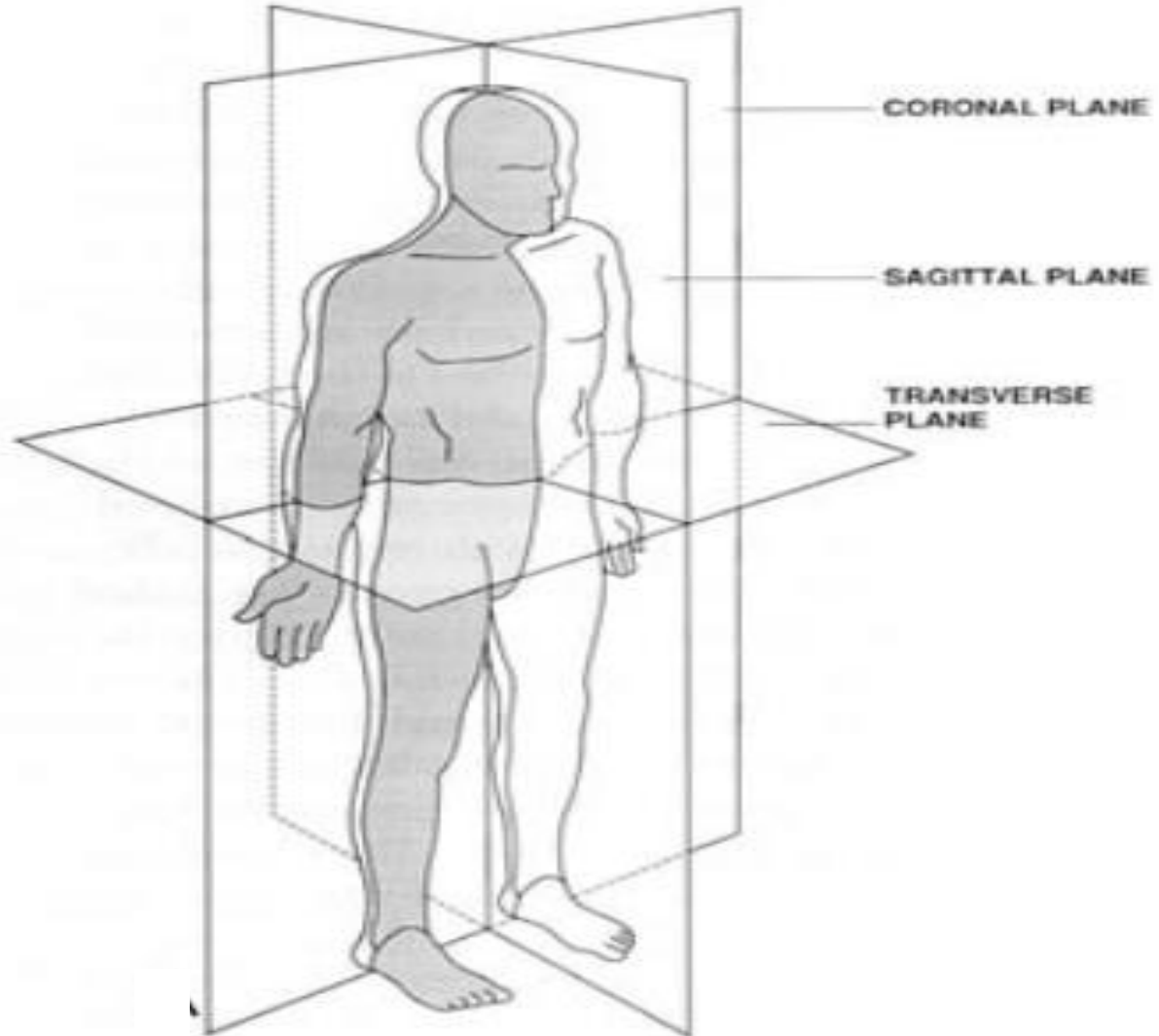


(b) Standard Limb Lead

RECAP: ANATOMICAL PLANES

RECAP:

Standard Limb Lead are bipolar leads, exploring the activity of the heart in **coronal plane based on Einthoven Triangle.**



