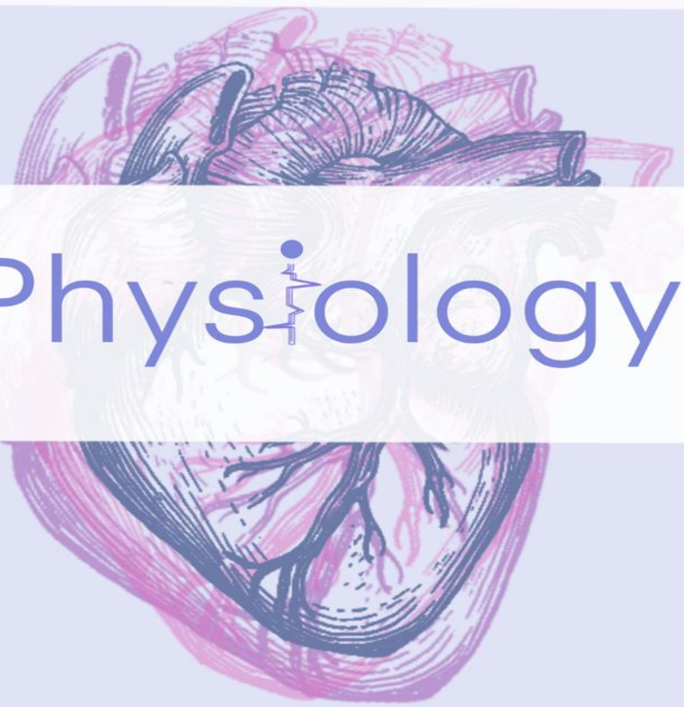
Cardio-Vascular System

6



Physiology

Writer: Sarah Basel

S.corrector: Mohammad Alsayed

F.corrector: Ibrahim Elhaj

Doctor: Faisal

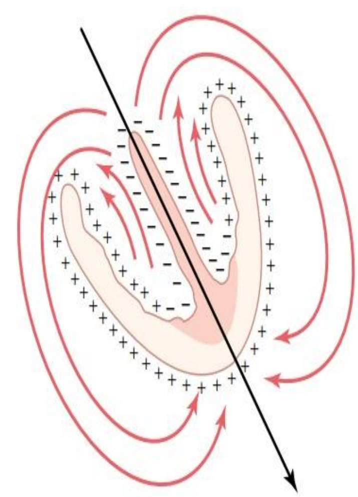
♥ Normal Electrocardiography:

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

Objectives:

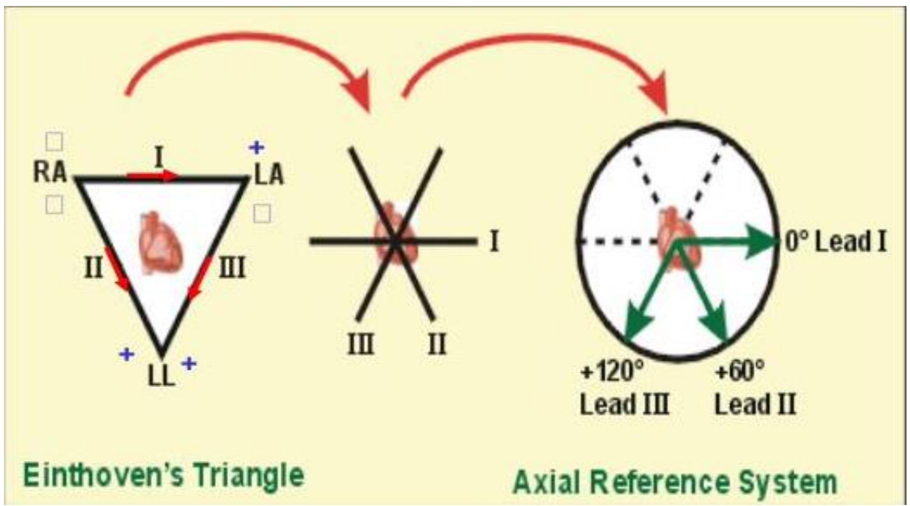
1. Recognize the normal ECG tracing.
2. Calculate the heart rate.
3. Determine the rhythm (normal Vs abnormal).
4. Calculate the length of intervals and determine the segments deflections (upward Vs downward).
5. Draw the Hexagonal axis of the ECG (bipolar + unipolar leads, both at the frontal plane).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

