ECG 12 lead system

ver: A-1

Before discussing the ECG leads and various lead systems, we need to clarify the difference between **ECG leads** and **ECG electrodes**. An **electrode** is a conductive pad that is attached to the skin and enables recording of electrical currents. An **ECG lead** is a graphical description of the electrical activity of the heart and it is created by analyzing several electrodes. In other words, each **ECG lead** is computed by analyzing the electrical currents detected by several electrodes. The standard ECG aka 12-lead ECG since it includes 12 leads, is obtained using 10 electrodes.

These 12 leads consist of two sets, Chest/precordial or Limb leads.

The advantage of using all these 12 leads is that each lead detects the electrical activity of a certain part of the heart, as if it focuses on that part and in that way, we get a view on the whole heart from most parts!

So as we said, each lead is generated by analyzing the electrical currents detected by several electrodes, an electrode, for that lead can be either +ve or -ve.

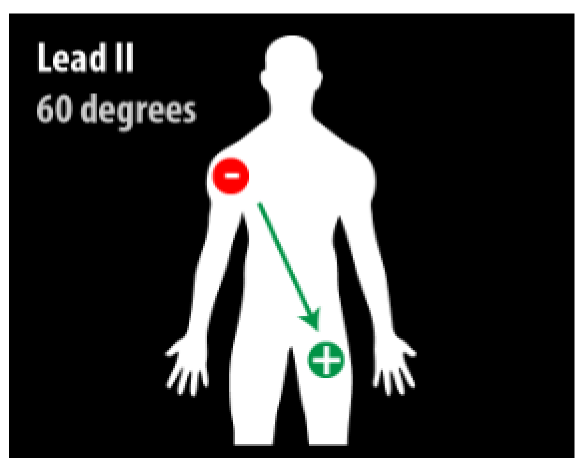
Just as an example, I'll use **lead II**. This lead uses a +ve electrode on the left leg, a -ve electrode on the right arm.

That forms something like an **AXIS** between these electrodes!

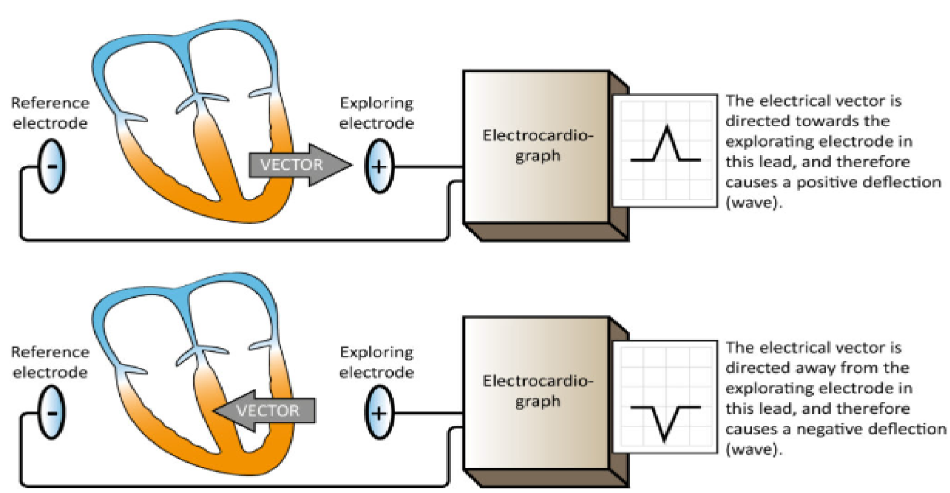
To determine the part that a lead focuses on, imagine as if the +ve electrode is an eyeball looking at the heart!

So what part does lead 2 focus on ?

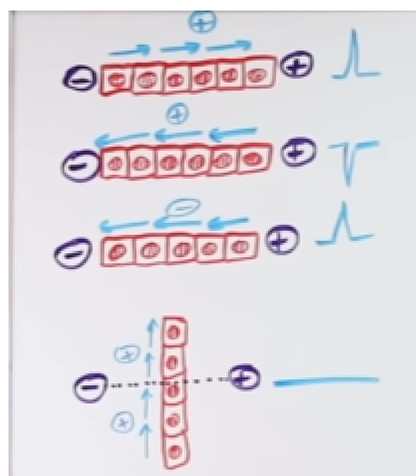
It's actually the inferior wall of the heart! That should make some sense now.



