ECG

Sheets 4-5-6-7 and first part of 9

ECG:

Electrocardiography is recording the electrical changes that happen in the heart (depolarization and repolarization aka the action potential of the ventricle and atrium) and it has nth to do with the mechanical changes (systole, diastole …contraction, relaxation or heart rate)

Although heart rate can be measured using ECG 'we will know how later in this sheet ,but this is not the main purpose for it

***NOTE:** one action potential in one cell in the atrium will be transmitted to the rest of the cells in the atrium at the same time (they work as if they are one cell) and this implies to the ventricles as well and this happens due to the gap junction between the cells (**syncytium**)

Electrocardiography is recorded using the galvanometer that records voltage difference. it has 2 poles, so it's bipolar; Logically these 2 poles must be put in the surface of the heart, But this is not applicable.

That's why we will record them from the surface of the body (we must measure and record it from different angles to have a full picture of the heart (different planes). One pole in the right arm and the other in the left foot. right foot left hand and so on)

How much are the potential differences that occur in the heart and how much it differs from the potential differences that occur at the level of the skin ?

The membrane potential at the resting state is =-90 and in the overshot (max)= 30

So there is difference of almost 120 and this is at the level of the heart

At the level of the skin it is going to reach 2-3 millivolt due to resistance

-so how is this problem solved?

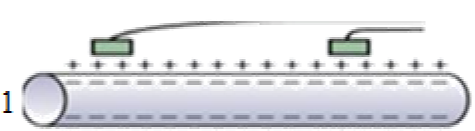
By amplification

*So the machine or the instrument that is used in ECG is **electrocardiograph** which is a galvanometer that records voltage difference (action potential) and an amplifier

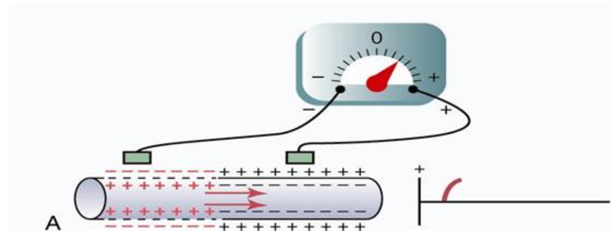
Depolarization and Repolarization waves:

Lets imagine (figure 1) that we have a strip of muscle that is in the **resting state** 'polarized' (outside is positive and inside is negative) the galvanometer record will be zero because there will be no potential difference
ALL WITH THE SAME CHARGE.

1

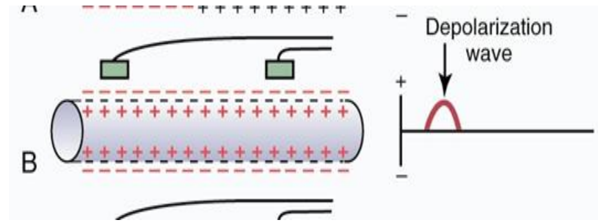


When the wave of depolarization starts, electrical potential differences can be recorded. Part of the muscle depolarize (outside neg and inside positive) and the other part is still in the resting state.



This potential difference is going to increase until we reach the midway (when half of the muscle is depolarized and the other half is still in its resting state) **figure A**.

When reaching the **midway** maximum recording (maximum pot difference) is recorded and then it will start to decrease until the whole membrane is depolarized (outside they will be all negatively charged, no potential difference ,recording=zero) **figure b**

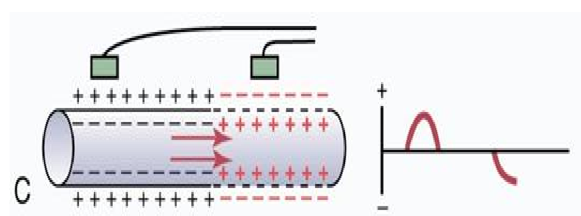


Reaching the Isoelectric line

This wave is called the **depolarization wave**
Note: depolarization wave doesn't always mean an upward reflection this can be changed and this depends in the arrangement of the 2 electrodes

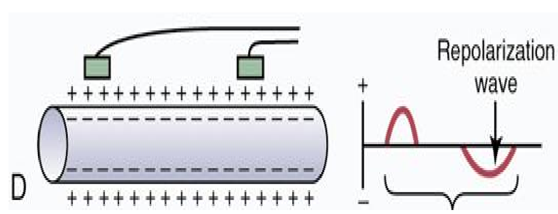
But it has been agreed internationally that the depolarization wave is an upward reflection and repolarization wave is a downward reflection

Repolarization state :where the k+ potassium channel open until reaching the resting state again .



the membrane is fully depolarized (neg outside, positive inside) then **repolarization** starts to happen and now charges outside the membrane are becoming positive again (increase the potential difference) until reaching the maximum level **midway** **figure c**

Then after exceeding the midway it starts to decrease till reaching the **fully repolarized** state (outside positive and recording is zero) **figure d**

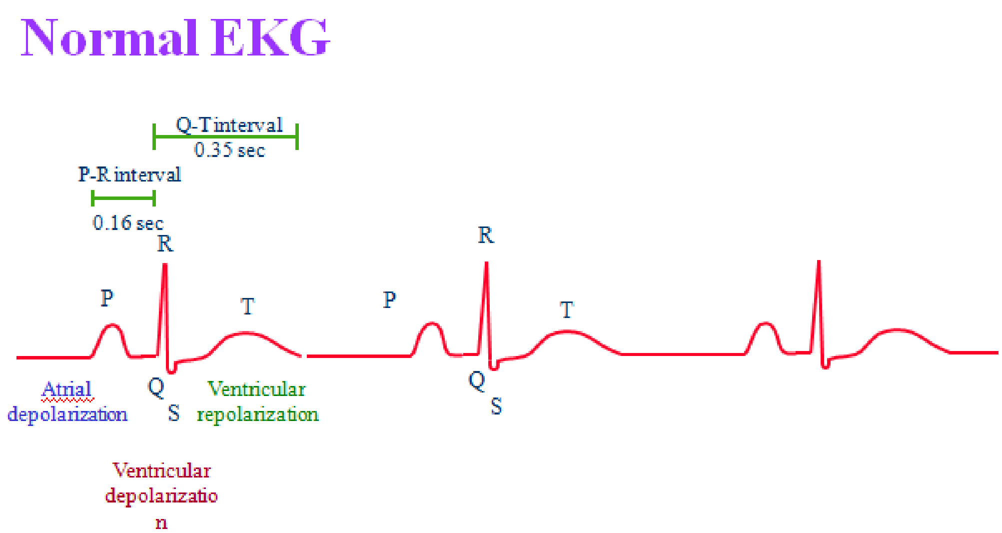


Note: the isoelectric line means : no potential difference , recording=zero , fully depolarized or fully repolarized state.

Normal EKG:

*** everything we are going to discuss is for normal EKG for a healthy person**

This figure shows a normal EKG (it shows depolarization of the atrium, depolarization and repolarization of the ventricles).



Waves:

P wave :that shows the depolarization of the atrium, This wave is slow because the atria have slow-conducting system.

QRS wave : depolarization of the ventricles, it is called a complex because all these waves refer to one thing, which is ventricular depolarization. Enlarged QRS complex occur when there's ventricular hypertrophy

(larger muscle mass means more currents, and thus higher reading), common causes of ventricular hypertrophy are hypertension, mitral valve stenosis or we may simply find it in athletes.

Prolonged QRS complex occur when there's a problem in ventricles, like bundle branch destruction.T wave represents repolarization, is expected to be seen as a negative deflection, but it's a positive deflection on ECG. Why is that?

-Because depolarization and repolarization don't start from the same point (Depolarization goes from the endocardium to the epicardium and from the base to the apex, while repolarization goes from the epicardium to the endocardium and from the apex to the base). This wave is potassium dependent, But why?

Remember that T wave represents repolarization wave that migrates from pericardium toward endocardium, and repolarization is basically efflux of K^+.

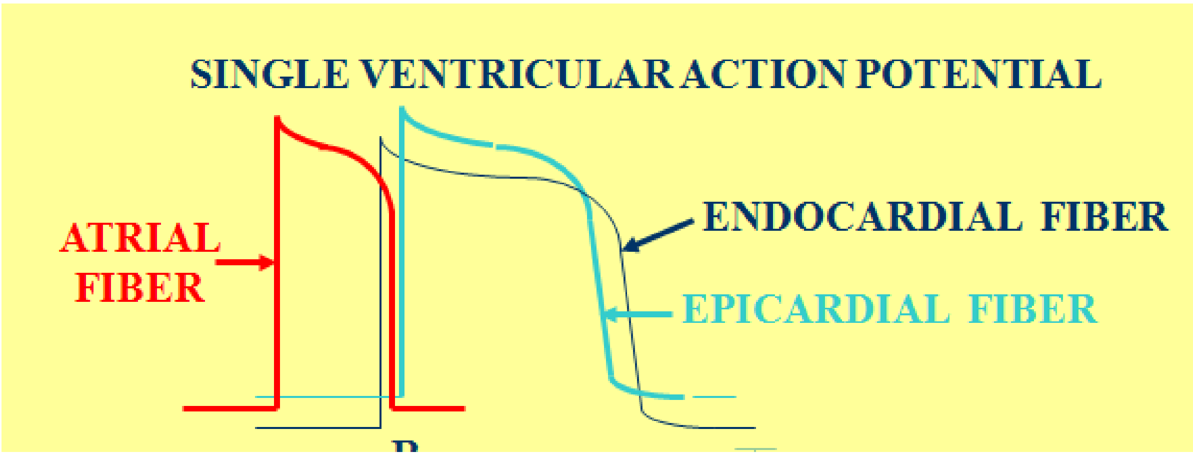
when there's hyperkalemia, T wave will be peaked.