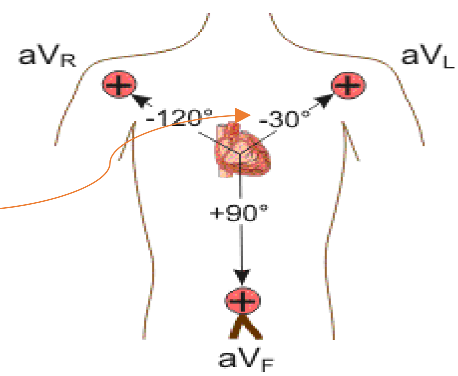


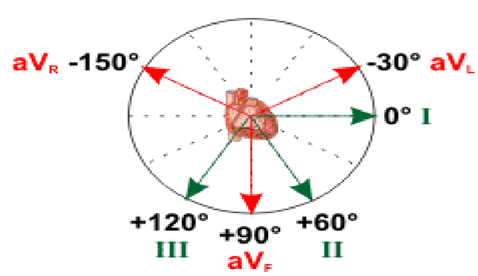
♥ Einthoven's triangle and law:

- 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.

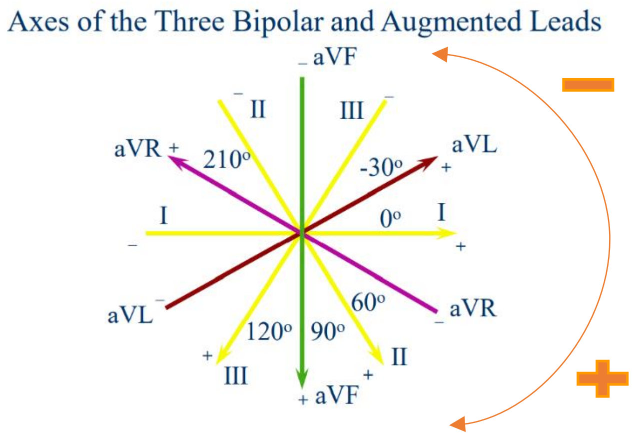


- Also, the augmented limb leads are recorded from one limb at a time (unipolar), the limb carrying the positive electrode, and the negative pole being represented by the central point. The three augmented limb leads (aVR, aVL, aVF) form another triaxial reference system, with each axis being separated 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°.

