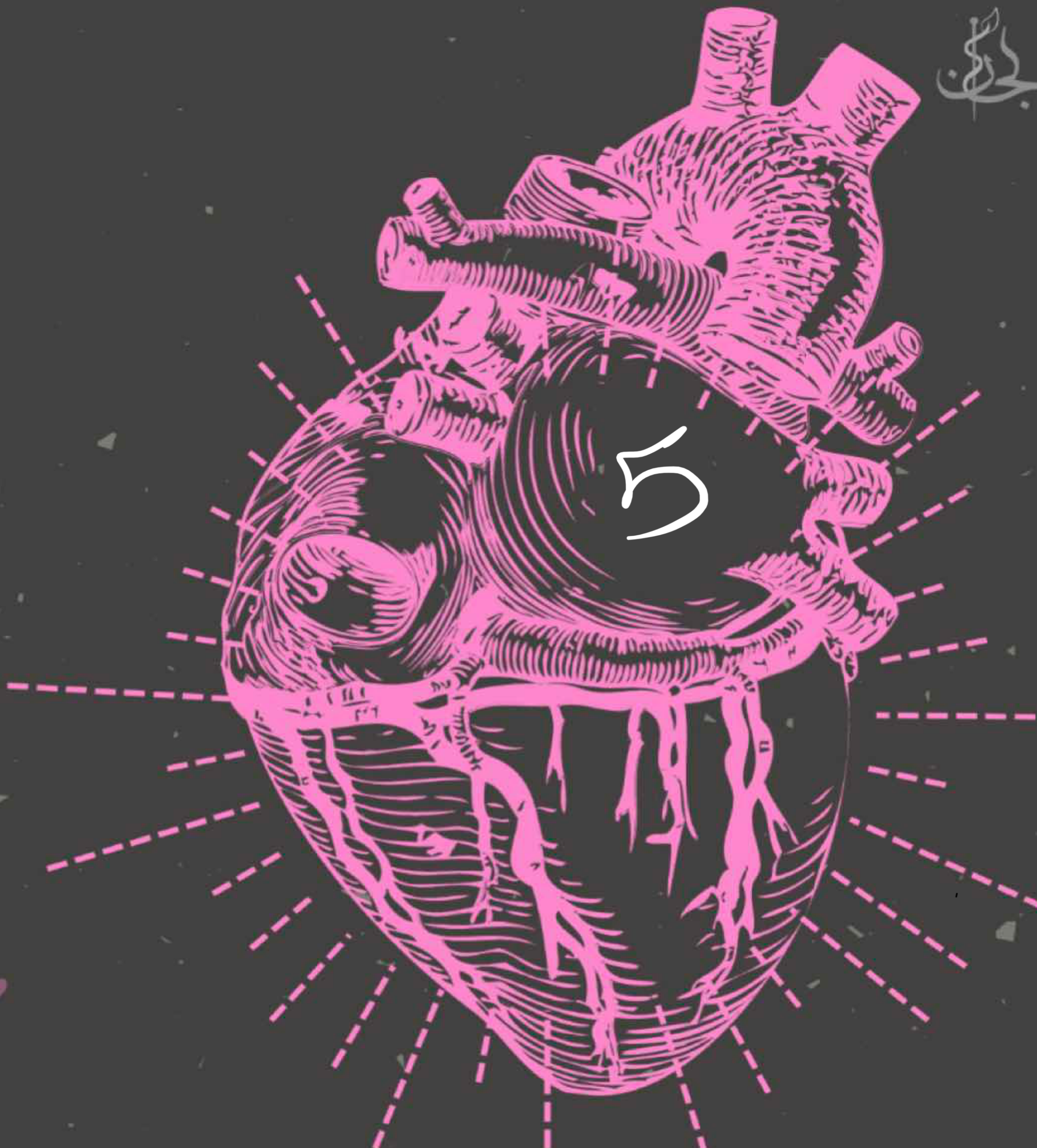
CVS



PHYSIOLOGY

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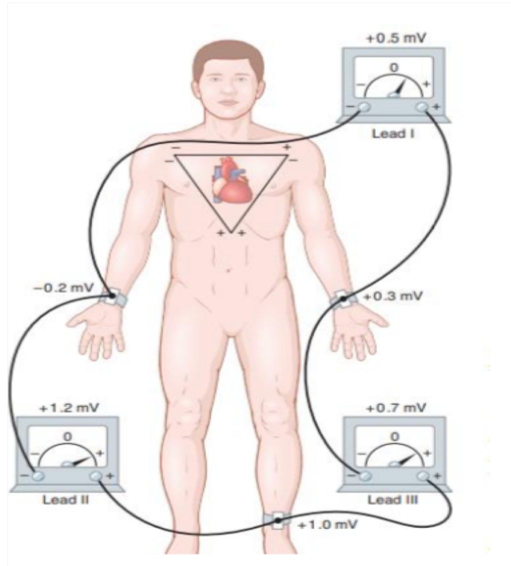
Bipolar Limb Leads