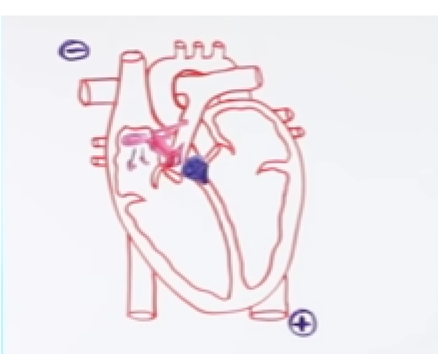
So, at any given instant during the cardiac cycle, all ECG leads analyze the same electrical events but from different angles. This means that ECG leads with similar angles must display similar ECG curves (diagrams).
For some purposes (e.g diagnosis of some arrhythmias) it's not always necessary to analyze all leads, as the diagnosis can often be established by examining fewer leads. On the other hand, for the purpose of diagnosis that is the morphological changes (e.g myocardial ischemia), ability to do so increases as the number of leads analyzed increase. Increasing the number of leads will increase the sensitivity, decrease the specificity. E.g 120 leads system which was tested, was more sensitive at the expense of specificity and certainly feasibility (we need to use more electrodes), Later on in this article you'll understand why multiple leads are necessary to diagnose morphological changes. **LETS START!**
The movement of charged particles generates an electrical current. In electrocardiology the
charged particles are represented by intra and
extracellular ions (Na^+, K^+, Ca^{2+})
And between cells, these ions flow across cell membranes via gap junctions, so that the depolarization can spread between the cells.
Electrical potential differences arise as the electrical impulse travels through the heart. Electric potential is defined as the difference in electric potential between two measurement points. In ECG these measurement points are the skin electrodes! Thus, these electrodes will calculate the difference in electric potential between 2 points on the heart.



When a tissue is stimulated, that'll generate an electrical current that flows in a certain direction. We have set a certain lead's electrodes around; +ve and -ve.
So if that flow was a:
(depolarization):
If those positive charges were going **towards** the positive electrode they'll be picked up by the electrode, to show as an **upward deflection** on the ECG.
If those charges were going **away** from the positive electrode they'll be picked up by the electrode, to show as a **downward deflection** on the ECG.
(repolarization):
When repolarization occurs, it's a flow of negative charges, same principle, **negative towards negative electrode: upward deflection** and vice versa.
If the axis of the lead was perpendicular to the flow direction, towards the axis is an upward deflection, away is a downward deflection, but these deflections will only show when there's **NET** movement, if it was the same flow of charges the ecg will just cancel it to show as an isoelectric line.

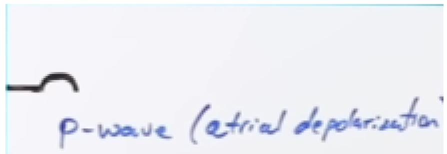


An ecg has 12 leads.
Lead II is the most commonly used, it has the
-ve on the RIGHT ARM
+ve on the LEFT LEG
The axis is from -ve to +ve, imagine it NOW.
As you know, the whole electrical activity starts, from the atria, SA node to be exact.



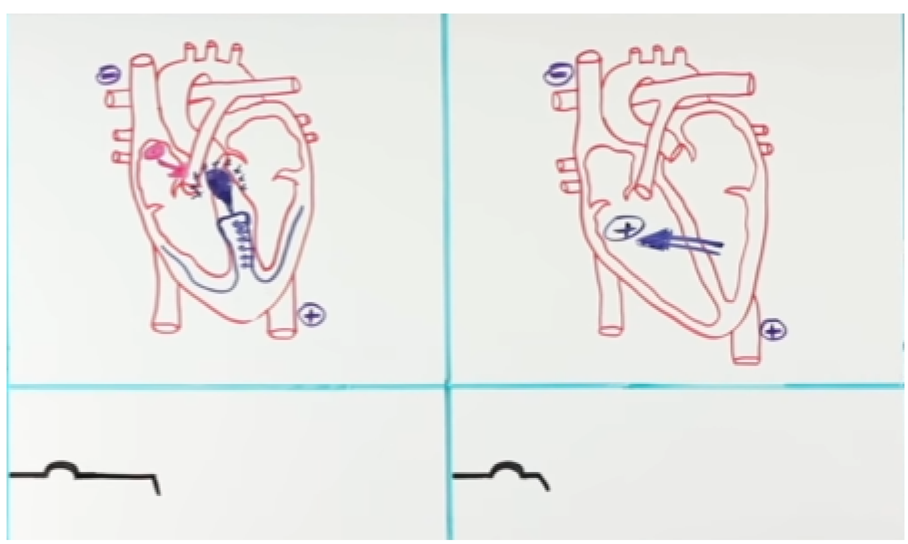
The mean of all these waves of depolarization generated by the SA node has a direction from the SA towards the AV downwards and to the left, which direction is it in respect for the positive electrode? Towards it! =
= upward deflection!