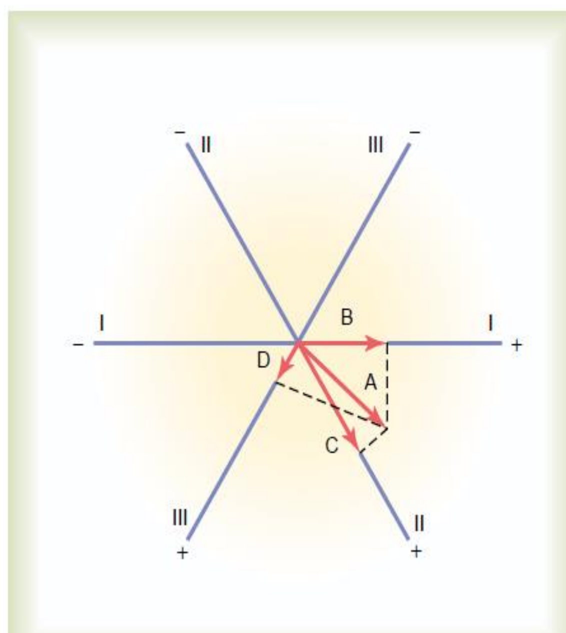




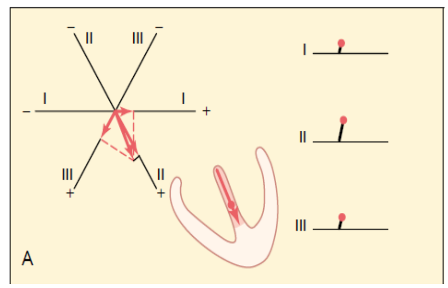
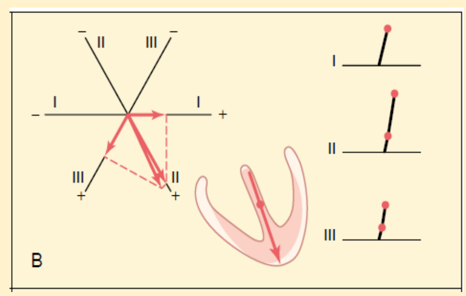
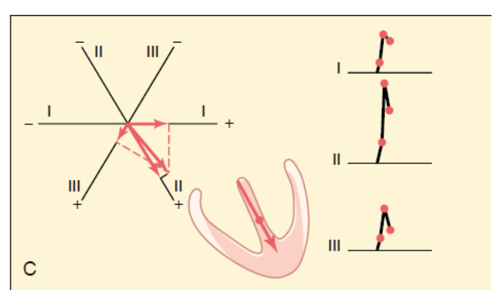
- Note that each of the six leads retains its polarity and orientation. The hexaxial reference system is important in determining the major direction of the heart's electrical forces (the electrical axis of the QRS complex).
- Perpendicular leads:
    1. L I and aVF
    2. L II and aVL
    3. L III and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

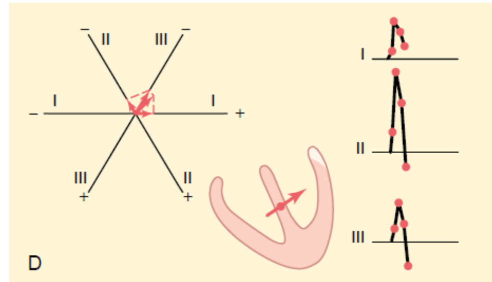
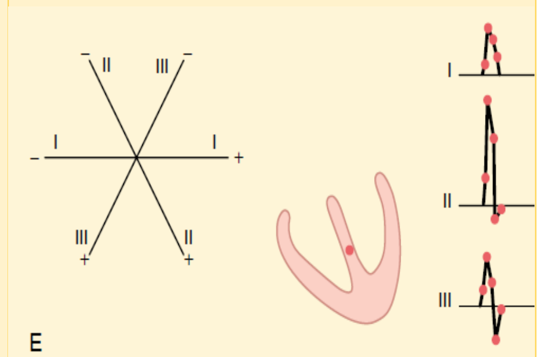
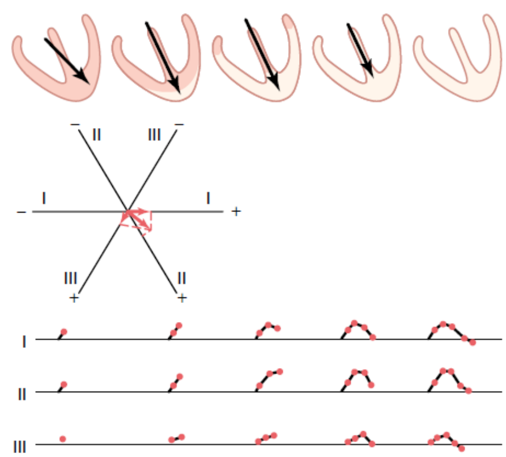


- Lead I is recorded from two electrodes placed respectively on the two arms. Because the electrodes lie exactly in the horizontal direction, with the positive electrode to the left, the axis of lead I is 0 degrees.
- In recording lead II, electrodes are placed on the right arm and left leg. The right 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).

the ventricular muscle has just begun to be depolarized. At this time, the vector is short because only a small portion of the ventricles—the septum—is depolarized. Therefore, all ECG voltages are low, as recorded. The voltage in lead II is greater than the voltages in leads I and III because the heart vector extends mainly in the same direction as the axis of lead II. • Q wave is present if the left side of the septum depolarizes first.	
The heart vector is long because much of the ventricular muscle mass has become depolarized. Therefore, the voltages in all electrocardiographic leads have increased (especially lead II). the depolarization vector is large because half of the ventricle is depolarized. Lead II should be largest voltage when compared to I and III when the mean vector is 60°.	
the heart vector is becoming shorter and the recorded electrocardiographic voltages are lower. Also, the axis of the vector is beginning to shift toward the left side of the chest because the left ventricle is slightly slower to depolarize than the right.	