- Bipolar means that the ECG is recorded from two electrodes on the body.
- There are 3 bipolar limb leads (Leads I, II and III).
- In each lead, we have a galvanometer with two electrodes, positive and negative.
- In bipolar limb leads, we use the right arm, left arm and the left foot. The right foot is considered an earth (ground lead).



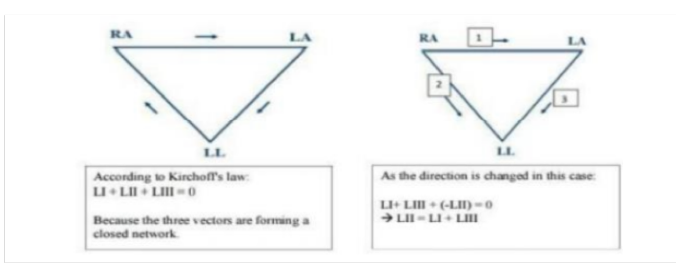
- Lead I: RA (-) to LA (+): the negative terminal of the electrocardiogram is connected to the right arm, and the positive terminal is connected to the left arm
- Lead II: RA (-) to LL (+): the negative terminal of the electrocardiogram is connected to the right arm, and the positive terminal is connected to the left leg
- Lead III: LA (-) to LL (+): the negative terminal of the electrocardiogram is connected to the left arm, and the positive terminal is connected to the left leg

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 0.5 + 0.7 = 1.2 mv

- In other words, if the electrical potentials of any two of the three bipolar limb electrocardiographic leads are known at any given instant, the third one can be determined by simply summing the first two. Note, however, that the positive and negative signs of the different leads must be observed when making this summation.
- If we change the direction of Lead II to go from Left Foot to Right Arm the resultant summation of all three leads would equal to ZERO. This is because the three vectors form a closed circuit.
- ➔ According to Second Law of Electricity (Kirchhoff's law): if a current goes in a closed circuit, the summation of the currents of lead I, lead II and lead III equals zero. Einthoven reverses the direction of lead II; so that there is no closed circuit.

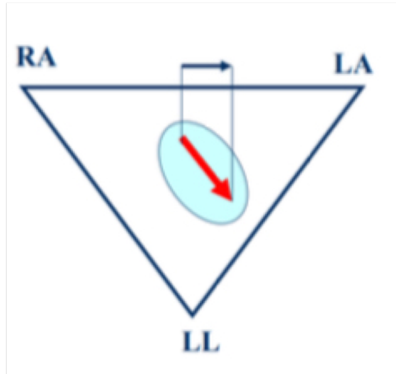
Lead I potential + Lead III potential + Lead II potential = 0



Now, we'll learn how to record the positive recording in those leads

- **Lead I**

▪ We said that the mean electrical axis of QRS is pointing to the left, inferiorly and anteriorly.



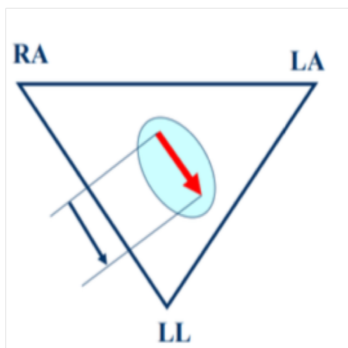
▪ In recording limb lead I, the negative terminal of the electrocardiograph is connected to the right arm and the positive terminal is connected to the left arm, so the axis of lead 1 will be directed from the right arm to the left arm

▪ In order to record the value of lead I we draw a perpendicular angle from the mean electrical axis to the axis of lead I and this will be the recording of the QRS in lead I

▪ When the point where the right arm connects to the chest is electronegative with respect to the point where the left arm connects, the electrograph records positively, when the opposite is true it records negatively.