In cases of hypokalemia or ischemia, T wave will be flattened

- If the recording stopped and a continuous straight line appeared this means this person is dead, as death is diagnosed with a straight line in the EKG.

-As you can see depolarization of both atria and ventricles are shown but only the repolarization of the ventricle).

We can't see the atrial repolarization ..why ?!



As you can see from the figure above, the atrial repolarization happens while the ventricles are being depolarized.

So the atrial repolarization doesn't show up because:
1. It is small 2. It is masked by ventricular depolarization.

(**Phase 3 of the atrium happens at the same time as phase 0 of the ventricle)**

- another thing that we can see from the EKG is that the depolarization of the ventricle and the **repolarization** waves (QRS wave and the T wave) are **upwardly** recorded !

before saying why that happens note to self we said that the direction of depolarization and repolarization depends on how the electrodes are arranged so changing the poles direction changes the direction of the wave but logically this is **not** the case here.

- this means that the change happened from the heart itself and not from the electrodes…

depolarization starts from the endocardium to pericardium and from the base of the heart to the apex

but repolarization is different it starts from pericardium to endocardium and from apex to base.

why?!

1.the intrinsic property of the muscle: the pericardium action potential is shorter in duration than the endocardium so the wave of repolarization starts from the pericardium to the endocardium.

2. During ventricular contraction, intraventricular pressure (i.e. pressure inside the myocardium of the ventricle) increases. This pressure is the highest close to the endocardium and the lowest close to the epicardium, and this may change the electrolyte environment in the endocardium to the extent that delays repolarization.

Also, you can notice that the ventricular depolarization(black line in the figure above) occurs almost at the same time with the atrial repolarization. This is why atrial repolarization doesn't show up on ECG.

- Can you think of one situation at which atrial repolarization may appear?

Yes. It's when ventricular depolarization is delayed. For example, AV block delays ventricular depolarization, so both events don't occur simultaneously and hence they both appear on ECG. (To be discussed)

There are 4 main electrical events that occur in the heart: 1- Atrial depolarization 2- Atrial repolarization
3- Ventricular depolarization 4- Ventricular repolarizatio

Atrial repolarization and ventricular depolarization occur at the same time, so atrial repolarization doesn't show up on ECG, as it's masked by the stronger ventricular depolarization.

So, now we have 3 events left, and each is represented by waves on ECG.

P wave represents atrial depolarization. This wave is slow because the atria have slow-conducting system.

We said that the ventricles contract in 3 stages: septal, major and basal, and these are represented by Q, R and S waves, respectively.

QRS complex is called a complex because all these waves refer to one thing, which is ventricular depolarization.

The septum and the base (posterior aspect of the ventricle) are very small, that's why they create very small waves. Whereas, the major part of the ventricle is big and that's why it creates a very high peak, which is the R wave.

Additional information from Dr. Najeeb (But it's important to understand AV bundle blocks later):

Now, if you compare the R wave to the P wave, you will definitely notice that the P wave is slow and the R wave is very fast. Why?

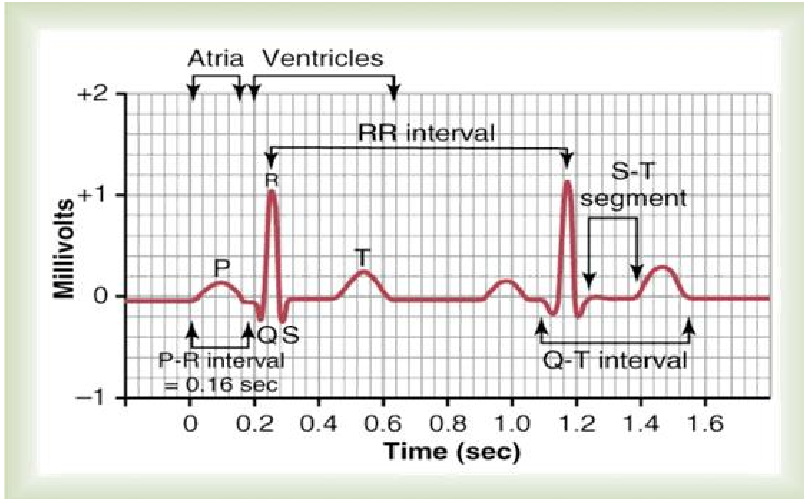
The atria have slow-conducting system, which is the atrial myocardial cells □ Flow of current is slow □ Atrial depolarization takes a long time □ P wave is slow.

The ventricles get their current from the Purkinje System (which is a specialized fast-conducting system) □ Flow of current is fast □ Ventricular depolarization takes a short time □ R wave is fast.

- The electrical activity always precedes the mechanical activity. P wave precedes atrial contraction. QRS complex precedes ventricular contraction. T wave precedes ventricular relaxation.
- Note: T wave, which represents repolarization, is expected to be seen as a negative deflection, but it's a positive deflection on ECG. Why is that?

  Because depolarization and repolarization don't start from the same point (Depolarization goes from the endocardium to the epicardium and from the base to the apex, while repolarization goes from the epicardium to the endocardium and from the apex to the base).

So back to the normal EKG



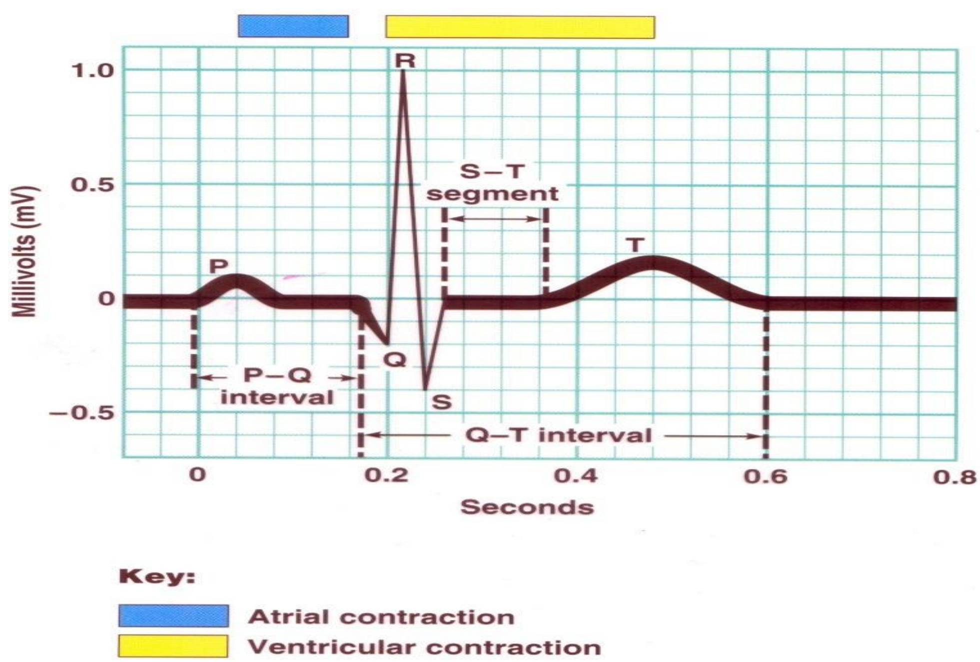
-It will be recorded at a speed of 25mm/sec in a paper (x axis presents the time and the y axis presents the voltage)

-As u can see the paper is full with squares, Each square (the smallest square) = 1mm
è 1 second is represented by 25 square on ECG paper.

So that means each square presents =0.04 sec.

- calculation of the heart rate from ECG paper. Typically, we look at two successive waves (R-R interval). R-R intervals is the duration of the **cardiac cycle**, and the number of cardiac cycles per minute equals the heart rate.
- ex: Cardiac cycle = 0.8 seconds Heart Rate = 75 Beats/min
- When the duration of the cardiac cycle decreases, heart rate increases and vice versa.
- Normal range of heart rate (60-100) beats/min. Below this is bradycardia and above it is tachycardia.

Observe the next figure:



<u>Intervals :</u> (there must be a wave in between)
R-R interval: represent the time between two successive ventricular depolarizations (i.e. the duration of the cardiac cycle).

-the time between one R and the next R or between one T and the other T = **cardiac cycle** = one heart beat and from this we can calculate the heart rate.
Heart rate (how many beats per minute)

example : if we measured the R-R interval and found that it is 1 sec ..what is the heart rate?

each heart beat occurs in 1 sec so the number of beats in one min (60 seconds) will be 60 beats

so the heart rate =60 beats / min

-so when the cardiac cycle decreases the heart rate increases (If the beat needed more time to occur this means that the number of beats per min will be less)

P-R interval: represents the duration of atrial depolarization and repolarization.