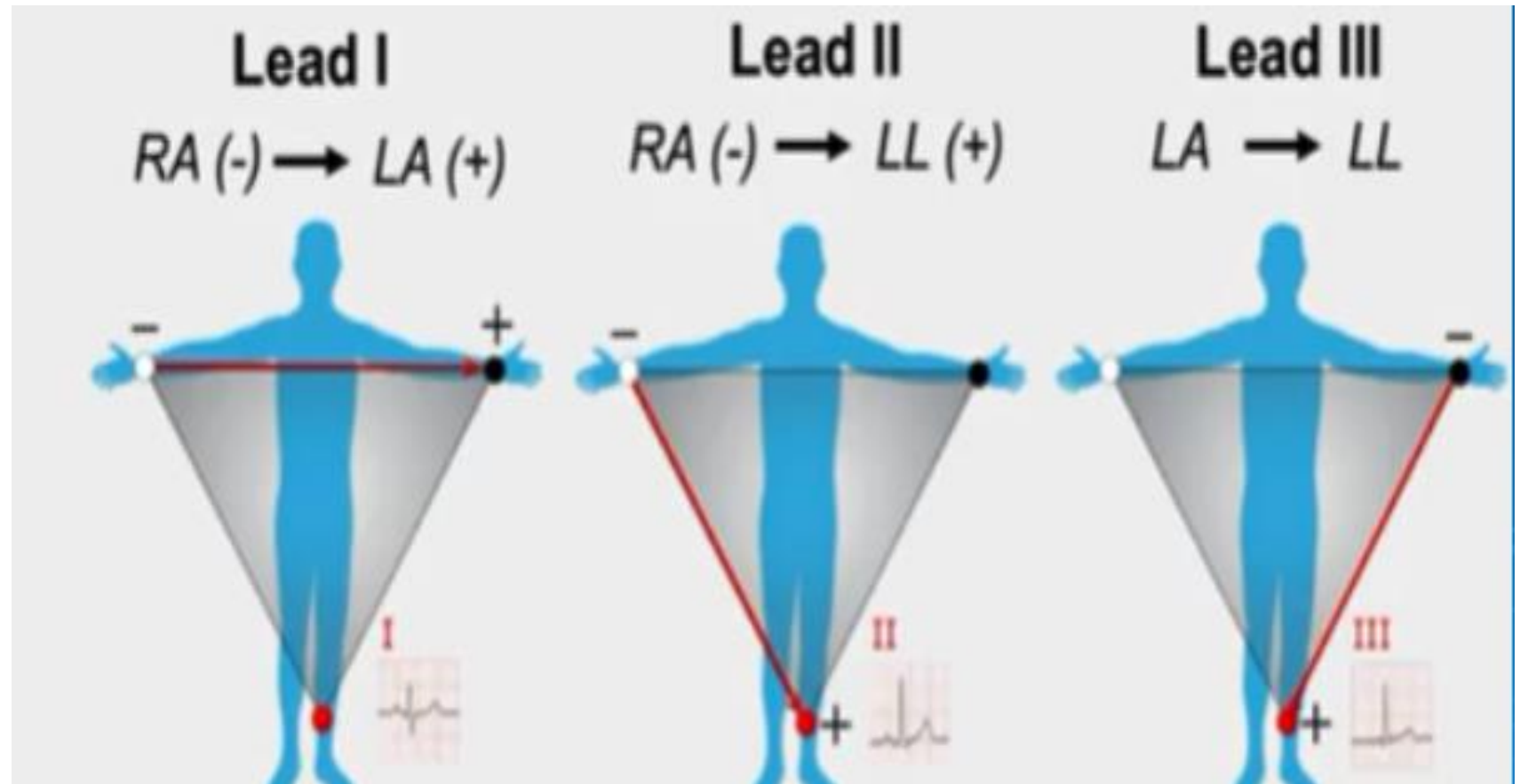
STANDARD LEAD SYSTEM

Standard Lead uses electrodes are located on the limbs – one on each arm and one on the left leg