▪ For better understanding, let's take a numerical example. Let us assume that momentarily, the right arm is −0.2 millivolts (negative) and the left arm is +0.3 millivolts (positive), and the left leg is +1.0 millivolts (positive). Lead I records a positive potential of +0.5 millivolts because this is the difference between the −0.2 millivolts on the right arm and the +0.3 millivolts on the left arm.

- **Lead II**



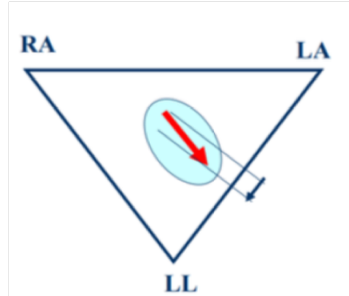
▪ In recording limb lead II, the negative terminal of the electrodiograph is connected to the right arm and the positive terminal is connected to the left leg

▪ We record the value of Lead II in the same way we calculated the value of Lead I by drawing a perpendicular angle

▪ When the right arm is negative with respect to the left leg, the electrodiograph records positively, when the opposite is true it records negatively

▪ Going back to our numerical example, lead II records a positive potential of +1.2 millivolts because these are the instantaneous potential differences between the respective pairs of limbs.

- **Lead III**



▪ To record Lead III, the negative terminal of the electrodiograph is connected to the left arm and the positive terminal is connected to the left leg

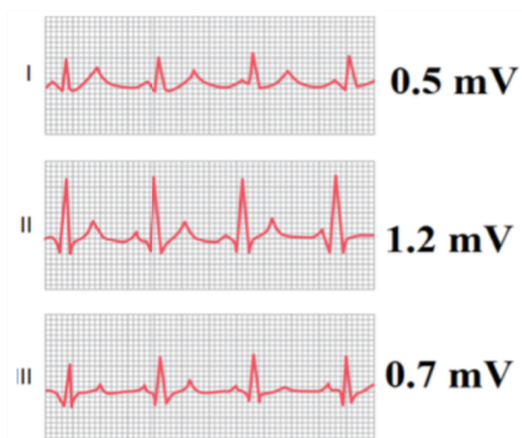
▪ Just like we did before, we record its value by drawing a perpendicular angle

▪ When the left arm is negative with respect to the left leg it records positively, when the opposite is true it records negatively

▪ As for the above-mentioned example, lead III records a positive potential of +0.7 millivolts as these are the instantaneous potential differences between the respective pairs of limbs.

-From the three leads, it is clear that lead II contributes the most to the resultant vector (as it is parallel to it) so it will have the highest magnitude.

-You can get the mean electrical axis by drawing a perpendicular line from every lead's axis and these three lines should meet in the middle in one point and this is the mean electrical value.



The following figure represents the recording of the mean QRS in every lead, we calculate the mean QRS by algebraic summation (it is done by the summation of the small squares)

▪ You can notice that **lead II** is equal to **lead I + lead III** and this is called **Einthoven's law**

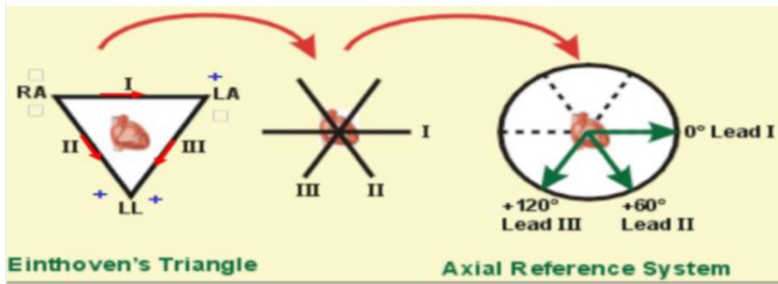
- By drawing the axis of each lead you'll end up with an equilateral, equiangular triangle (each angle is 60 degrees)

- The heads of this triangle are between the right arm, left arm and left foot, with the heart being at the center

- When you draw a perpendicular line from the midpoint to the sides you are going to have two equal sides