- Normal duration: 0.16 sec
- P-R interval shouldn't exceed 0.20 sec. If it exceeds this range, this indicates that there's a delay in AV conduction.

- Also known as P-Q interval, but because Q may be absent on some ECGs, we prefer to use P-R to standardize the terminology.

-Also from the figure we can see the **p-q interval <u>represents the time that's</u> <u>required to transmit</u> <u>action potential from the atria toward the ventricles through AV node</u>**

The normal duration of PQ interval is between 0.16 to 0.2 Seconds (*160 to 200 mSeconds*).

If it was greater than 0.2 this indicates damage in AV node or the conducting system for example if AV node conduction decreases the P-Q interval increases. (AV block)

Q-T interval : the time between the beginning of the q wave to the end of t wave it represents the duration of ventricular depolarization and repolarization.

- Normal duration: 0.35 sec
- Can be lengthened by electrolyte disturbances, conduction problems; coronary ischemia, or myocardial damage.

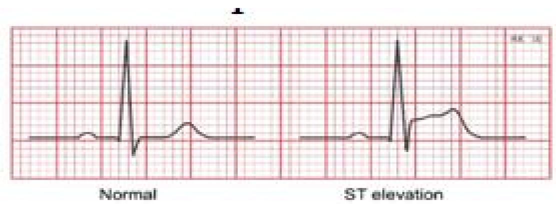
*Q-T is variable whenever the heart rate changes Q-T value changes as well

QRS interval: ventricular depolarization. It shouldn't exceed **0.12 sec.**

<u>Segments:</u> an isoelectric line that presents complete depolarization or complete repolarization (no wave in between)

p-R segment : very small, from the end of p to the beginning of r and represents phase 2 for the atrium (during plateau).

S-T segment : end of s to the beginning of t, This represents the time between the end of depolarization and the start of repolarization in the ventricles i.e.phase 2 for the ventricles (during plateau). Here, we don't care about the duration of the segment but rather we look at it if it's elevated or depressed from the isoelectric line. Both elevation and depression of the S-T segment indicate ischemia.



- Ischemia may develop into infarction. So, a patient with S-T elevation or depression on ECG should be kept under control to avoid the development of MI

***Remember :** ischemia is decrease in blood flow while Infarction is complete stop of blood flow.

NOTES:

1. Ventricular depolarization starts at the ventricular septum and the endocardial surfaces of the heart.

2.The average current flow positively from the base of the heart to the apex

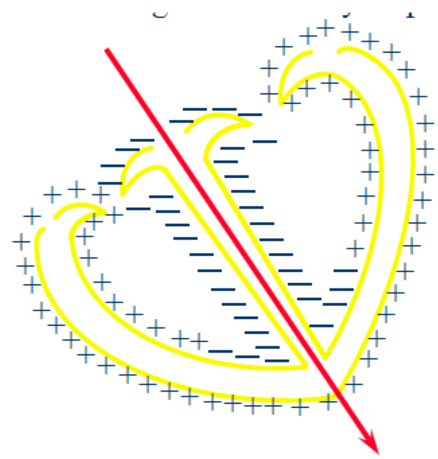
3. P wave precedes atrial contraction

4. QRS complex precedes ventricular contraction

5. T precedes ventricle relaxation

(depolarization precedes contraction and repolarization precedes relaxation)

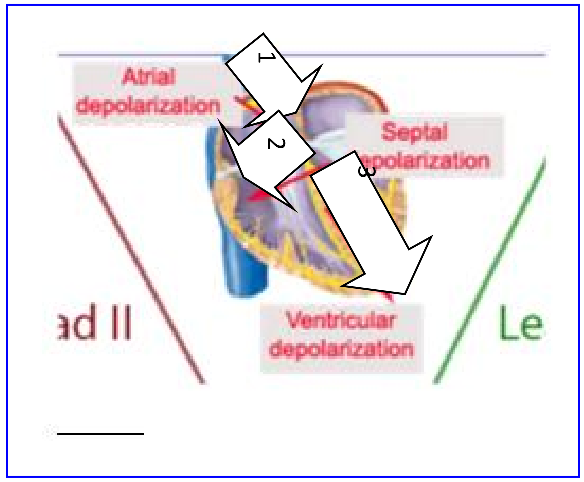
Flow of electrical currents in the chest around the heart:
-When there is electricity there is an electric current going from negatively charged area to positively charged area.
-As depolarization starts in the interventricular septum the electrical current spread this depolarization from depolarized area to the still polarized area. so we have many currents that are spreading in different directions toward the polarized area. Each current is a vector (has a magnitude and a direction) so having different vectors means we must calculate a *resultant vector* (each vector has a contribution on the x axis and the y axis) so we analyse each vector and took the sum of all the vectors contribution in the x axis and the sum of their contribution in the y axis.



-After that resultant can be calculated (magnitude+ direction)

- The figure shows the mean vector through the partially depolarized heart
*Depolarization starts from the interventricular septum then to the left and right ventricle and the last part to be depolarized is the posterior aspect of

the left ventricle.



1- Atrial depolarization:
The wave of depolarization is going from the SA node towards the AV node. This flow is indicated by arrow 1, leftwards and anteriorly.

2- Septal depolarization: the wave is going in the direction of arrow 2.

This vector is directed away from positive electrodes (as we will see when we talk about the limb leads), so it appears as a negative deflection (Q wave).

3- Major ventricular depolarization: going in the direction of arrow 3.

Remember: When a positive vector is going towards the positive electrode, the reading would be positive. And, when it's going towards the negative electrode, the reading would be negative.

Remember that the heart is 3D so the direction of this resultant is anterior to the left

Now, we will talk about the leads used to record ECG

- At any moment in time, there is electrical flow in the heart. This electrical flow has a value and direction, so it can be represented by a vector. All the time, there are vectors in the heart and from them we can find instantaneous currents.
- From these currents, we can find the resultant vector. (See the arrows).
- All these currents represent positive vectors (because depolarization is a spread of positive ions).
- When the positive vector is directed towards the:
  a- positive electrode, it will be recorded as a positive deflection. b- negative electrode negative deflection.
  c- When there's no current flowing, there would be an isoelectric line.

This is how the electrical activity is translated into graphical representation on the ECG machine.

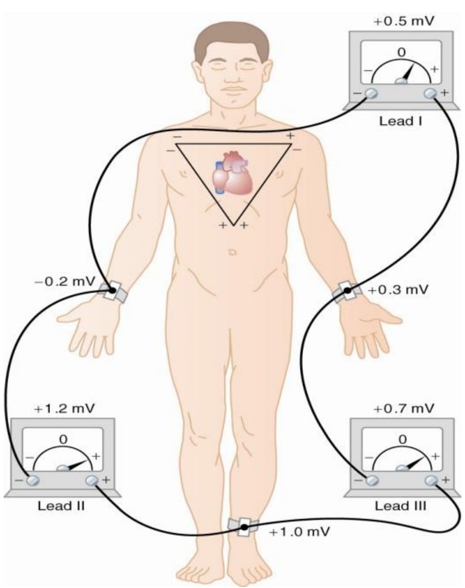
Now, we will talk about the 12 leads (6 limb leads and 6 chest leads).

Bipolar limb leads means that we are connecting the leads to upper and lower limbs (hence the "limb") and we connect positive and negative electrodes (hence the "bipolar").
- There are 3 bipolar limb leads (Leads I, II and III). In these leads, we have galvanometers with two electrodes, the positive attached to one limb and the negative is attached to another.

- To get a positive deflection on ECG, we have to arrange the electrodes so as to get a positive deflection in all leads. Knowing that the vector of the major parts of the heart is directed **downwards, leftwards and anteriorly**, where would you expect the positive electrode to be attached?

Note: We said anteriorly because the heart is a 3D structure.
-To get a positive deflection, the positive electrode should always be on the left limbs rather than the right.

- In all leads, we use the right arm, left arm and the left foot. The right foot is considered an earth (ground lead).



Lead I : positive electrode>>>left arm negative electrode>>>right arm the recording will be positive.
Lead II : positive electrode>>>left foot negative electrode>>>right arm the recording would be postive
Lead III : positive electrode>>>left foot negative electrode>>>left arm the recording would be positive

Note: The right arm is always negative and the left foot is always positive.

- **Einthoven's Triangle:**
Einthoven made an equilateral triangle. The heads of this triangle represent the RA, LA and LL, with the heart at the center.
- An equilateral triangle is also equiangular, that is, all three internal angles are congruent to each other and are each 60 degrees.

Einthoven’s Law:

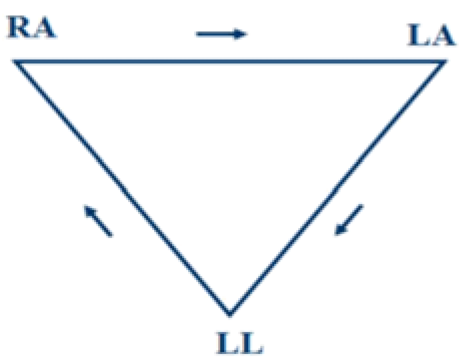
It states that the electrical potential of any limb equals the sum of the other two (+ and - signs of leads must be observed).