That’s our P WAVE, so that P wave “look” indicates that it was generated by the SA node.



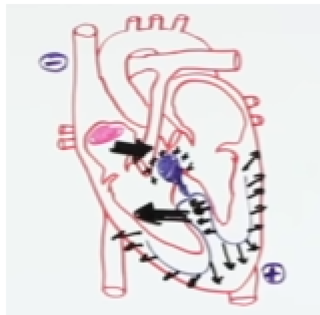
If you look at a normal ecg, after the p wave there’s an isoelectric line, that line as we said earlier, occurs if we have no NET movement of charge, in that case it happens because of the AV delay! Where the charges are collected in that AV node, not yet fired (to give time for ventricular filling). (That’s the PR-segment)
Remember, a segment contains no waves, only isoelectric line, an interval on the other hand does contain a wave of some kind.

After that, the AV node finally conducts these positive charges down to the AV bundle (bundle of HIS), which then splits to RIGHT and LEFT branches, the LEFT branch will then depolarize the ventricular septum, causing a flow of charges almost towards the right, but as the heart has its tilt, the flow will look like it’s going away from the positive electrode, remember yet? That’ll cause the tiny downward deflection that’s shown in the beginning of the QRS wave!



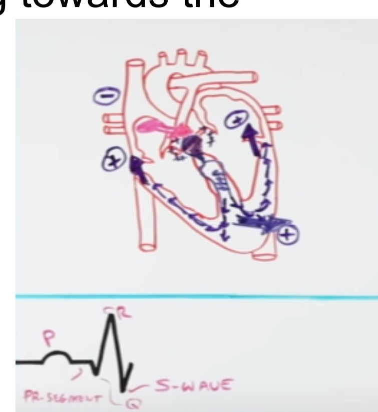
Q wave
It’s indicative of **septal depolarization.**
It can be absent (normal)
The size of this Q wave, determines whether its physiological pathological.

The electrical activity will continue flowing outwards from the bundle branches, down the ventricular septum towards the apex, then upwards towards where the base is. So now, where would the net vector be!



Remember, the left ventricle is the thicker side, containing more myocardium, conducting more action potentials and higher voltages, thus more intense net vector that's pointing to the right.
The right ventricle will produce a net vector pointing towards the left +slightly downwards, this vector is smaller than the one from the LV.
The mean of these 2 vectors will lean towards the bigger one of course, generating a mean vector that's towards the right electrode, again! That's an upward deflection!
R-wave, (mean R wave vector)
It's representative of the total ventricular depolarization.

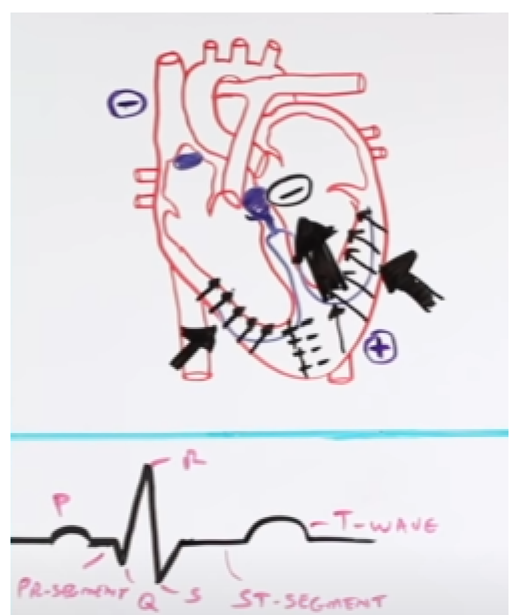
Remember when we said "then upwards towards where the base is"? The flow will continue but now towards the base, which is upwards but with the tilt it's also slightly towards the right too, that's away from the positive electrode, generating a downward deflection. This is called the S-wave, which is still indicative of ventricular depolarization but now its last part which is moving towards the base of the heart.