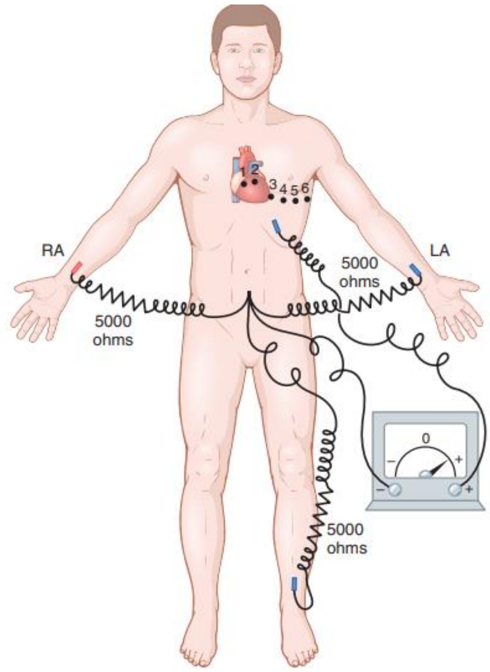
- We can also convert the information from equilateral triangle to a triaxial reference system, this is done by moving the axis of lead I, II, III in a parallel manner so that they meet at the center

- In the triaxial reference system, each lead is 60 degrees clockwise of the next and we take lead 1 as a reference.



✳ Augmented Unipolar Limb Leads

- Another system of leads in wide use is the augmented unipolar limb lead. In this type of recording we connect on the **negative** electrode three connections on the same exact positions where we put the Bipolar Limb Leads (right arm, left arm and left foot). These connections have Very High Resistance (=5000 Ohms) so that the net current in these three connections will be ZERO (called **indifferent** electrode).
- Note that all three connections are considered one negative electrode
- Then we place the positive electrode on a different position (Right Arm, Left Arm and Left Foot) each at a time calculating (VR, VL, and VF, respectively). The electrode is called **exploring** electrode.



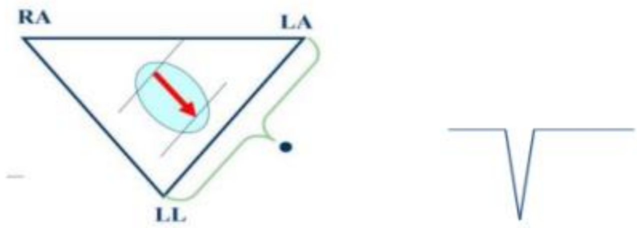
- The problem with the above-mentioned experiment is that the recording was too small, so a scientist called Wilson removed the high resistance from the right arm and kept the high resistance in the other two limbs.
- After removing the high resistance connected to the right limb, he found that the recording was augmented (amplified) which was way better to calculate. He called the new recording aVR (augmented vector right arm).
- He did the same with the left arm and got an augmented record and called it (aVL), and the same with the left foot and got another augmented record and called it (aVF).

➔ To summarize, 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.

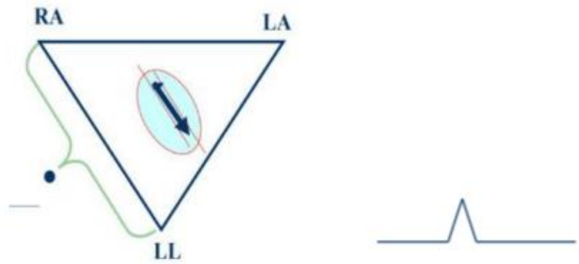
	Indifferent Electrode	Exploring Electrode
aVR	Connected to the left arm and left foot	**Connected to the right arm**
aVL	Connected to the right arm and left foot	**Connected to the left arm**
aVF	Connected to the right and left arms	**Connected to the left foot**

- It is called unipolar limb leads because we connect one pole to each of these limbs
- The mean electrical axis records positive if it's going towards the positive electrode, and negative if it is going away from the positive electrode

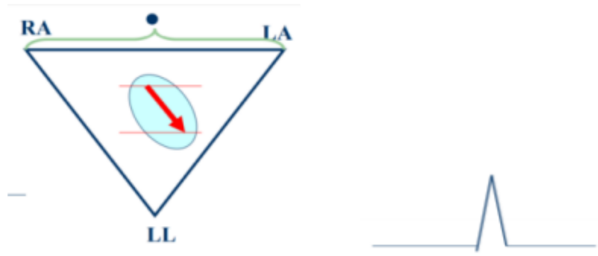
- **aVR:**
  - aVR = (LA-LL) vs. RA (+)
  - The measured potential difference is between RA (+) and the center point between LA and LL (-)
  - If we put the positive electrode in the right arm, aVR will move in opposite direction to the mean electrical axis so recording will be negative