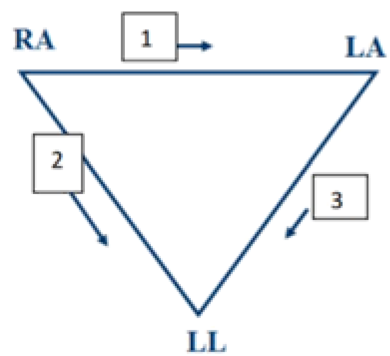
L II= L I + L III

- If lead I = 1.0 mV, Lead III = 0.5 mV, then Lead II = 1.0 + 0.5 = 1.5 mV

The physical basis of Einthoven's law:
Einthoven's law depends on Kirchoff's second law, which states that the directed sum of voltages in any closed network =0.

What Einthoven did is that he changed the direction of electrodes in lead II, so as to make it opposite to the closed circle. (Look at the following two figures, they will clarify this point).



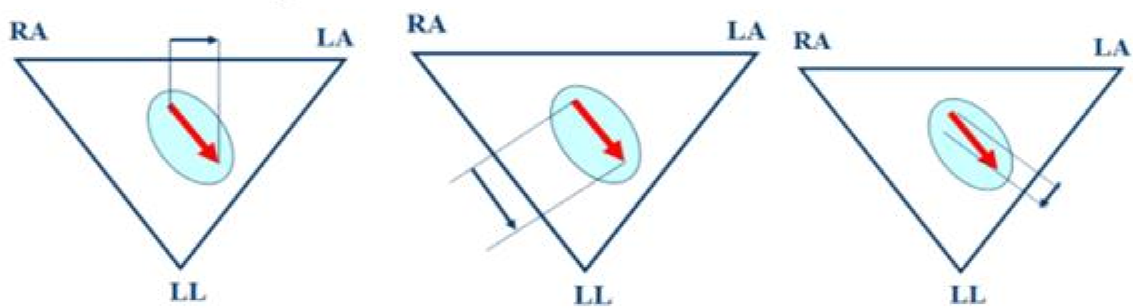


According to Kirchoff's law:
LI + LII + LIII = 0

Because the three vectors are forming a closed network.

As the direction is changed in this case:

LI+ LIII + (-LII) = 0 □□LII = LI + LIII



- If we draw a circle inside this equilateral triangle that touches its sides, its center will be the same as the center of the triangle. In order to introduce other leads into the picture, it's more appropriate to transform this triangle with its vectors into a circle.

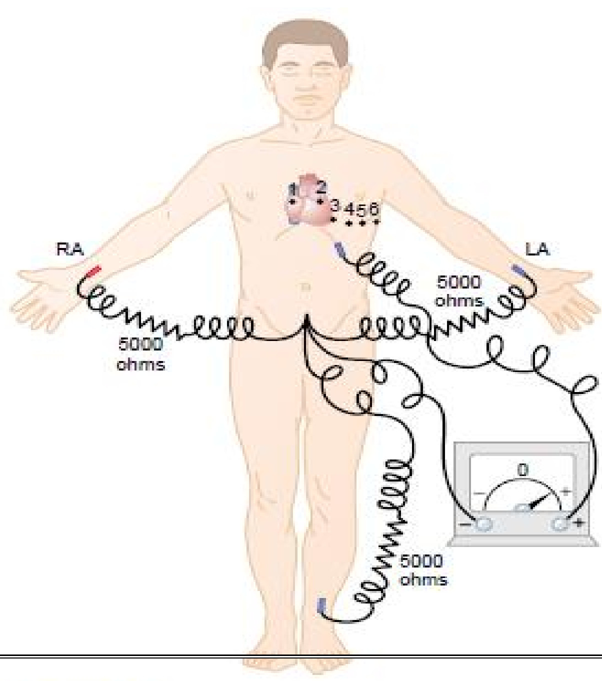
- Vector transformation means to move the vectors in a parallel way (i.e. without changing the direction or the value).

- We use this circle to know the mean electrical axis. In this case (in the figure above), the mean electrical axis is 60 degrees.

- We will talk about mean electrical axis and its calculations in the next two lectures. For now, just know the following information.
- Physiological normal range of mean electrical axis is between -30 and +110.
- Clinically, the normal range is between 0 and +90.
- If the mean electrical axis is above +90, we say that the patient has right axial deviation.

- If it was below 0, we say that the patient has left axial deviation.

B. Augmented Unipolar Limb Leads:
Here, we use the three limbs as the bipolar leads but the difference is that we connect two of the limbs to the negative electrode and the third to the positive electrode.



The idea here is that we connect the two limbs to the negative electrode through very high resistance (5000 ohms). So, there would be no current moving because of the high resistance and the voltage will be almost zero.

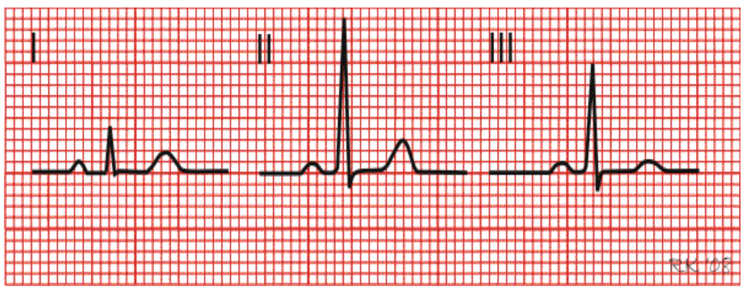
The third limb is connected to the positive electrode and its voltage is thus recorded.

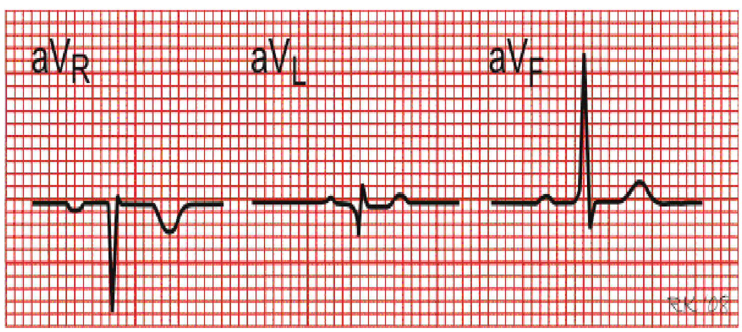
This is the recording of the six limb leads on ECG.
Three bipolar and three unipolar limb leads.

- aVR→ Right arm to the positive electrode and the other two to the negative.
- aVL→ Left arm to the positive and the other two to the negative.
- aVF→ Left foot to the positive and the other two to the negative.

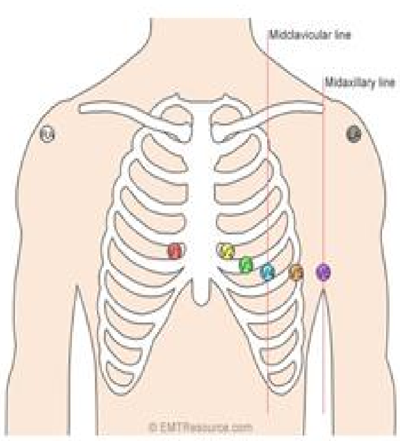
Why is the recording negative in aVR?

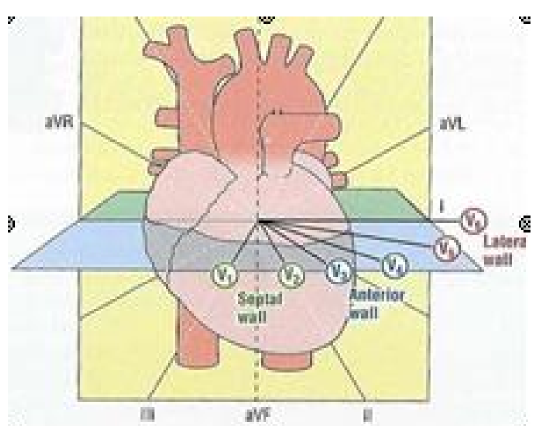
When we talked about the bipolar limb leads, we said that the positive electrode is always attached to left limbs in order to get positive deflections on ECG. But here, the positive electrode is attached to the right arm (i.e. the resultant vector is against the positive electrode), so the recording would be negative.





C. Chest Leads (Precordial Leads):

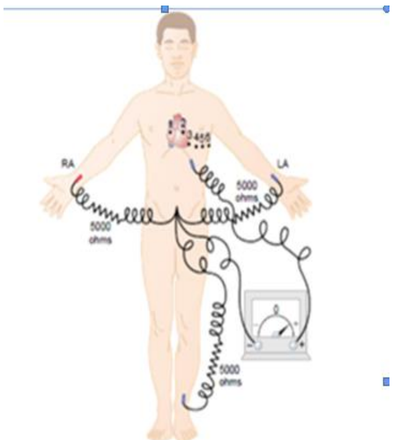




To present the transverse plane we use the precordial chest leads.

Here the positive electrode is placed on the anterior surface of the heart and the negative electrode is attached to the three limbs with very high resistance, When there's high resistance, no current will move and the voltage will be zero, that's why when something is attached to the negative electrode through very high resistance, the electrode is called "indifferent electrode".
-Six unipolar leads from c1 to c6 (or v1 to v6, v for vector) are used.