I = LA - RA

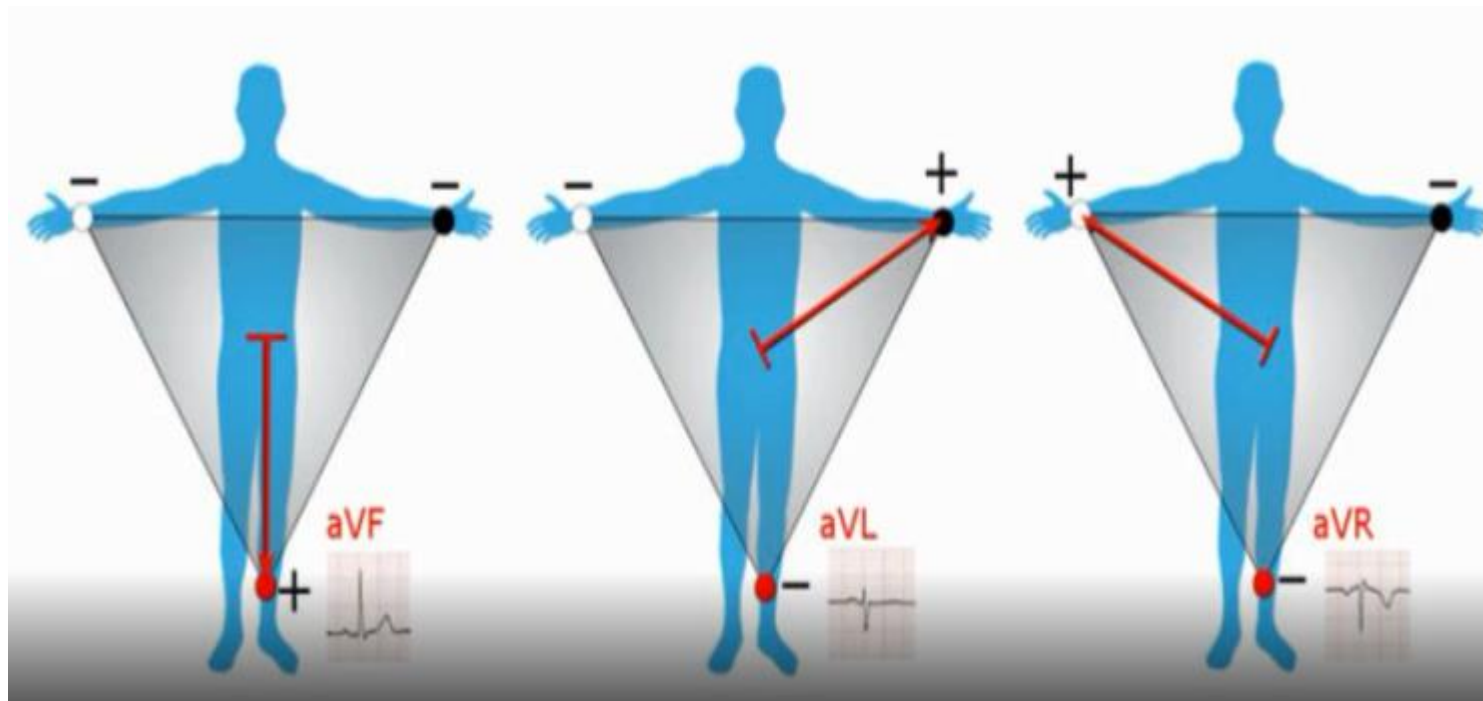
II = LL - RA

III = LL - LA



AUGUMENTED LIMB LEAD

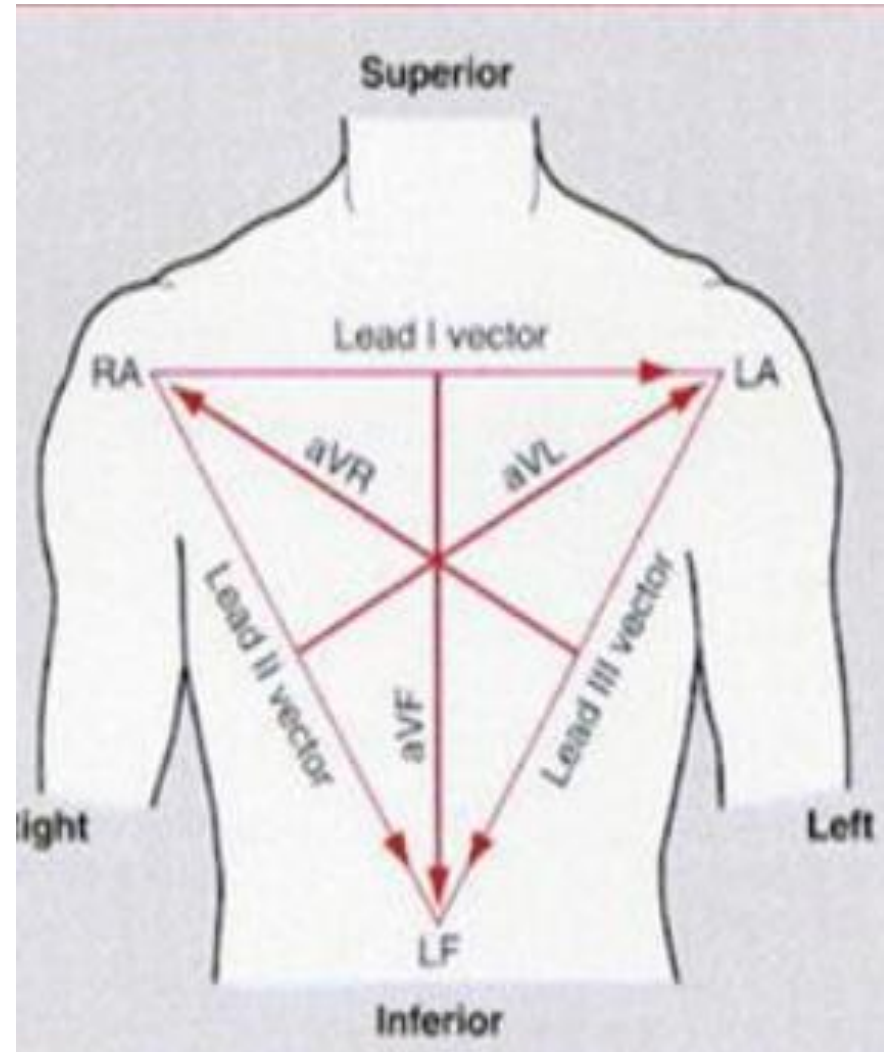
1. To obtain the augmented limb leads, the same electrodes are placed in the same as for limb leads position (R, L, F) as **unipolar lead**
2. **Augmented limb lead** is used to explore the activity of the heart in the **coronal plane**.