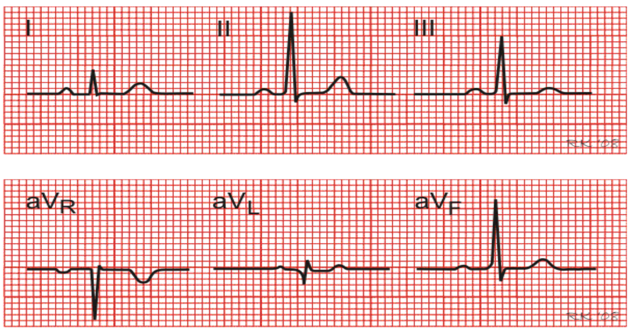
- **aVL:**
  - aVL = (RA-LL) vs. LA (+)
  - The measured potential difference is between LA (+) and the center point between RA and LL (-)
  - If we put the positive electrode in the left arm, aVL will move in the same direction to the mean electrical axis so recording will be positive (even though it's small, it records positively)



- **aVF:**
  - aVF = (RA-LA) vs. LL (+)
  - The measured potential difference is between LL (+) and the center point between RA and RA (-).
  - If we put the positive electrode in the left foot, aVF will move in the same direction to the mean electrical axis so the recording will be highly positive (most positive)



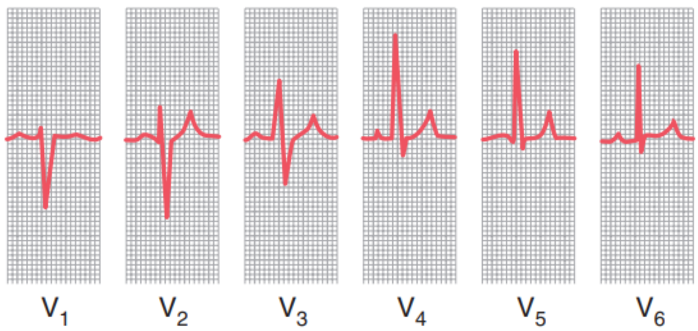
➔ Let's summarize using the following figure. aVR is negative because we are going away from the positive electrode, aVL is positive but in a small record and aVF is highly positive because it's mean electrical axis is going towards the positive electrode in the left foot.



❈ Chest leads

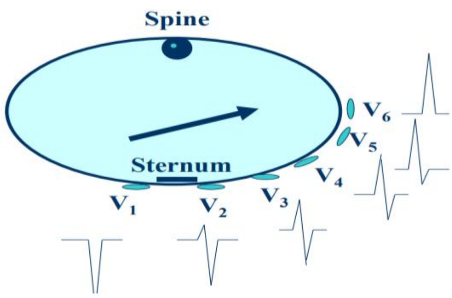
- In the limb leads we looked at the activity of the heart from the frontal plane, however using the Chest leads we will look at it from the horizontal plane.
- There are 6 unipolar chest leads (V1,V2,V3,V4,V5,V6) or we can call them (C1,C2,C3,C4,C5,C6).

Chest Lead	Location
V1	in the 4th intercostal space (right side) just beside the sternum
V2	in the 4th intercostal space (left side) around the sternum
V3	in the mid-way between V2 and V4
V4	in the 5th intercostal space (left side) in the mid-clavicular line
V5	in the 5th intercostal space in the anterior axillary line
V6	in the 5th intercostal space in the mid axillary line



- The following graph represents precordial (chest leads): indifferent electrode (RA-LA-LL) vs. chest lead moved from position V1 through position V6:
- The direction of the mean electrical axis is in V1 and V2 is away from the positive electrode so as we can see in this graph V1 and V2 are recorded negative
- V3 is recorded in the middle between positive and negative
- The direction of the mean electrical axis in V4 and V5 and V6 is toward the positive electrode so they're recorded positive

- Chest leads are very sensitive to electrical potential changes underneath the electrode
- Chest leads are considered unipolar leads