To determine any point we need two lines; horizontal and perpendicular lines:

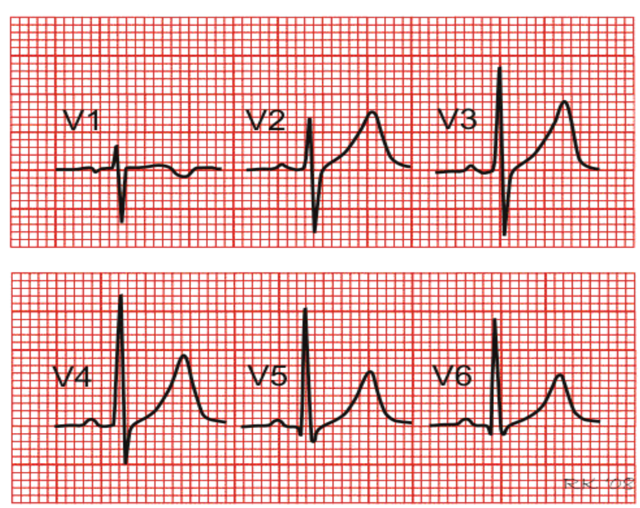


Position according to sternum				Recording(+/-)
On the right side	V1	Vertical	Parasternal line right	Negative
		Horizontal	4^{th} Intercostal space right	
On the left side	V2	Vertical	Parasternal line left	
		Horizontal	4^{th} Intercostal spaceleft	
	V3	Between leads V2 and V4		Same(equel)
	V4	Vertical	Mid-Clavicular line left	Positive
		Horizontal	5^{th} Intercostal Space left	
	V5	Vertical	Anterior Axillary lineleft	Positive
		Horizontal	5^{th} Intercostal Space left	
	V6	Vertical	Mid-Axillary line left	Positive
		Horizontal	5^{th} Intercostal Space left	

-We do too many leads to know the abnormality EXACTLY {where is it? left side? right side? Anterior or posterior part of the heart?}

-If the abnormality is in the posterior aspect of the heart, so how can we discover it?!

- We put an **esophageal lead** which is a unipolar lead. Remember the esophagus is posterior to the heart separated from the left atrium by PERICARDIUM. Then we are able to record an accurate ECG. Nowadays, there is something called transesophageal echocardiogram (echo), where we put a transducer in the esophagus(closely related to the heart).
We may put the lead in the back but because of too much muscles then it may interrupt the recording.



Observe the next figure

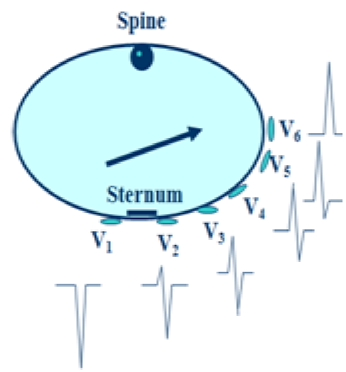
1-both V1 and V2, the **Total** QRS recording is **negative** deflection, why ?!Bcz the mean electrical axis is to the left and anterior, so they move Away from these two leads! (this will be clearer in the next figure).

*2- In V3, the **total** would be **zero** (in the figure* *the R equal S but different directions then the total = Zero), why?!* Because it is located in the middle.

3- *In V4,V5 and V6, the QRS recording is positive deflection, why ?! Bcz the mean electrical axis is to the left and anterior, so they move towards these vectors!*

This figure shows us the chest leads from V1 to V6 and the mean electrical axis. It's upward view not anterior (plz don't get confused!)

from this figure we can see that the mean electrical axis is going toward the V4,5 and 6 and away from V1 and V2. This explains the difference in the direction and magnitude of the QRS complex in different chest vectors!



This is the ECG for the 12 leads we discussed before:

- Our objectives
  1) **Recognize the normal ECG tracing we may discuss some abnormalities!**
  2) **Calculate the heart rate:**

  we can calculate the heart rate from the ECG m but keeping in mind it's regular .

  3) **Determine the rhythm:**

  i. the rhythm of Heart Rate may be regular or irregular .

  the irregularity could **be irregular in irregularity** (RR interval in first cardiac cycle is .8 the second cycle .6 then .7 then .9) or **regular in irregularity** (RR interval in first cardiac cycle is .8 the second cycle .6 then .7 then .8 then .6 then .7 then .8 an so on) .

  4) **Calculate the length of intervals and determine the segments deflections**

  i. To calculate the intervals, we count the small squares then multiplying it with 0.04 seconds.

  ii. In segments, we don't care about the duration of the segment but rather we look at it if it's elevated or depressed from the isoelectric line.

5) **Draw the Hexagonal axis of the ECG**
6) **Find the mean electrical axis of QRS (Ventricular depolarization)**

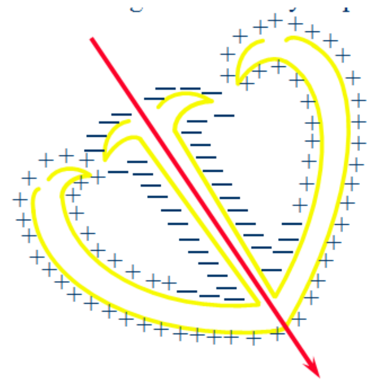
Drawing the hexagonal axis of QRS:

As said before, the current of the heart will move from the depolarized area to the still-polarized area, the vector has direction "the angle" and value "the length of the vector".

The normal mean QRS vector is 60^{O} { in Guyton + 59} ,,, the normal range is (-30◦ - 110◦) , but clinically normal range is (0-90)

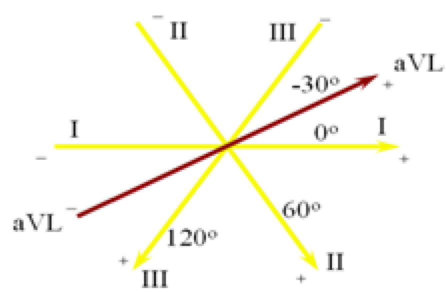
At any instance there are a lot of vectors for different directions then we have to calculate the resultant!

The depolarization of the ventricle, from the septum to the majority of ventricle and finally to the posterior part (Base).

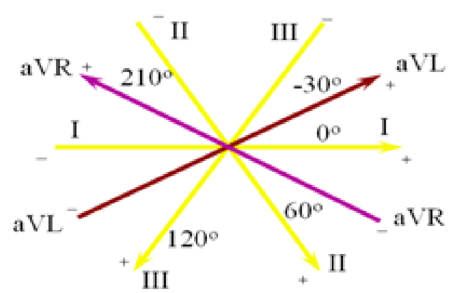


-When we discussed Einthoven's triangle, we draw the trigonal axis of QRS, as in this figure:

*Note that **the lower half of this circle is positive and the upper half is negative!**

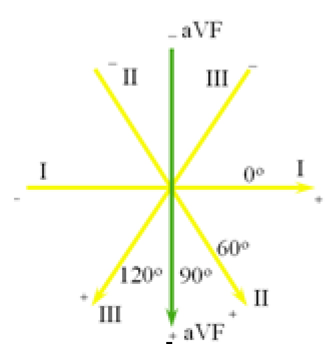


- Now, how to draw the hexagonal axis:
  - We draw the trigonal axis then add the Augmented unipolar leads.
    - aVL: from the heart to the left arm, intersects (bisects) the angle between the **lead III and lead I à** the resultant angle would be **-30**



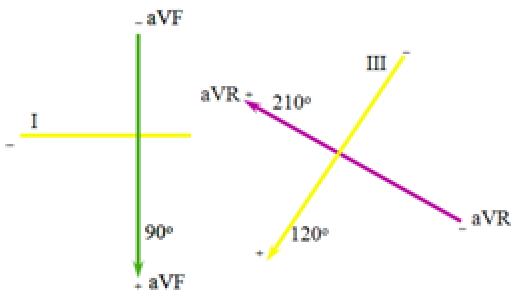
    - aVR: from the heart to the right arm, intersects (bisects) the angle between the **lead II and lead I à** the resultant angle would be **210** (180 +30).

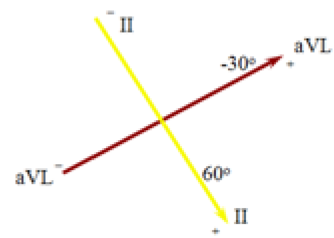
aVF: from the heart to the left foot, intersects (bisects) the angle between the **lead II and lead III** , the resultant angle would be **90** .



There are some things should be taken in consideration:

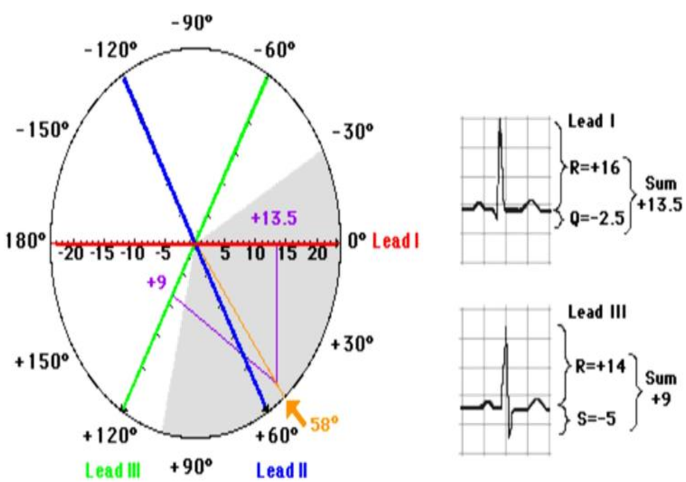
I. **Lead I and aVF** should be perpendicular to each other.
II. **Lead II and aVL** should be perpendicular to each other.
III. **Lead III and aVR** should be perpendicular to each other.