AXES OF AUGUMENTED LEADS

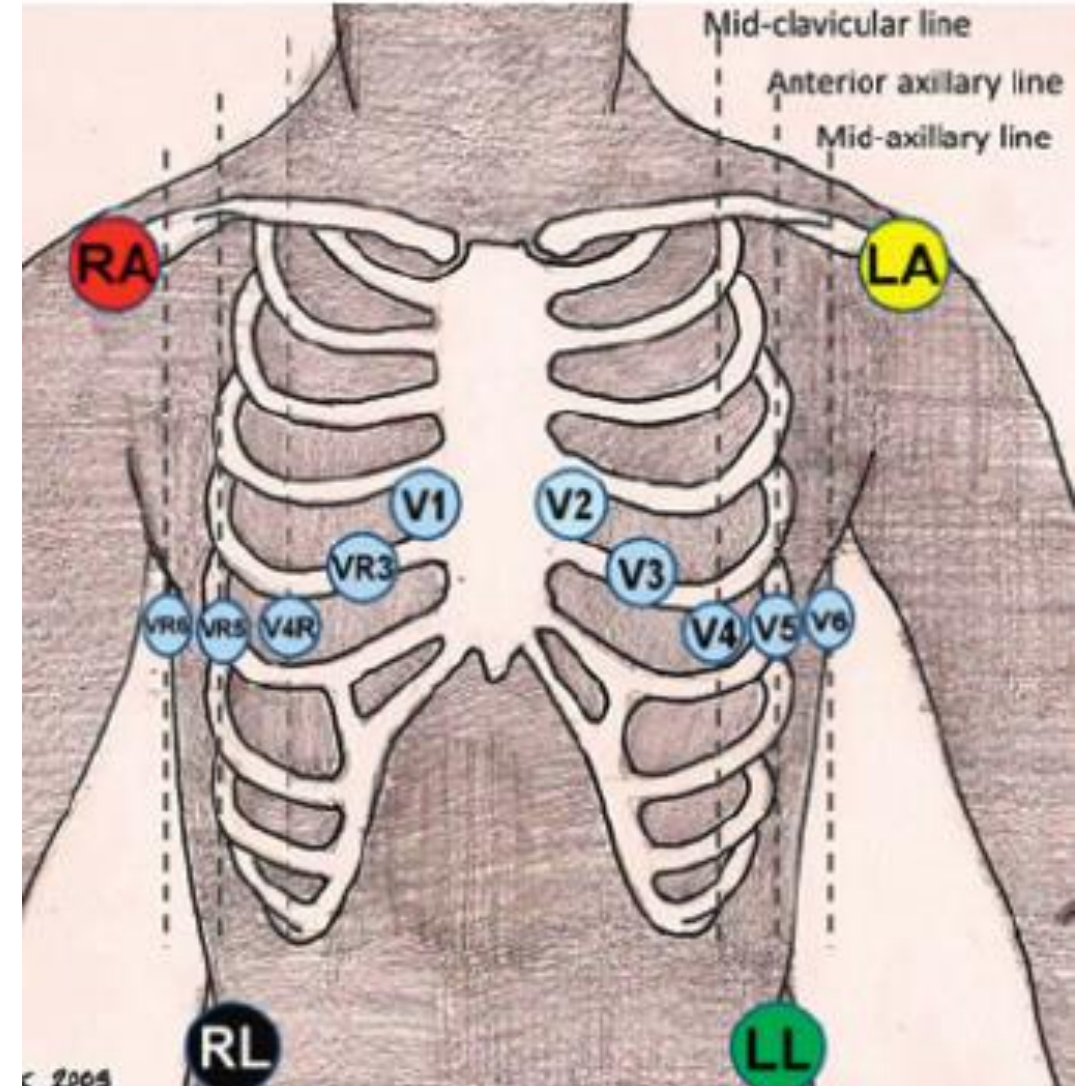
1. The axes of the unipolar limb leads are perpendicular to the axes of the limb leads.
2. The axes point towards the exploring electrodes as shown.
3. Applying Kirchhoff's 2nd Law, it turns out that:

$$AVL + AVR + AVL = 0$$



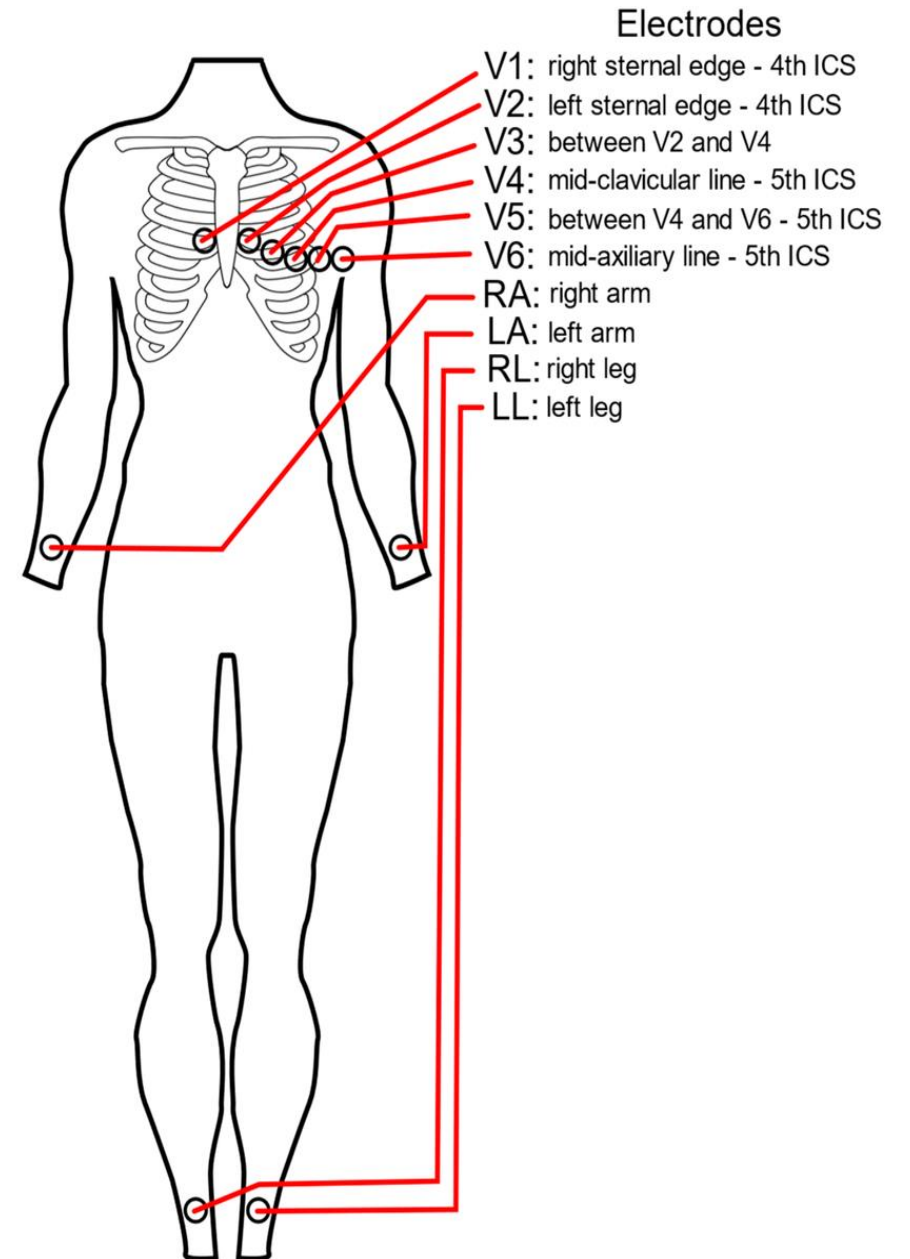
CHEST (PRECORDIAL) LEAD

1. **Precordial leads lie in the transverse (horizontal) plane, perpendicular to the coronal plane.**
2. The electrodes are placed at the surface of the chest as follows:
 - V1**- in the 4th intercostal space, right of the sternum.
 - V2**- in the 4th intercostal space, to the left of the sternum.
 - V3**- between V2 and V4.
 - V4**- in the 5th intercostal space, on the midclavicular line.
 - V5**- in the 5th intercostal space, on the anterior axillary line.
 - V6**- in the 5th intercostal space, on the midaxillary line.



SUMMARY - ECG ELECTRODE PLACEMENT /01

1. The name and placement of the standard **ten electrodes** used to collect and calculate a standard twelve-lead ECG are as shown.
2. **These ten electrodes** include the limb leads (RA—right arm, LA—left arm, RL—right leg, and LL—left leg) as well as the chest leads (V1–V6).
3. **The RL lead** is used as a ground electrode.



NORMAL RESTING HEART RATES AT DIFFERENT AGES

AGE	NORMAL HEART RATE (BPM)
Newborns	100–205
Infants under 1 year	100–180
From 1–2 years	98–140
From 3–5 years	80–120
From 6–7 years	75–118
Older children, teens, and adults	60–100

1. The resting heart rate can vary within this normal range.
2. It will increase in response to
 - a) Exercise
 - b) Body temperature
 - c) Emotional triggers
 - d) Body position, such as for a short while after standing up quickly.

[Heart rate: What is a normal heart rate?](http://medicalnewstoday.com)
(medicalnewstoday.com)

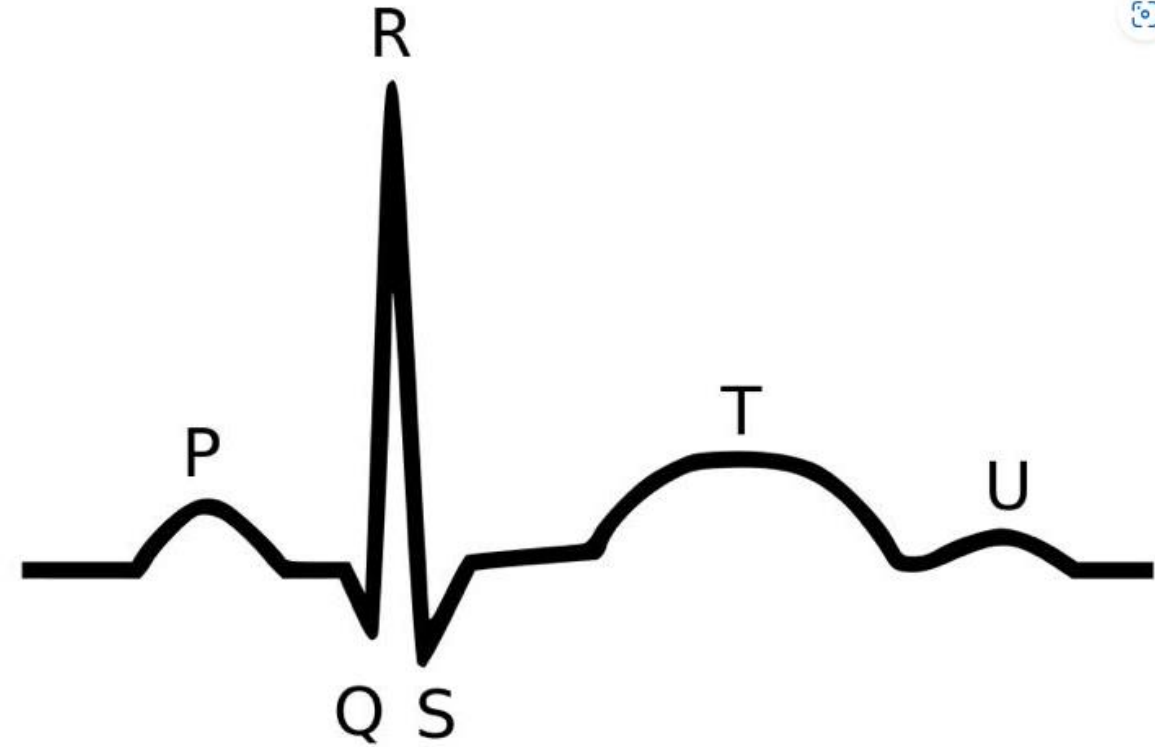
HEART RATES AT DIFFERENT AGES UNDER EXERTION

Age (years)	Target heart rate zone at 50–85% exertion (bpm)	Average maximum heart rate at 100% exertion (bpm)
20	100–170	200
30	95–162	190
35	93–157	185
40	90–153	180
45	88–149	175
50	85–145	170
55	83–140	165
60	80–136	160
65	78–132	155
70	75–128	150
75	73–123	145
80	70–119	140
85	68–113	135
90	65–111	130

[Heart rate: What is a normal heart rate? \(medicalnewstoday.com\)](#)