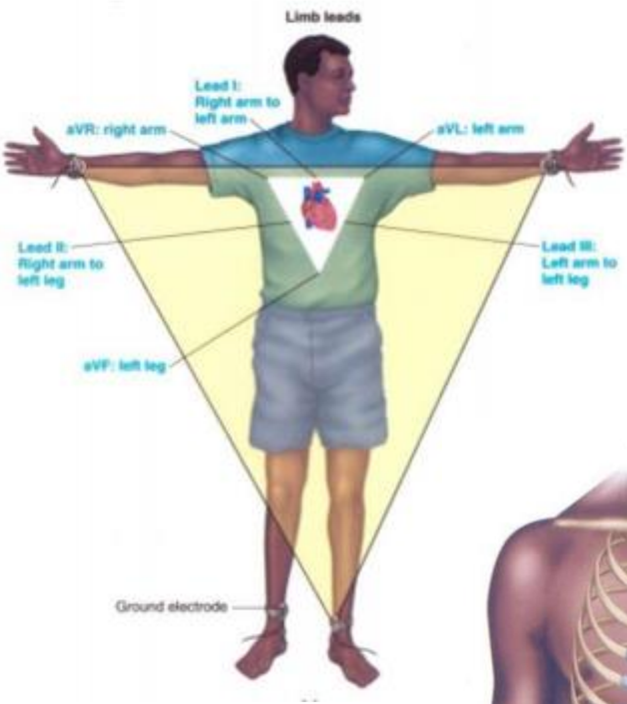
→ In conclusion, we have 12 leads, 9 of them are unipolar and 3 of them are bipolar

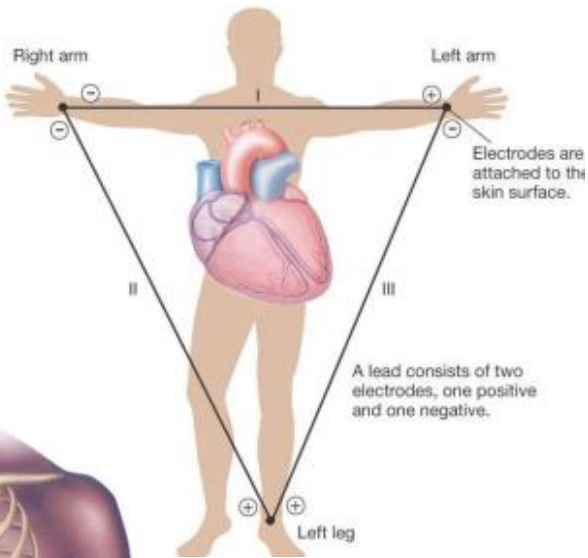
- The chest leads are from the transverse plane whereas the bipolar limb leads and the augmented unipolar leads are from the frontal plane.

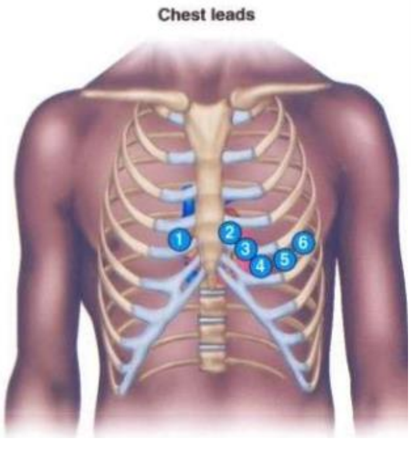
- The following figure presents a complete ECG (12 leads recording), as you can see:
  - The QRS in lead II equals the QRS in both lead I and lead III
  - aVR is negative whereas avF and aVL are positive
  - V1 and V2 are negative and V3 is starting to be positive (midline)
  - V4, V5, V6 are positive

- Chest leads are placed anteriorly on the chest, they can tell you about what is happening in the anterior and inferior aspects of the heart, but they can't tell you about the changes in the posterior aspect of the heart. To inspect the posterior aspect of the heart, we use another type of electrode that's called esophageal electrode.
- You use esophageal lead if you have a suspicion that there might be something abnormal in the posterior surface of the heart. Esophageal lead is used by putting the exploring electrode in the esophagus through the larynx → throat → esophagus and you start recording when it becomes posterior to the heart.

- The following pictures are for further understanding:







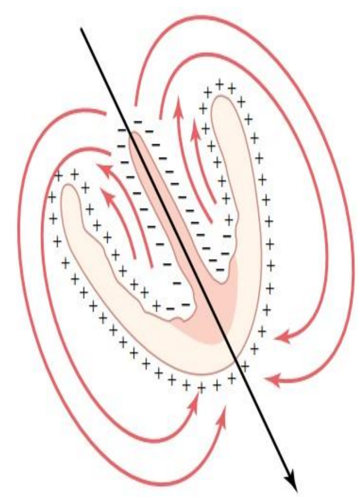
♥ Normal Electrocardiography:

In this sheet we will continue talking about the normal ECG of the heart.