Now, remember when we talked about how the AV node collected all those charges but didn't actually cause a movement of charge towards the av bundle? That was the PR-segment.
In the same way, the entire ventricular myocardium has already been completely depolarized, super positive, hasn't begun to repolarize yet, no net movement of electrical charges, which will also generate another segment, now called the ST-segment, a very important segment regarding pathological conditions!

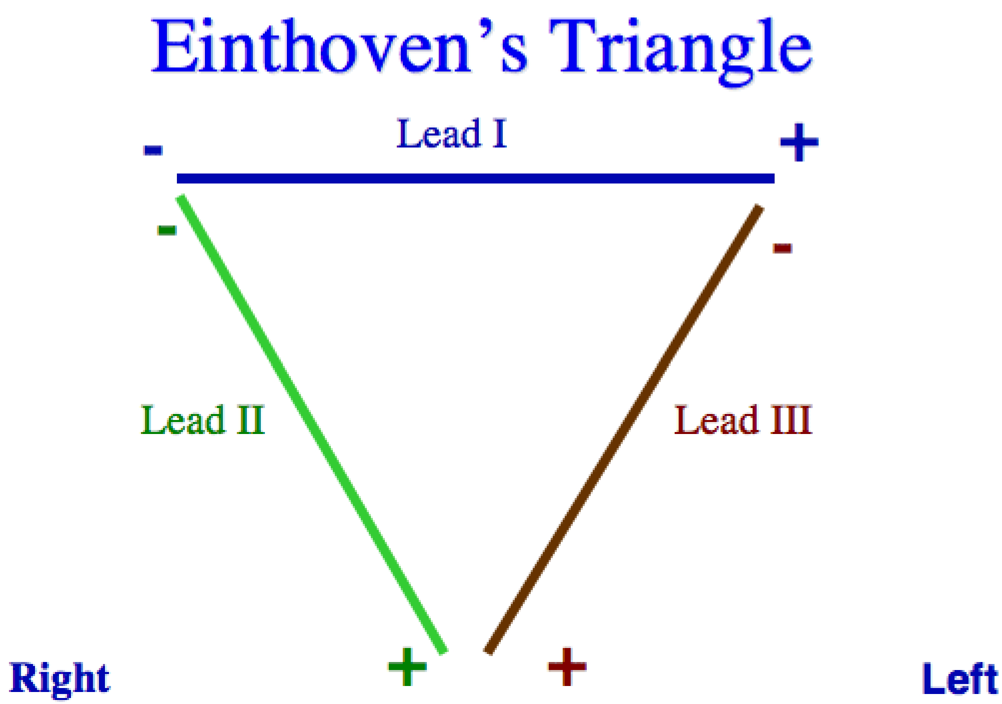
Our ventricles now have to repolarize, and they'll do that as a negative charge flow against the direction of the original R wave, same principal here, where left is thicker than right and so on, Repolarization starts against the direction of depolarization, but as -ve and not +ve.
So if you flip the R wave mean vector, it'll be pointing away from the positive, but those are -ve charges, pointing towards the -ve electrode, again what will that generate? An upward deflection!

And that's our **T wave, indicating our ventricular repolarization.**



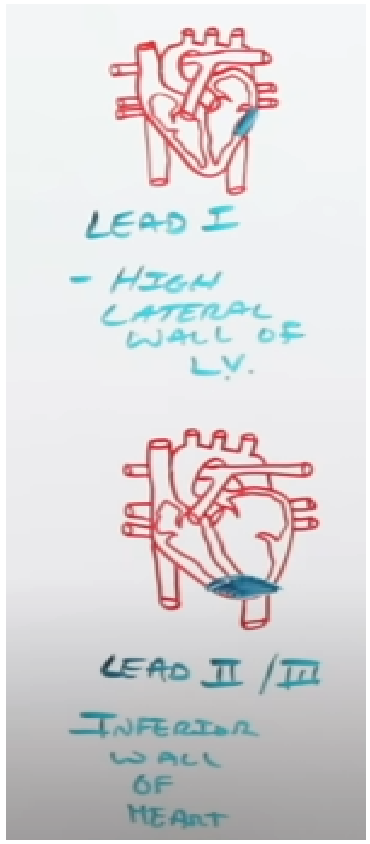
Now we finished talking about lead II
out of the total 12 leads we have in an ecg machine
After this we'll talk about the full machine with all the
Leads!