ECG RECORDING/DISPLAY -WAVES

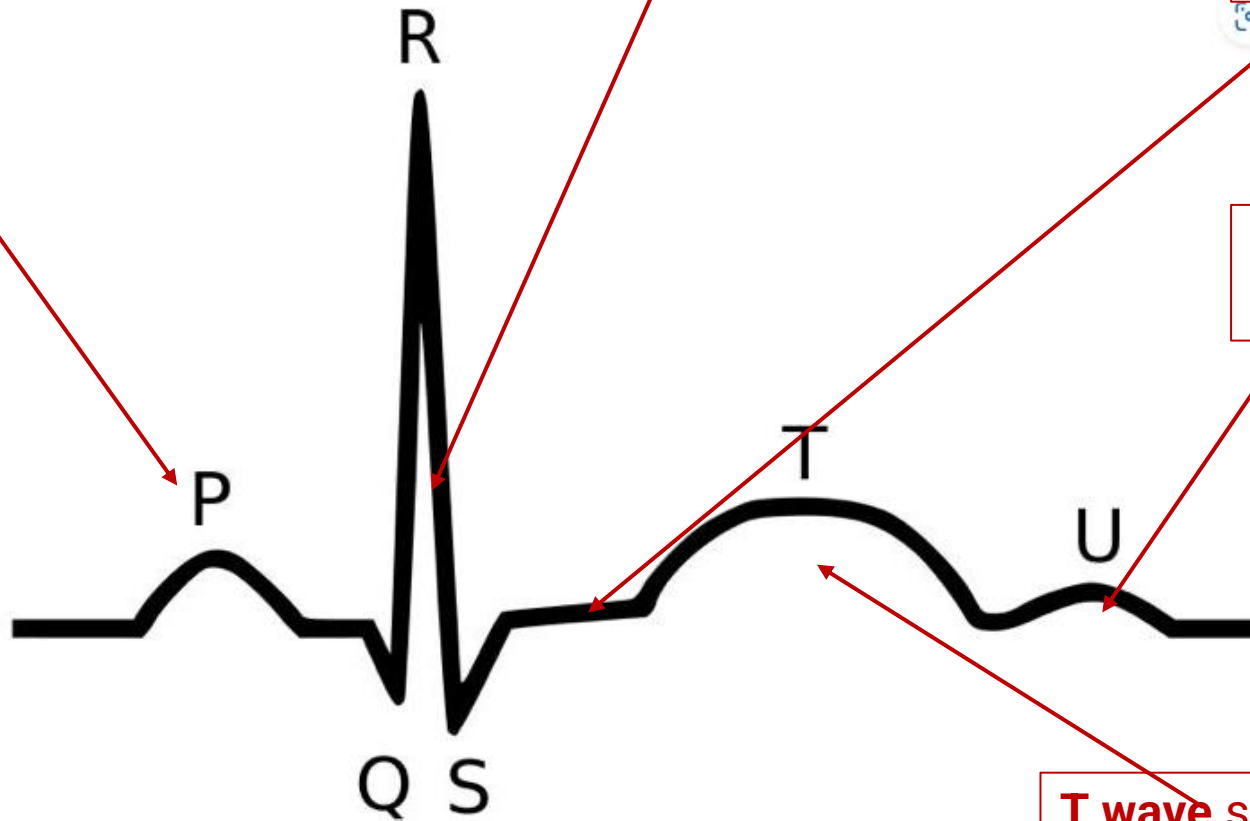
1. **Electrocardiogram** translates the heart's electrical activity into line tracings on paper.
2. The **spikes and dips** in the line tracings are referred to as waves which can be described as follows:
3. **P wave** is a record of the electrical activity through the upper heart chambers (atria)
4. **QRS complex** is a record of the movement of electrical impulses through the lower heart chambers (ventricles).
5. **ST segment** shows when the ventricle is contracting but no electricity is flowing through it.
6. **T wave** shows when the lower heart chambers are resetting electrically and preparing for their next muscle contraction.



P wave is a record of the electrical activity through the upper heart chambers (Atria)

QRS complex is a record of the movement of electrical impulses through the lower heart chambers (Ventricles).

ST segment shows when the ventricle is contracting but no electricity is flowing through it. (repolarization).