Since we are talking about the same plane "frontal plane" for all leads, so we can choose any two leads and draw the mean electrical axis.The doctor prefers lead I and aVF because they are perpendicular to each other

To determine the mean electrical axis:



1-Take 2 different leads. The doctor recommends taking leads I and aVF. However, in the following example, leads I and III are used.

2-Measure the sum of the height and the negative depth of the QRS complex. In the example shown below:
Sum of QRS of lead I = R+Q = (+16) + (-2.5) = +13.5 Sum of QRS of lead III = R+S = (+14) + (-5) = +9
Q was used in lead I because S was not visible. S was used in lead III because Q did not show up on the EKG as shown below.

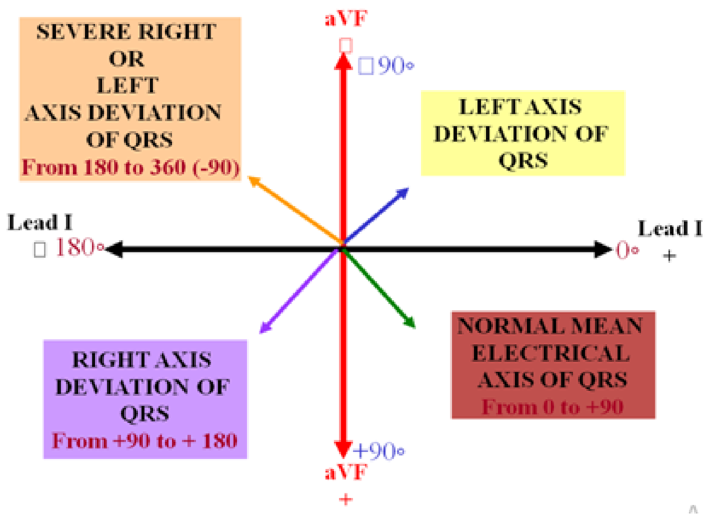
3-Use the summations calculated for each of the 2 leads to measure the distance starting from the center of the circle to a certain point on the corresponding axis (move 13.5 mm on lead I from the center of the circle, and move 9 mm on the axis of lead III from the center of the circle).

4-From the points you reach on the axes, draw perpendicular lines. The intersection of the lines will guide you to the location of the mean electrical axis.

5-Draw the mean electrical axis line from the center of the circle to the point of intersection.

6-Use a protractor or trigonometry (tan θ = Opposite/Adjacent) to determine the angle of the mean electrical axis. In the example below, the mean electrical axis is 58°. Physiologically normal values for mean electrical axis range from -30° to 110°.

Ø If the algebraic summation **for both is negative** then between the -90 and -180 then **extreme axis deviation** , don't know is it right or left ?! so we have to look to the patient ; if he has **right heart disease then it's Extreme RIGHT** Axis Deviation but ; if he has **left heart disease then it's Extreme LEFT** Axis Deviation https://www.youtube.com/watch?v=_CCUWdAaQoA, watch it to make sure that you understand the idea.



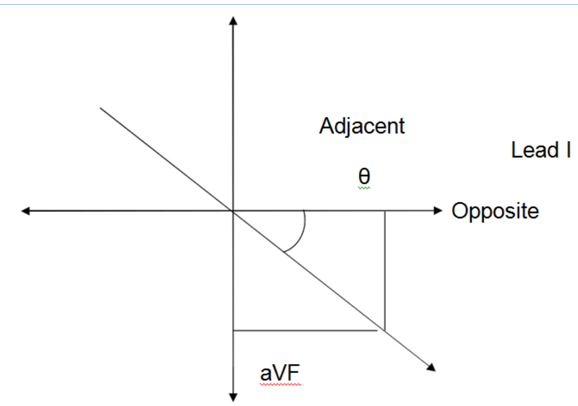
Why did the doctor recommend using lead I and aVF not lead I and III?

tan θ = Opposite/Adjacent

aVF would be the opposite and lead I would be the adjacent in the above equation.

Enter the following into a calculator: $\tan^{-1}$ (aVF value / lead I value)

The answer would be θ (the angle of the mean electrical axis).



Factors Causing Electrical Axis Deviation:

- **Left ventricular hypertrophy** causes **left axis deviation**. Hypertrophy of the left ventricle signifies that the right ventricle reaches complete depolarization before the left ventricle. In this case, the vectors will be pointed to the left. Hypertrophy of the left ventricle is caused by hypertension, aortic stenosis or aortic regurgitation. The result is a slightly prolonged QRS and high voltage.

- **Left bundle branch block** also causes **left axis deviation**. The left bundle branch moves the impulse from the AV node to AV bundle to the left ventricle. Should this left bundle branch be blocked, the left ventricle will depolarize through the ventricular muscles. Depolarization through the ventricular muscles (by gap junctions) is very slow (0.5 meters/sec). Depolarization through the purkinje fibers is 4 meters/sec.

- **Left axis deviation** also occurs in short and obese people. It might be normal since it would not be less than -30°.

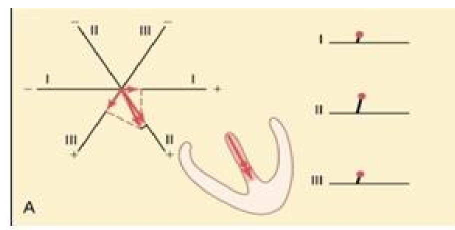
- Changes in heart position due by expiration and lying down cause **left axis deviation**.
- **Right axis deviation** occurs in tall and thin people.

- **Right ventricular hypertrophy** and **right bundle branch block** cause **right axis deviation.** Hypertrophy of the right ventricle is caused by pulmonary hypertension, pulmonary valve stenosis, or interventricular septal defect. All of them cause slightly prolonged QRS and high voltage.
- In both bundle branch blocks, QRS complex is prolonged.

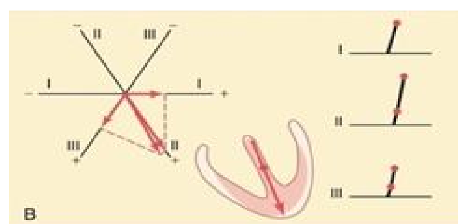
Now , why **the QRS complex is composed of three waves ?!**

- The depolarization of the ventricles occurs firstly in the septum then spread through the ventricles until reaching the base of ventricle (the last are to be depolarized) and **for every instant there is a value.**

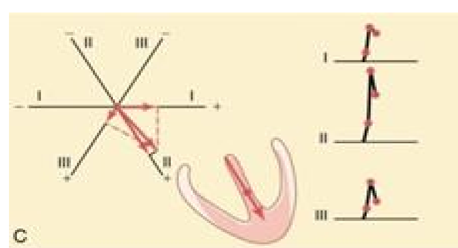
A. The first are to be depolarized is the **septum**, at this instance there is a resultant vector. If we analyze it in lead I, II and III to measure its value {note that the vector is going toward the positive side then it's up deflection in the three leads}



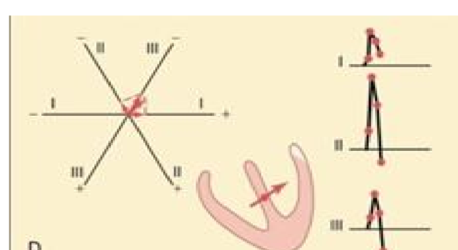
B. The depolarization will **continue and spread, so the result in a new vector** (different value and direction). note that the value in the three leads **increases**. The depolarization vector is <u>large because now about half of the ventricles is depolarized</u>! {toward the positive electrode à up deflection}



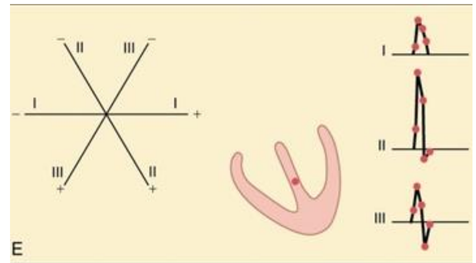
C. There is **decrease** in the in value?! <u>Because the outside of the heart apex is now electronegative, neutralizing much of the positivity of the other surfaces</u> . Also, there is shifting toward the left side because the left ventricle is slower to depolarize that the right ventricle.



D. Here, the last depolarization occurs in the posterior part of the ventricle. Remember that the current of the heart will move from the depolarized {most of the ventricle} to the still polarized area {the posterior part of the ventricle} that's <u>why it'll be negative deflection in both lead II and III { away from the positive electrodes } but in lead I will be less positive</u> , **This is S wave**



E. Completely depolarized ventricle, note we record the R and S waves, with no instantaneous vector. So, now we have **isoelectric segment!**



Notes:

-The Q wave is not always recorded, it's recorded when **the left side of the interventericular septum is depolarized before the right side {the direction of the vector is to right then away from the positive electrode}** and it's usually have small value.