ECG has 12 leads;
3 Limb leads, I II III
3 Augmented unipolar limb leads, AVR, AVL, AVF
6 chest leads, V1, V2, V3, V4, V5, V6
If we utilize the vector format that we talked about above, we should be able to see how all of these waves would look like in each lead! You're really better off to start watching as the Legend starts explaining with his hands **HERE!**



The first system of 3 was created by a guy named Einthoven, where we usually put a -ve electrode on the R. ARM, a +ve electrode on the L.LEG and a +ve electrode on the L. ARM, that creates 3 axes,
Lead 1's pointing to the right
Lead 3's pointing downwards
Lead 2's pointing downwards and to the left as we know
Luckily, 1,3 are really similar to 2, and that shows also on the readings generated by these leads, it's very similar with slight differences that's caused by the tilting of these axes compared to the one we studied; (2).

With how each lead is set, each lead will tell us about a different particular part of the heart and be more focused on it.
So look at lead 1, it’s positive is at the right, so it’s focused on showing the electrical activity of the “High lateral wall of LV”.
Lead 2/3 are almost the same, they both focus on the “Inferior wall of the heart”.



Little summary for y'all:
Lead 1 tells us about "High lateral wall of the LV"
Lead 2,3 tell us about "Inferior wall of the heart"
Lead avR tells us about "Right Ventricle+Basal septum"
Lead avL tells us about "High lateral wall of the LV"
Lead avF tells us about "Inferior wall of the heart"

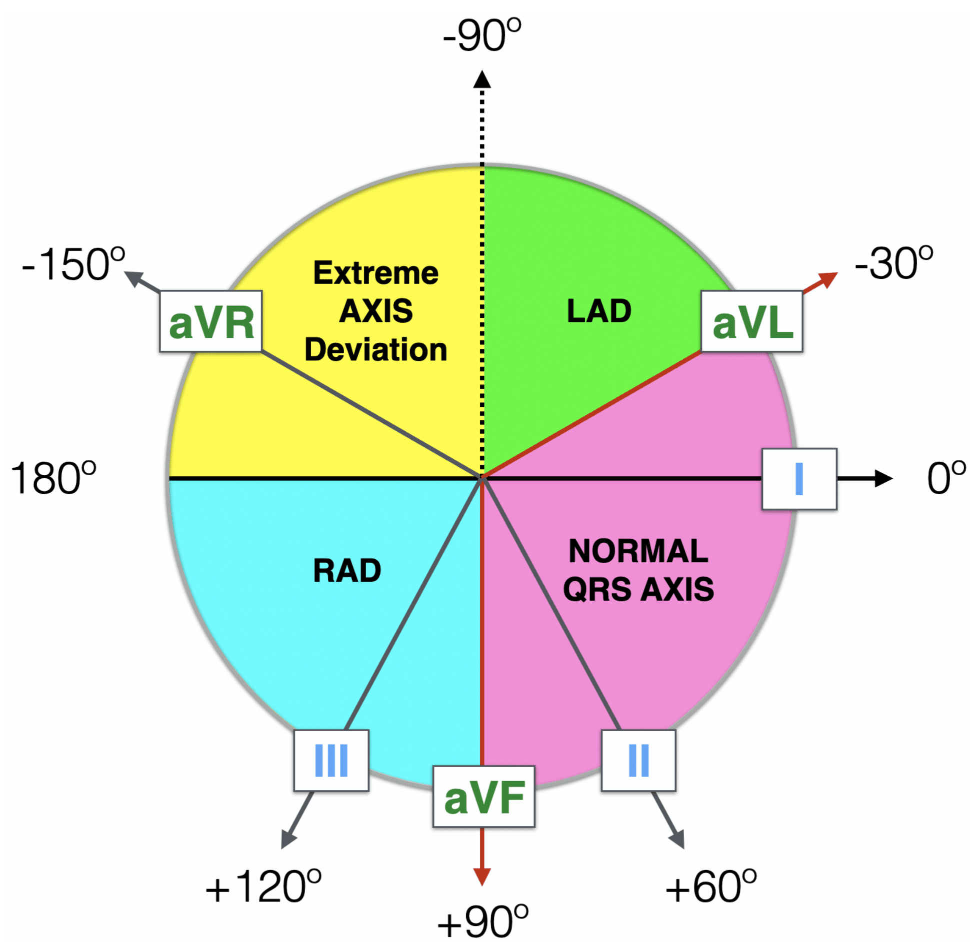
Lead 1, avL tell us about the high lateral wall of the LV
Lead 2, 3, avF tell us about Inf wall of the heart