Objectives:

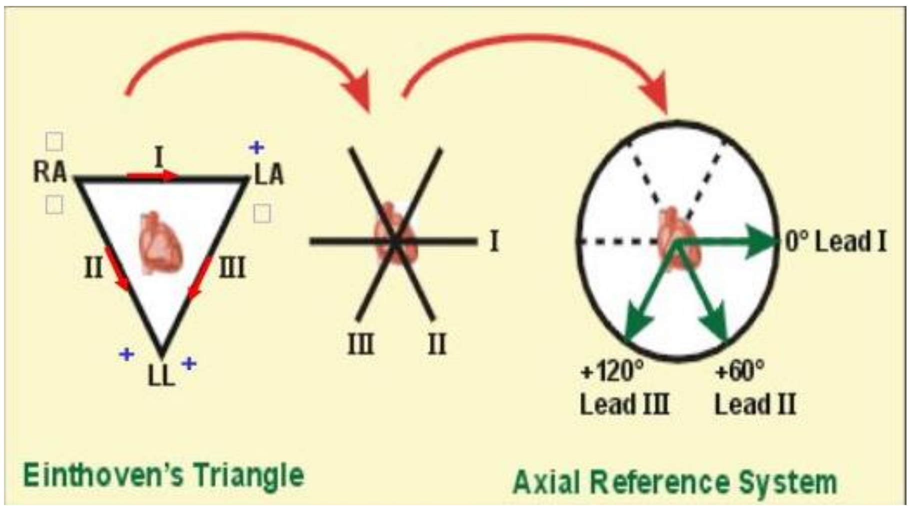
1. Recognize the normal ECG tracing.
2. Calculate the heart rate.
3. Determine the rhythm (normal Vs abnormal).
4. Calculate the length of intervals and determine the segments deflections (upward Vs downward).
5. Draw the Hexagonal axis of the ECG (bipolar + unipolar leads, both at the frontal plane).
6. Find the mean electrical axis of QRS (Ventricular depolarization).

- The current in the heart flows from the area of depolarization to the polarized areas, and the electrical potential generated can be represented by a vector, with the arrowhead pointing in the positive direction. By convection, the length of the vector is proportional to the voltage of the potential.
- Direction of current flow is always from the negative point toward positive point. Current flows in all directions. ***Mean direction*** of flow of electrical potential at one instance is known as instantaneous mean vector.
- In a normal heart, the average direction of the vector during spread of the depolarization wave through the ventricles, called the mean QRS vector, is 60° (-30◦ - 110◦). **Clinically**, the normal mean QRS is between 0° and +90°.
- The figure shows, depolarization of the ventricular septum. At this instant of heart excitation, electrical current flows between the ***depolarized areas inside the heart and the non-depolarized areas on the outside of the heart***. More current flows downward from the base of the ventricles toward the apex than in the upward direction. Therefore, the summated vector of the generated potential at this particular instant***, the instantaneous mean vector,*** is represented by the long black arrow drawn through the center of the ventricles in a direction from ***base toward apex***. Furthermore, because the potential is large, the vector is long.

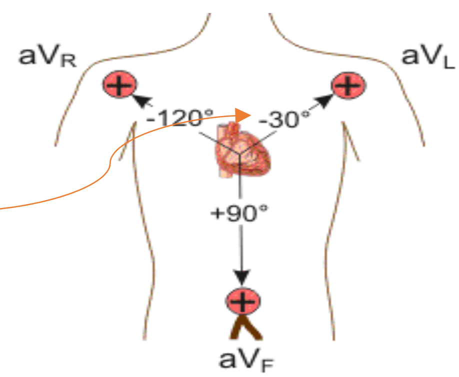


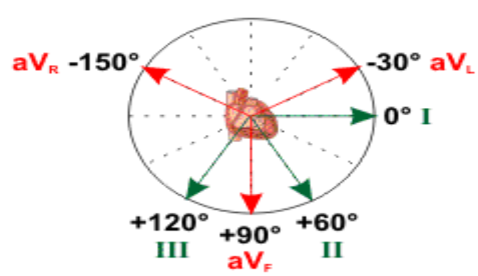
♥ Einthoven's triangle and law:

- The three standard limb leads (I, II, III) can be seen to form an equilateral triangle (each angle is 60°), with the heart at the center. This is called the Einthoven's triangle. To facilitate the representation of electrical forces, the three limb leads of the triangle can be drawn in such a way that the three leads bisect each other and pass through a common central point. This produces a ***triaxial reference*** system with each axis separated from the next by 60°. with the lead polarity (positive and negative poles) and orientation (direction) remaining the same.