-if the value of the **Q wave increase** then we have to think of **multi node infarction**! in these patients we notice that there **is elevation in the ST segment!**

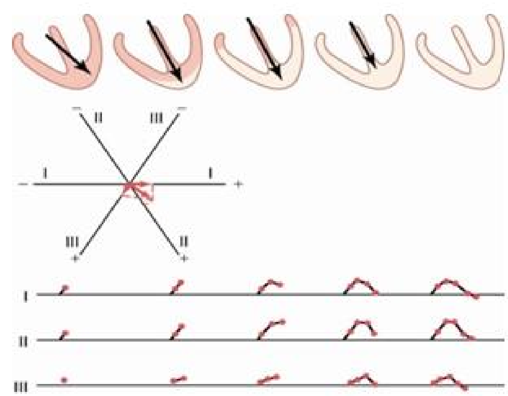
The T Wave (Ventricular Repolarization) :

- First area to repolarize is near the apex of the heart to the base (from the pericardium to the endcardium) because after the QRS the ventricles will contract that will compress the middle and inner layers more than the outer layer that will weaken the blood flow to the inner layer and change the permeability of the endocardium fibers, which will delay the action potential of the endocardium making the pericardium repolarize first.

-Last areas, in general, to depolarize are the first to repolarize.

-Repolarized areas will have a positive **charge first; therefore, a + net vector occurs and a positive T wave.**

-It won't be sharp but it's **gradual and slow** because of slow K channels.



-Atrial Depolarization (P-Wave) and Atrial Repolarization (Atrial T Wave):

-Atrial depolarization begins at sinus node and spreads toward A-V node. This should give a + vector in leads I, II, and III.

-Atrial repolarization can't be seen because it is masked by QRS complex. If it's seen it will be **down deflection**! Because Atrial depolarization is **slower than in ventricles, so first area to depolarize is also the first to repolarize.**

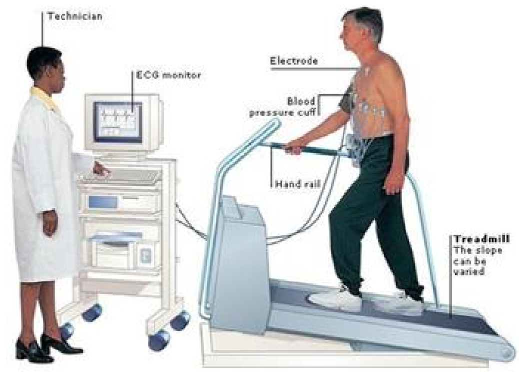
-This gives a negative atrial repolarization wave in leads I, II, and III.

Stress Test:

-while the patient is doing exercise, we do ECG. If after a while the ST segment is depressed then patient may have obstruction in LAD so we have to do catheterization {CATH} for him! Remember: any elevation or depression in the ST segment >>> Ischemia.

Heart Rate Calculation:

The heart rate can be calculated from the EKG using the **R-R interval**.



-The R-R interval represents **one complete cardiac cycle**.

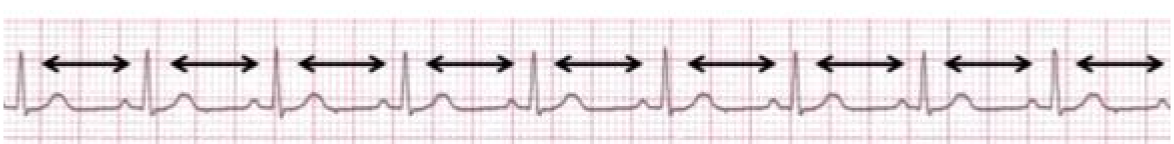
-The R-R interval is calculated through multiplying the number of small squares on the grid of the EKG between 2 consecutive R waves by 0.04 seconds (which is the value of each small square).

Suppose the R-R interval was 0.83 seconds, the heart rate would be: Heart Rate=60seconds per minute/0.83 seconds = 72 beats per minute.

✓ REMEMBER:

- ✓ PR interval is usually 0.16 seconds and it should not exceed 0.2 seconds.
- ✓ QRS interval should not exceed 0.12 seconds.
- ✓ QT interval is usually 0.35 seconds and it should not exceed 0.4 seconds. It is variable and usually half of the R-R interval.
- ✓ The P wave immediately precedes atrial contraction.
- ✓ The QRS complex immediately precedes ventricular contraction.
- ✓ If the PR or ST segments are deflected upward or downward, it means that there is ischemia (or an infraction).
- ✓ Every 5 small squares equal 0.2 seconds.
- ✓ The speed of the EKG machine is 25 mm/seconds.
- ✓ Sometimes the machine is overclocked (sped up) to 50 mm/seconds for cases of tachycardia to make measurement of the intervals easier.
- ✓ If a patient, for example, has an abnormality in the posterior aspect of the heart, then an esophageal lead is needed.

Determining Regularity



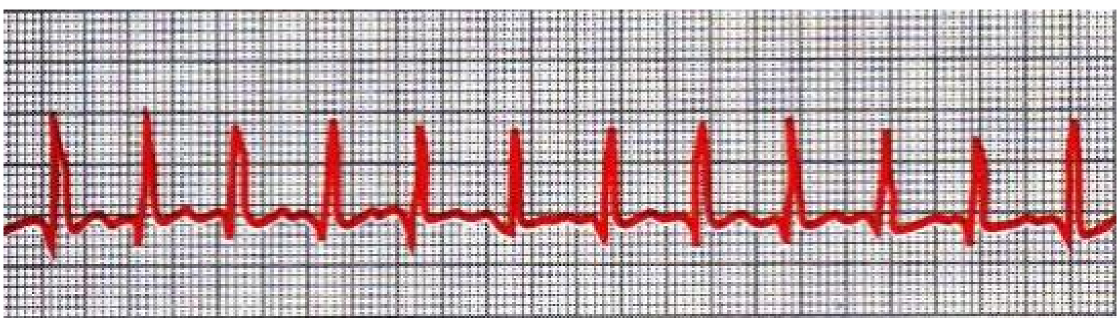
- Determining regularity of the EKG does not require much effort or tools.
- Simply mark the peak of the first and second R waves using a pen and paper and check if the other R-R intervals are equidistant.
- A caliper can also be used to determine regularity.
- A regular EKG would have equal distances between consecutive R waves.
- Other classifications include: occasionally irregular, regularly irregular, and irregularly irregular.

EKG Abnormalities:

- Causes of the **cardiac arrhythmias** include:
  - **Abnormal rhythm** of the pacemaker.
  - **Shift of pacemaker** from sinus node.
  - **Blocks** at different points in the transmission of the cardiac impulse.
  - **Abnormal pathways** of transmission in the heart.
  - Spontaneous generation of abnormal impulses from any part of the heart (**ectopic pacemaker**).

Abnormal Rhythm of the Pacemaker:

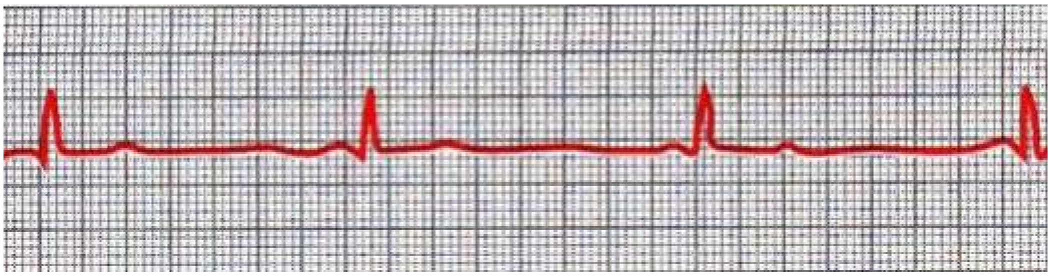
- Abnormal rhythm of the pacemaker means either bradycardia or tachycardia.
- **Bradycardia** means slow heart rate which is **less than 60 beats/min**.
- **Tachycardia** means fast heart rate which is **more than 100 beats/min**.
- An EKG for a typical case of tachycardia (shown below) graphically demonstrates the shortened R-R intervals. <u>R-R intervals are less than 0.6</u> <u>seconds</u>.



- **Tachycardia** is caused by:
  1. Increased body temperature.
  2. Sympathetic stimulation (positive chronotropic effect).
  3. Toxic conditions of the heart.
- **Sinus tachycardia** means that the electrical impulses are coming from the SA node. If there is no SA node, no impulses will be transmitted to the atria and consequently there will be no P wave.

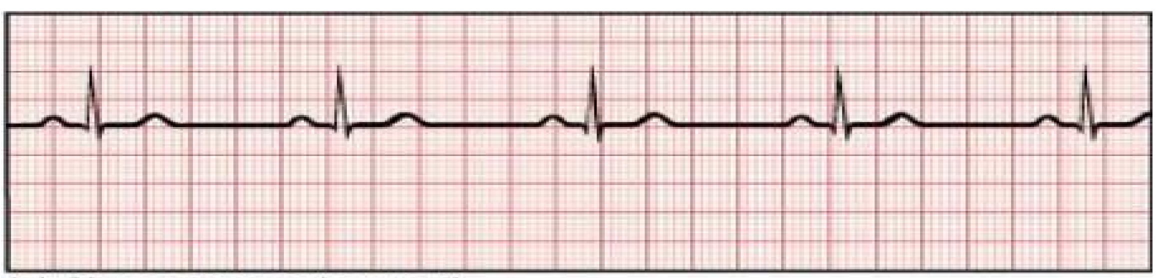
- SA node is depolarizing faster than normal, impulse is conducted normally.
- Sinus tachycardia is a response to physical or psychological stress, not a primary arrhythmia.