In total : +6 chest leads and regarding the heart:

Lateral wall of LV: V5-V6, also higher part by avL + lead I
Ant wall of the heart: V2-V4
Basal septum: V2-V3, avR
Right ventricle: V1-V3, avR
Inf wall of the heart: Lead 2, 3, avF

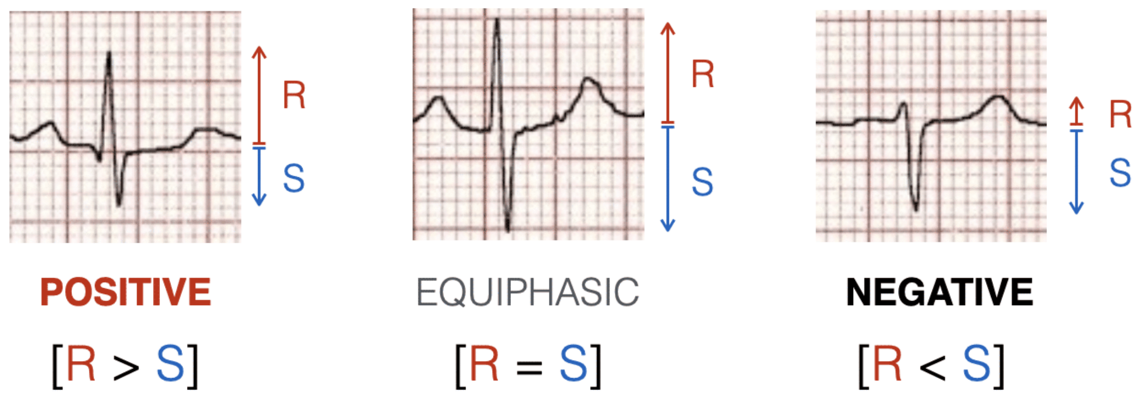
ECG axis interpretation

The cardiac axis represents the sum of depolarisation vectors generated by individual cardiac myocytes.
Clinically it is reflected by the ventricular axis, and interpretation relies on determining the relationship between the QRS axis (of the patient) and limb leads of the ECG (below diagram)
Since the left ventricle makes up most of the heart muscle under normal circumstances, normal cardiac axis is directed downward and slightly to the left:
Normal Axis: QRS axis between -30° and +90° guyton uses 59 deg
Abnormal axis deviation, indicating underlying pathology is demonstrated by:
Left Axis Deviation = QRS axis less than -30°
Right Axis Deviation = QRS axis greater than +90°
Extreme Axis Deviation = QRS axis between -90° and 180° (AKA "Northwest Axis")



The method to interpret that the doctor focused on and is the most efficient way to estimate is called "**The Quadrant Method**" looking at **LEAD I** and **LEAD aVF**