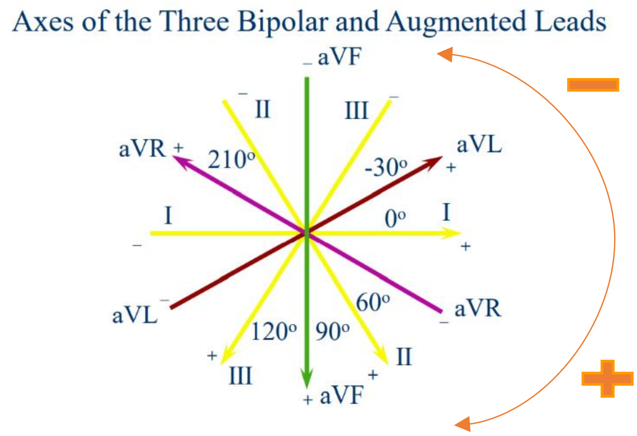


- Also, the augmented limb leads are recorded from one limb at a time (unipolar), the limb carrying the positive electrode, and the negative pole being represented by the central point. The three augmented limb leads (aVR, aVL, aVF) form another triaxial reference system, with each axis being separated from the next by 60°. When the triaxial system of the unipolar leads is superimposed on the triaxial system of the bipolar limb leads, we can derive a hexaxial reference system with each axis being separated from the next by 30°.

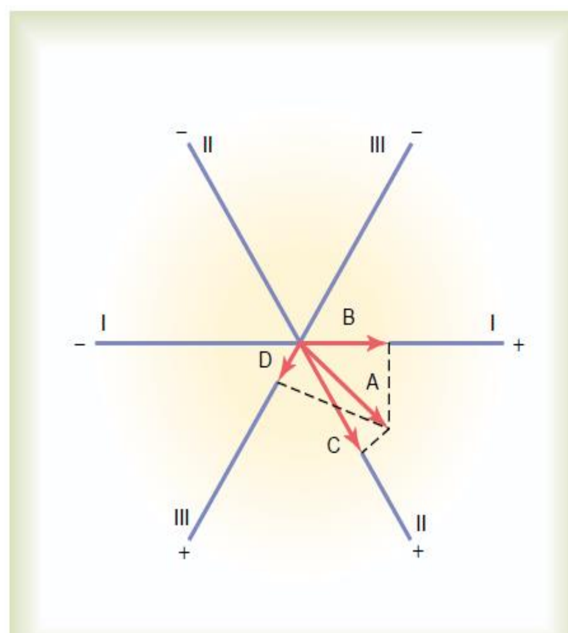




- Note that each of the six leads retains its polarity and orientation. The hexaxial reference system is important in determining the major direction of the heart's electrical forces (the electrical axis of the QRS complex).
- Perpendicular leads:
    1. L I and aVF
    2. L II and aVL
    3. L III and aVR



- Lead I is recorded from two electrodes placed respectively on the two arms. Because the electrodes lie exactly in the horizontal direction, with the positive electrode to the left, the axis of lead I is 0 degrees.
- In recording lead II, electrodes are placed on the right arm and left leg. The right arm connects to the torso in the upper right-hand corner and the left leg connects in the lower left-hand corner. Therefore, the direction of this lead is about +60 degrees.
- By similar analysis, it can be seen that lead III has an axis of about +120 degrees; lead aVR, +210°or -150°; aVF, +90 degrees; and aVL -30 degrees.
- Let's revise the basics of vectorial analysis by this example (extra example to clarify things before digging deeper in the analysis):
- Vector A is the instantaneous electrical potential of a partially depolarized heart. To determine the potential recorded at this instant in the ECG for each one of the three standard bipolar limb leads, perpendicular lines (the dashed lines) are drawn from the tip of vector A to the three lines representing the axes of the three different standard leads, as shown in the figure. The projected vector B represents the potential recorded at that instant in lead I, projected vector C represents the potential in lead II, and projected vector D represents the



potential in lead III. In each of these, the record in the electrocardiogram is positive that is, above the zero line because the projected vectors point in the positive directions along the axes of all the leads. The potential in lead I (vector B) is about one half that of the actual potential in the heart (vector A); in lead II (vector C), it is almost equal to that in the heart (because almost all of the electrical activity is coming toward the lead in that instant); and in lead III (vector D), it is about one third that in the heart (electrical activity is not heading directly toward this lead, but still detected by the lead).