the heart vector points toward the base of the left ventricle, and it is short because only a minute portion of the ventricular muscle is still polarized positive. Because of the direction of the vector at this time, the voltages recorded in leads II and III are both negative that is, below the line (S wave) whereas the voltage of lead I is still positive (sometimes it is also negative). • the last part to depolarize is near the left base of the heart which gives a negative vector (S wave).	
the entire ventricular muscle mass is depolarized, so that no current flows around the heart and no electrical potential is generated. The vector becomes zero, and the voltages in all leads become zero. **EXTRA:** The recording represents comparison in voltage detected by the electrodes at two different points not the actual potential. ECG does not record a potential at all when the ventricular muscle is completely depolarized or completely repolarized, because both electrodes are "viewing" the same potential, so no difference in potential between the two electrodes is recorded.	
After the ventricular muscle has become depolarized, repolarization begins and proceeds. This repolarization causes the T wave in the electrocardiogram. Because the septum and endocardial areas of the ventricular muscle depolarize first, it seems logical that these areas should repolarize first as well. However, this is not the usual case. The greatest portion of ventricular muscle mass to repolarize first is the entire outer surface of the ventricles. The endocardial areas, conversely, normally repolarize last. Because the outer surfaces of the ventricles repolarize before the inner surfaces, the positive end of the overall ventricular vector during repolarization is toward the apex of the heart. As a result, the normal T	

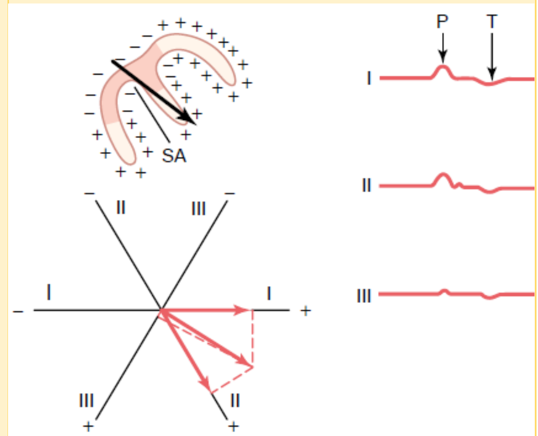
wave in all three bipolar limb leads is positive (upward deflection), which is also the polarity of most of the normal QRS complex.

Repolarization:

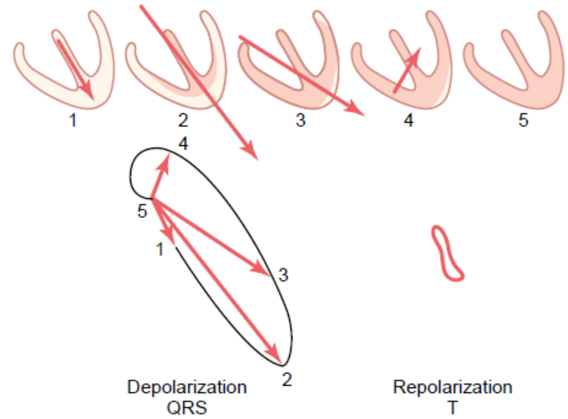
Apex→ base

Outer-surface→ inner-surface

- Depolarization of the atria begins in the sinus node and spreads in all directions over the atria. The direction of initial depolarization is denoted by the black vector. The vector remains generally in this direction throughout the process of normal atrial depolarization. Because this direction is generally in the positive directions of the axes of the three standard bipolar limb leads I, II, and III, the ECGs recorded from the atria during depolarization are also usually positive in all three of these leads, this record of atrial depolarization is known as the atrial P wave.
- The area in the atria that becomes repolarized first is the area that had originally become depolarized first. Thus, when repolarization begins, the region around the sinus node becomes positive with respect to the rest of the atria. Therefore, the atrial repolarization vector is backward to the vector of depolarization. **(Note that this is opposite to the effect that occurs in the ventricles).** atrial T wave follows the atrial P wave, but this T wave is on the opposite side of the zero-reference line from the P wave; that is, it is normally negative rather than positive in the three standard bipolar limb leads.
- In the normal electrocardiogram, the atrial T wave appears at about the same time that the QRS complex of the ventricles appears. Therefore, it is almost always totally masked by the large ventricular QRS complex, although in some very abnormal states, it does appear in the recorded electrocardiogram.



- point 5 is the zero-reference point. While the heart muscle is polarized between heartbeats, the positive end of the vector remains at the zero point because there is no vectorial electrical potential. However, as soon as current begins to flow through the ventricles at the beginning of ventricular depolarization, the positive end of the vector leaves the zero-reference point.