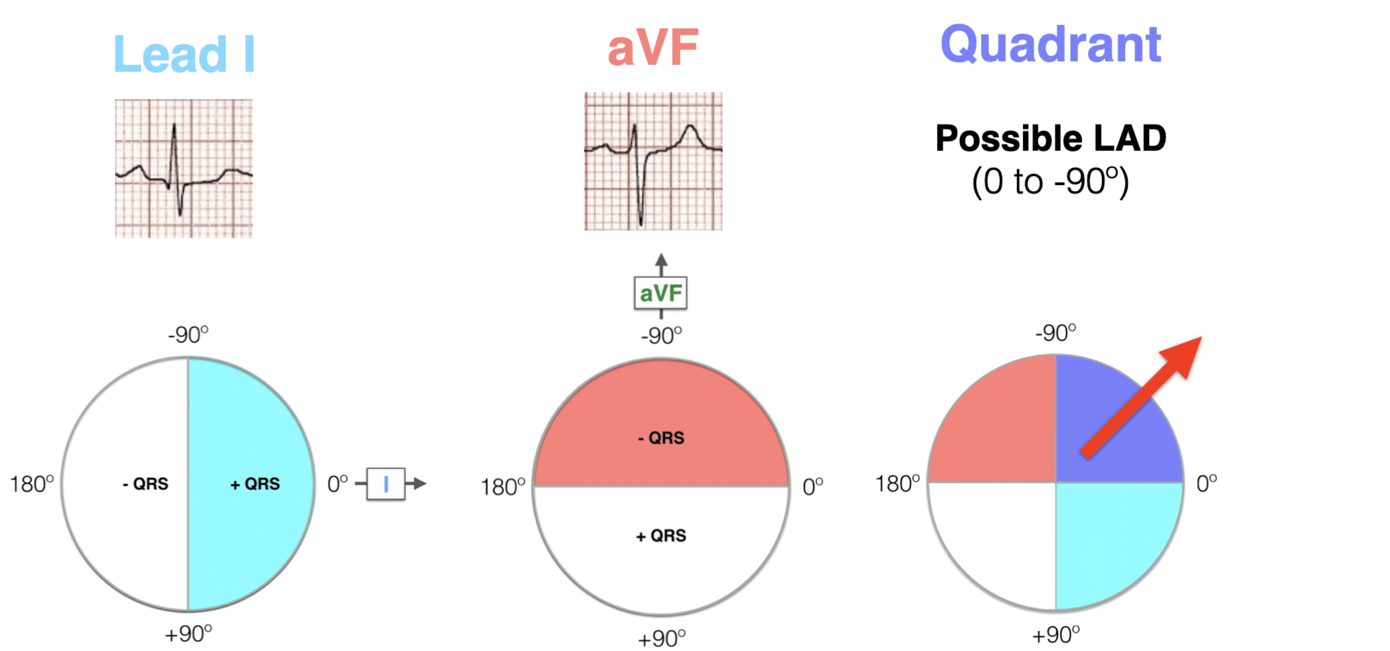
Examine the QRS complex in each lead and determine if it is Positive, Isoelectric (Equiphasic) or Negative:



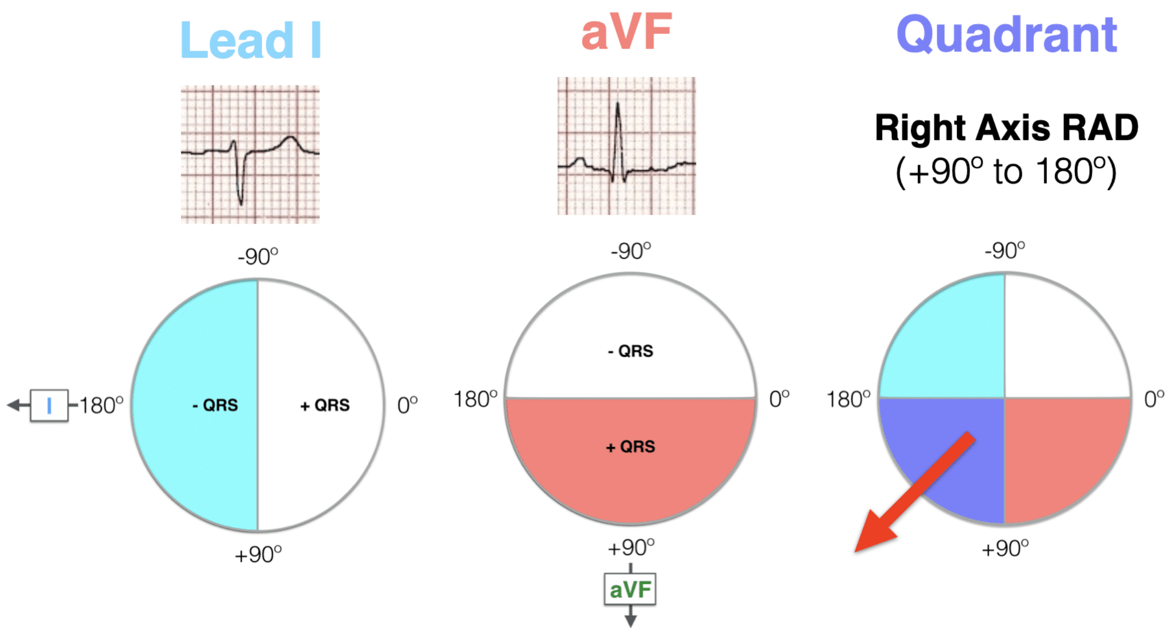
A positive QRS in Lead I puts the axis in roughly the same direction as lead I.