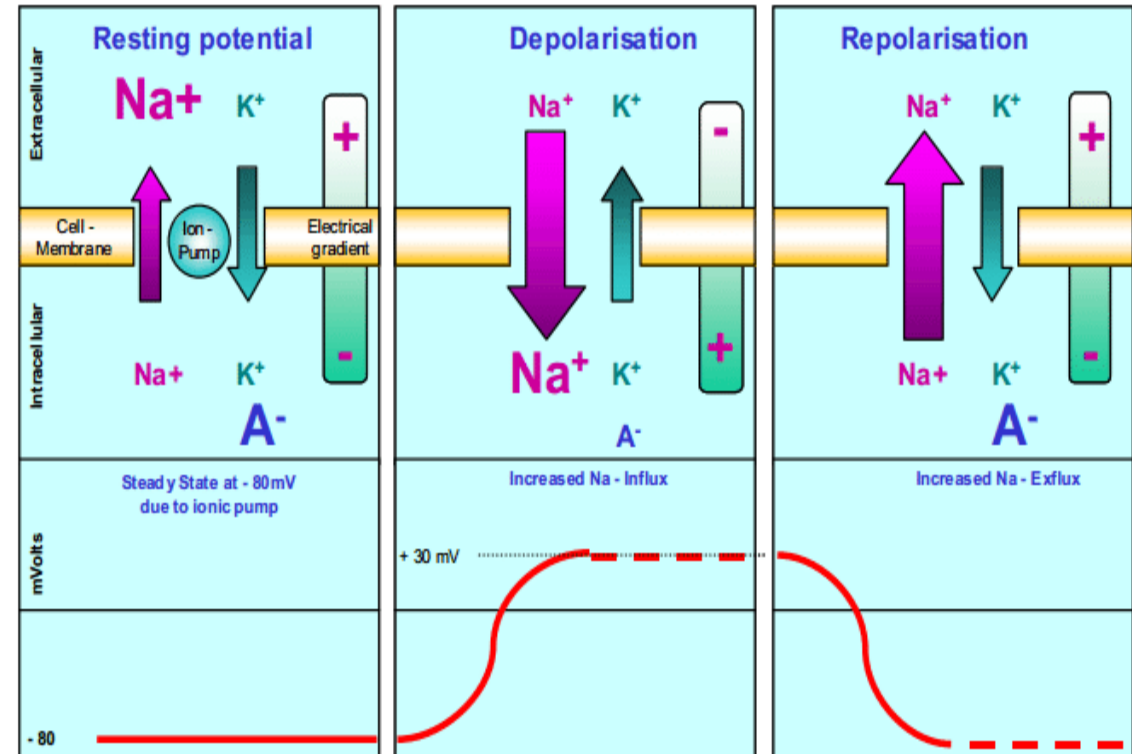


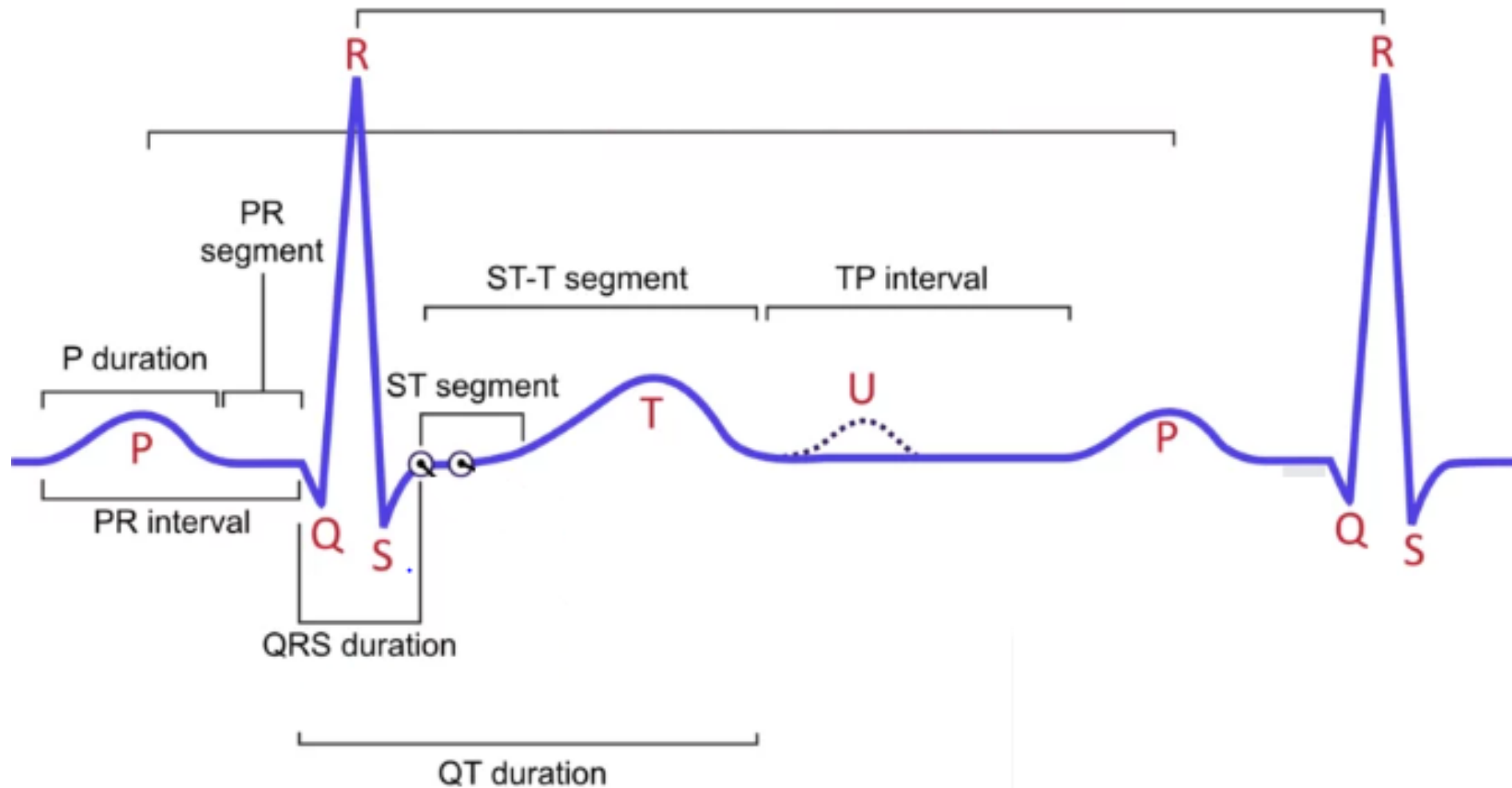
U wave represent the last phase of ventricular repolarization.