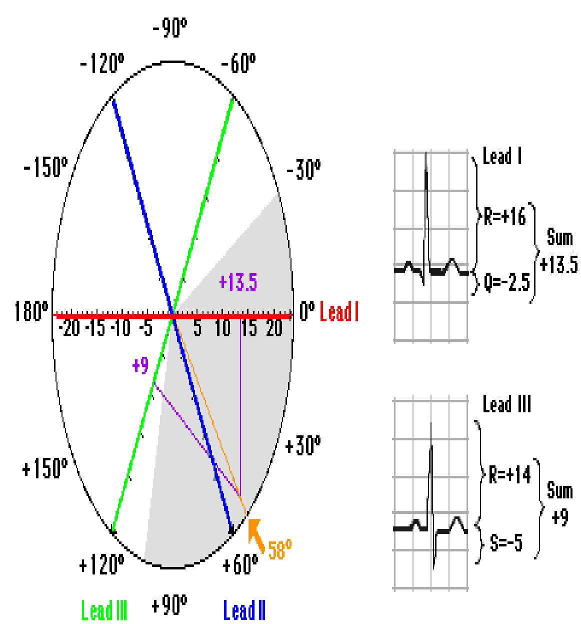


- When half of the ventricle is depolarized, vector-2 has the largest potential difference.
- Vector-4 represents depolarizing of the posterior aspect of the left ventricle (S-wave).
- The recording of the QRS complex is the same on all the leads, even on the unipolar leads and the horizontal chest leads (V1-6).

♥ Determining Mean Electrical Axis:

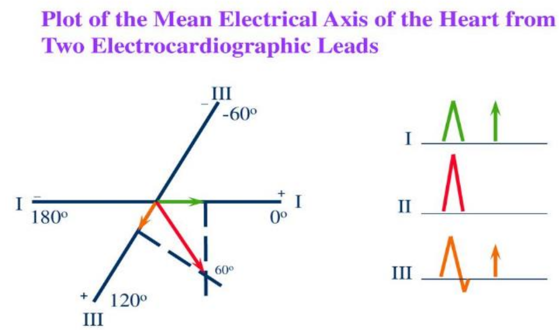
- To calculate the mean electrical axis of the QRS complex in this example, standard leads I and III were used but any combination of two of the six could have been used (we don't use chest leads). The vectorial sum of the deflections of the QRS complex for each lead is calculated in millimeters.

1. In this example, the Q wave is -2.5 mm deep and the R wave is +16 mm high to give a sum of +13.5 mm for lead I
2. The point corresponding to this sum is then located on lead I (the positive direction being towards the arrow of each lead) and a perpendicular is dropped from lead I
3. The same is done for lead III.
4. A line is then drawn from the center of the grid through the point of intersection of the two perpendicular lines to obtain the mean electrical axis. In this case, the mean

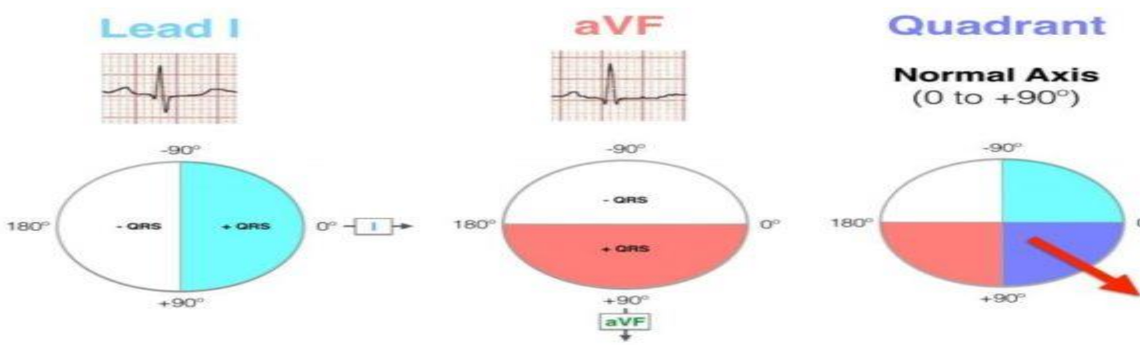


electrical axis of the QRS complex is 58 degrees, which is within the normal range.