A positive QRS in Lead aVF similarly aligns the axis with lead aVF.

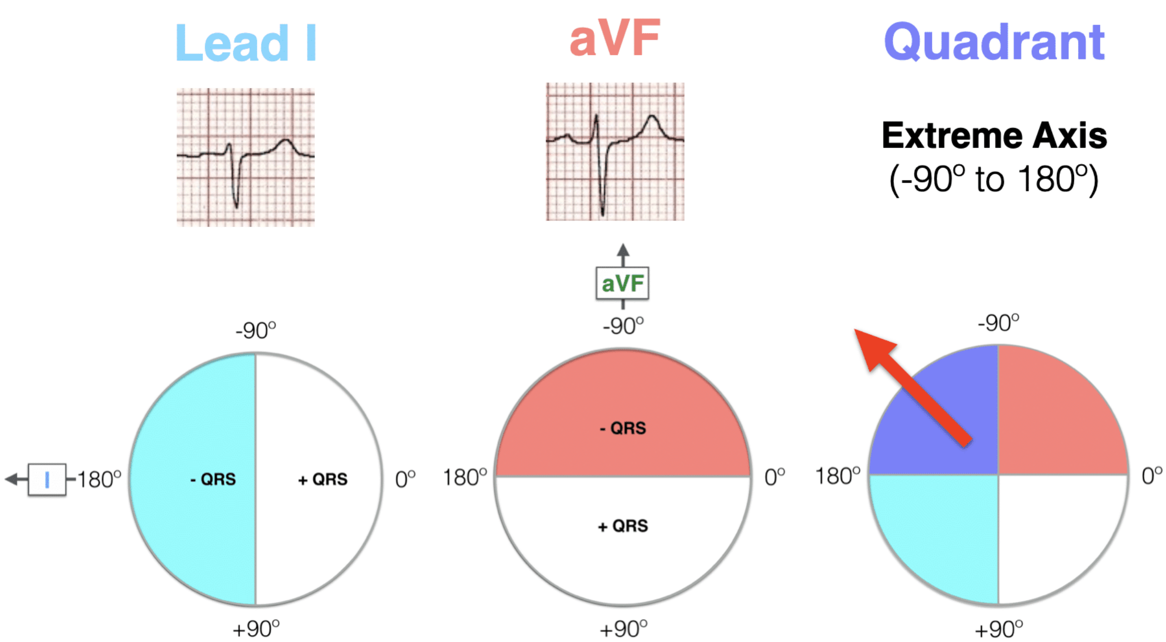
Combining both coloured areas – the quadrant of overlap determines the axis. So If Lead I and aVF are both positive, the axis is between 0° and +90° (i.e. normal axis). Try yourself in these readings: This is QRS +ve lead I and QRS -ve lead aVF which leads to an axis that's left deviated (LAD)



QRS -ve lead I, QRS +ve lead aVF :

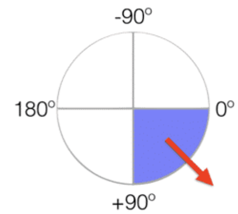
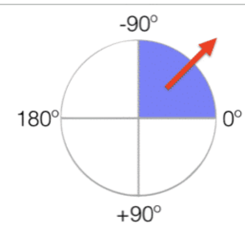
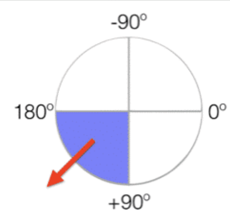
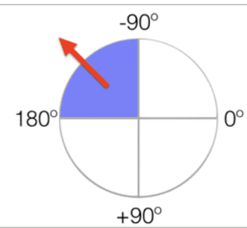


QRS -ve lead I, QRS -ve lead aVF:



Below there's a table that'll summarize it all.

Note: **Possible LAD, it's "possible" because it's not a final diagnosis, it can be further evaluated using Lead II in a whole another method of interpretation, idk if It's required at our level. Check guyton for more details!

Lead 1	Lead aVF	Quadrant	Axis
POSITIVE	POSITIVE		**Normal Axis** (0 to +90°)
POSITIVE	NEGATIVE		****Possible LAD** (0 to -90°)
NEGATIVE	POSITIVE		**RAD** (+90° to 180°)
NEGATIVE	NEGATIVE		**Extreme Axis** (-90° to 180°)

Check the latest version

Done by: Ahmad AlHurani

Best of luck