T wave shows when the lower heart chambers are resetting electrically (repolarization). and preparing for their next muscle contraction

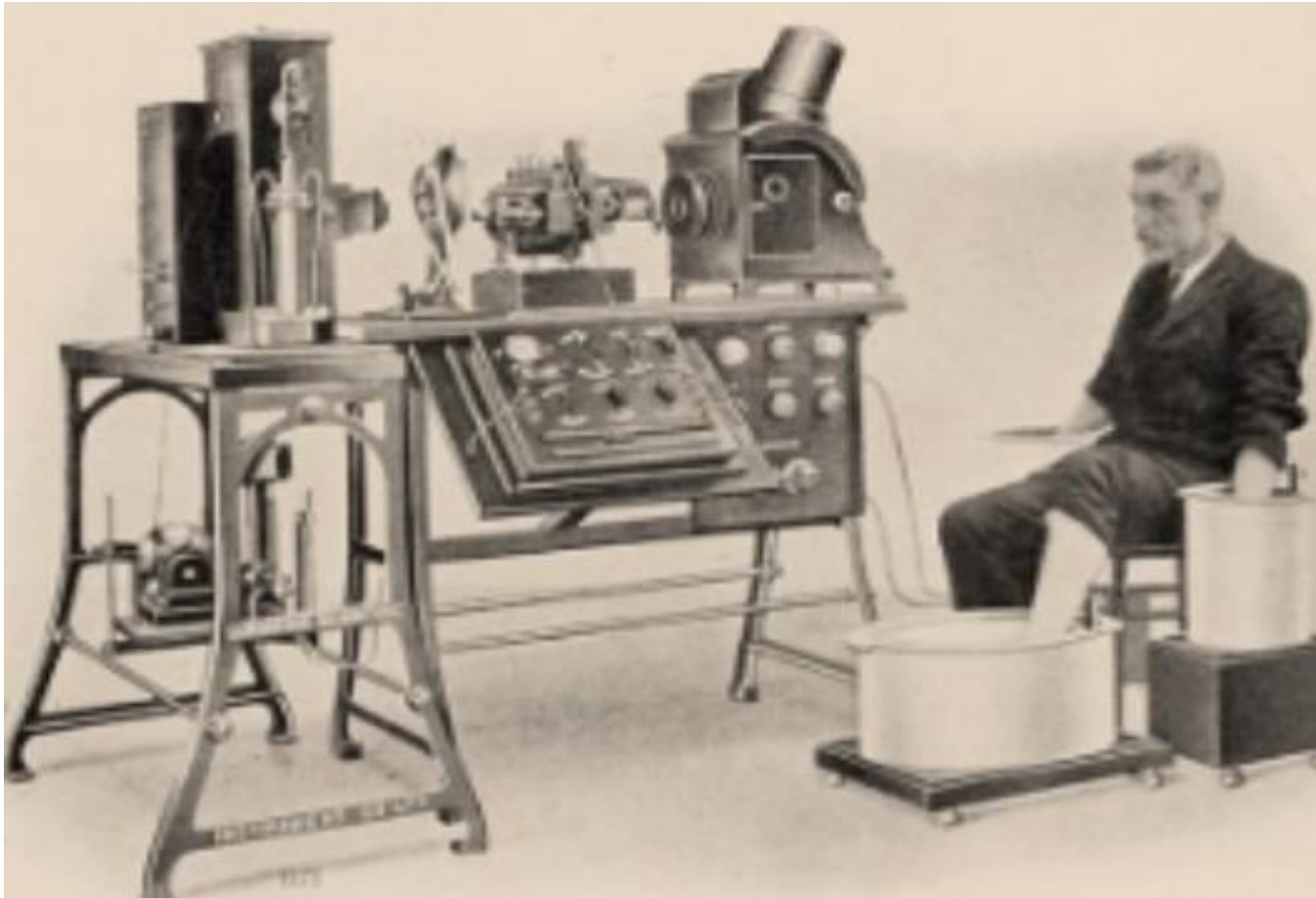
DEPOLARISATION & REPOLARISATION OF THE HEART

- **Depolarization and repolarization** are words that can be used to describe how a heart cell is responding to the electrical conduction system of the heart.
- **Depolarization:** Cells become depolarized (hence contract) when the ion concentration is shifted. When the cell is resting there are more sodium ions on the outside of the cell than the inside, and they can't get inside of the cell because of the impermeable cell membrane.
- When the cell is stimulated by electrical activity from SA or AV node) it causes the cell membrane to become receptive to sodium and sodium can now get inside. This makes the cell positively charged, which changes its polarized state to a depolarized state, and this leads to the contraction of the heart cell.
- **Repolarization:** After the heart cell contracts it relaxes. This is referred to as repolarization. Repolarization is where the cell goes back to its negatively charged state on the inside (hence it repolarizes) causing the heart muscle cell to relax.





FIRST ELECTROCARDIOGRAM MACHINE



(a) Willem Einthoven with his invention in 1903. He invented first practical electrocardiogram for which he received a Nobel prize in 1924.



(b) Modern ECG Machine

COMPONENTS OF ECG

The main components of an electrocardiograph are:

- 1. Signal acquisition system-** includes the electrodes and the cables;
- 2. 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.
- 3. Signal charting system,** displays the ECG trace either on millimeter

PRICE OF ECG MACHINE IN KENYA /01



Ge MAC 5500
HD ECG unit
Ksh 70,439....
US\$546.30 ...
AA Medical

ECG



Contec Contec
ECG1200G...
Ksh 50,157....
US\$389.00 ...
EastShore M...

ECG



Ge MAC 5500
HD EKG...
Ksh 322,350...
US\$2,500.00...
SakoMed

ECG Machine



Ge 5000 ECG
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- Limbs electrode
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