- **Bradycardia** is usually present in athletes with a large stroke volume because they have hypertrophic ventricles. This is normal.
- **Bradycardia** can be caused by vagal stimulation, one example of which is the carotid sinus syndrome.
- When the R-R interval is more than 1 second, then there is bradycardia.

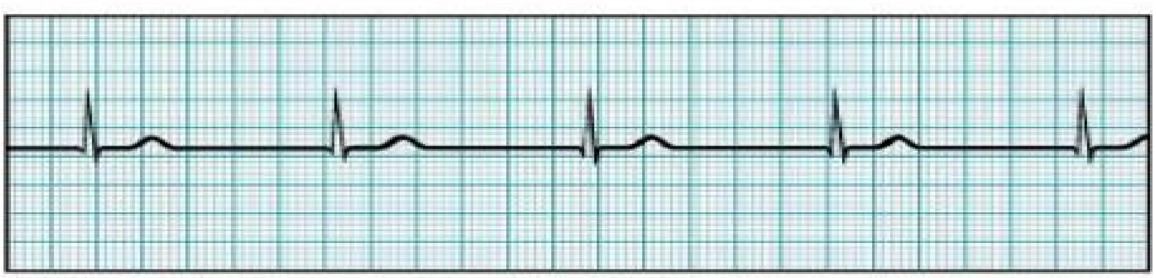


- In **sinus bradycardia**, the SA node is depolarizing the atria slower than normal, impulse is conducted normally (i.e. normal PR and QRS interval) and the rate is slower than 60 beats per minute.
-

Blocks at Different Points in the Transmission of the Cardiac Impulse:



(a) Sinus rhythm (normal)



(b) Nodal rhythm – no SA node activity

- The absence of the P wave in the above EKG indicates that there might be a SA node block (rare) or atrial fibrillation.

- **Atrial fibrillation** is when the muscle fibers of the atria DO NOT contract at the same time.

- Unlike ventricular fibrillation which could be fatal, atrial fibrillation does nothing and it could be found in healthy people because atrial contraction is not essential for the normal cardiac cycle.

- New pacemaker is found in the region of the heart with the fastest discharge rate, usually the A-V node.

- AV node block prevents the normal conduction of the AV node. This abnormality could be partial or complete. Partial means that the AV node sometimes conducts the impulse from the atria but not always.

- PR interval is longer than 0.2 seconds when the AV node is blocked.

- If every P wave is followed by QRS interval and the PR interval is longer than 0.2 seconds, then this is a first degree AV block. P-R interval seldom

  increases above 0.35 to 0.45 seconds.

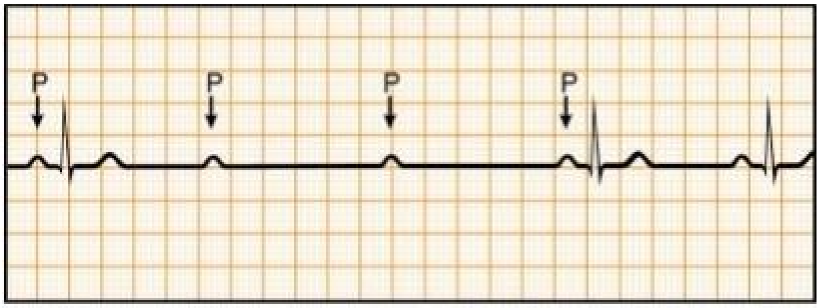
- In 2nd degree heart block P-R interval increases to 0.25 - 0.45 sec. Moreover some impulses will pass through the A-V node while others don't thus causing "dropped beats" or palpitations . However there is a rhythm that develops 2:1 or even 3:2…etc. This is called regular irregularity. so not all P waves are followed by QRS interval. There are 2 types of second degree AV blocks.

- **<u>Second degree AV blocks show a regular irregularity</u>**.
-
- This means that following a certain number of P waves, there has to be a specific number of QRS intervals. The number of P waves preceding the successive QRS intervals is always higher. For example, patient X's EKG shows that there are 4 P waves before every 3 QRS intervals, while patient Y's EKG shows that there are 3 P waves before every 2 QRS intervals.

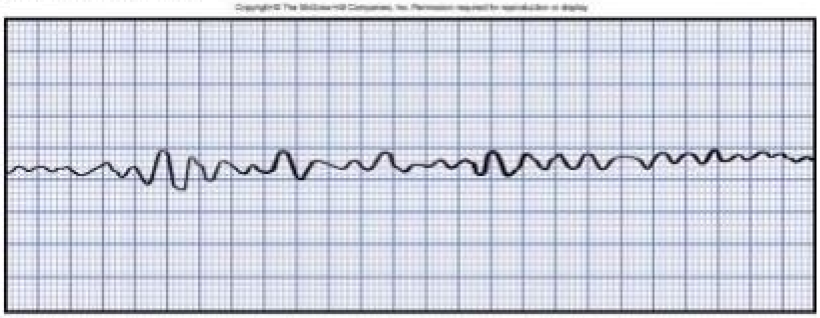
- In the **<u>third degree AV block</u>**, the AV node is completely destroyed. The heart rate is actually coming from the purkinje fibers. **Heart rate is less than 40** (it is between 15-40). The ectopic pacemakers are the purkinje fibers in this case.

- Unlike second degree AV blocks which have a regular irregularity, third degree AV block shows no relationship between the P waves and the QRS interval.

- The first and second degree AV blocks are called incomplete heart blocks while the third degree AV blocks is called a complete heart block.



(c) Heart block


(e) Ventricular fibrillation

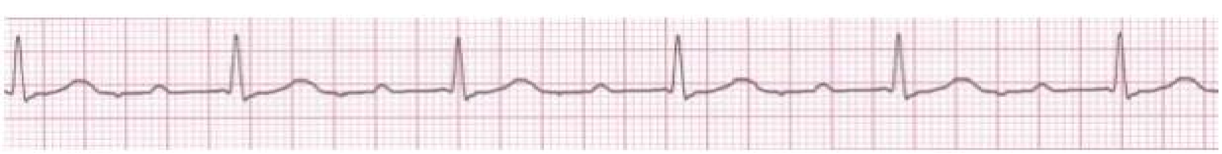
- **Ventricular fibrillation** is fatal. No P,Q,R,S,T waves are evident on the EKG (shown above).

- **Ventricular fibrillation** is an emergency. The first intervention would be defibrillation using a defibrillator to retrieve the normal sinus rhythm.

-Impulses through A-V node and A-V bundle (bundle of His) are slowed down or blocked due to :

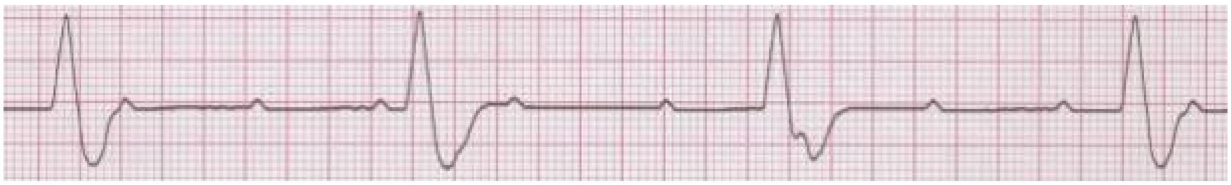
- **Ischemia** of AV node or AV bundle fibers (can be caused by coronary ischemia)
- **Compression** of AV bundle (by scar tissue or calcified tissue)
- AV nodal or AV bundle **inflammation**
- **Excessive vagal stimulation**

EKGs of Different Degrees of Heart Blocks



1st Degree AV Block

2nd Degree AV Block



3rd Degree AV Block

Stokes Adam Syndrome:

- Complete A-V block comes and goes.
- Ventricles stop contracting for 5-30 sec because of overdrive suppression meaning they are used to atrial drive.
- Patient faints because of poor cerebral blood flow.
- Then, ventricular escape occurs with A-V nodal or A-V bundle rhythm (15-40 beats /min).
- Artificial pacemakers connected to right ventricle are provided for these patients.

Final note:

We know that the normal ECG electrical changes occur with the range of 1 to 2 mV, but what does it mean if this voltage is changed?

- If the sum of voltages of Leads I-III is greater than 4 mV, this is considered to be a high voltage EKG. Most often caused by increased ventricular muscle mass (**hypertension, marathon runner**).
- Decreased Voltages in Standard Bipolar Limb Leads occur due to Cardiac muscle abnormalities (***old infarcts causing decreased muscle mass, low voltage EKG, and prolonged QRS***). The following Conditions surrounding heart that make it further away from the chest (***fluid in pericardium, pleural effusions, emphysema***).

The End.
Good luck all.