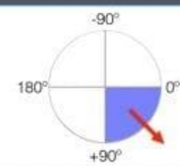
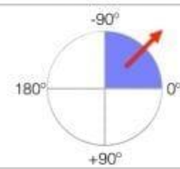
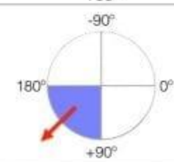
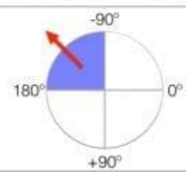
- In this example, the obtained mean electrical axis of the ORS complex is 60°, which is basically the axis of lead II.



- The most efficient way to estimate axis is to look at LEAD I and LEAD aVF.
  - 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).



- The following table summarizes all the possible cases:
  a. Normal Axis = QRS axis between 0° and +90°.
  b. Left Axis Deviation-LAD = QRS axis between 0° and -90°.
  c. Right Axis Deviation-RAD = QRS axis between +90° to +180°.
  d. Extreme Axis Deviation = QRS axis between -90° (+270) and +180°, to determine whether it is left or right you should trace the patient's history for any clues that suggest right or left deviation, because ECG is not the only tool to reach a diagnosis.

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°)

♥ Heart Rate Calculation:

Measure the distance between two successive ECG complexes (as the number of small squares). The number of ECG complexes by 1 min (beats/min) is equal to:

60/ number of small square X 0.04

Or basically **1500/No. of small squares**

Mostly used interval is the R-R interval

R-R interval = 0.83 sec or 20.75 small squares

Heart rate (beat/min) = 60/0.83

= 72 beats/min

- Keep in mind that the R-R interval (period) is the same in every cycle, because the heart rate should be regular. In irregular heart rate, the intervals are not identical.
- P-R interval is measured from the onset of the P wave to the beginning of the QRS complex, it should be less than or equal to 0.2 sec, if it is more than 0.2 it denotes that something is abnormal.
- QRS complex, starts from the beginning of Q to the end of S, and should be less than 0.12 sec.
- Q-T interval is usually about 0.35-0.4 sec
- S-T segment should be isoelectric, you look for deflection, either upward or downward. The same applies for the P-R segment.
- The reference point for the isoelectric line is the T-P segment.

♥ Determine regularity:

- The distance between R-R intervals and QRS complexes should be the same, if the distance differs the rhythm is irregular. Several methods can be used to determine rhythm regularity, these include using calipers, marking a paper with a pen. By counting the small squares between the R-R interval (each large square = 5 small squares) and comparing this distance each time (should be the same).
    - Patterned irregularity (regular irregularity) is when the irregularity repeats in a cyclic fashion.

Quiz:

1. **If there were 3 large squares in an R-R interval what would the heart rate be?**

    a. 100 bpm

    b. 90 bpm
    c. 80 bpm
    d. 70 bpm

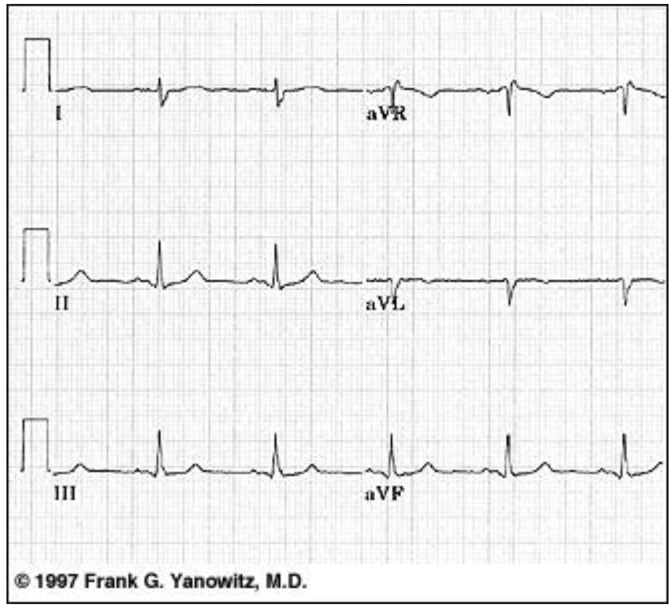
1. **Determine the QRS axis for this ECG:**
    a. -100 degrees

    b. -30 degrees

    c. +15 degrees

    d. +90 degrees

    e. Indeterminate



2. **P wave represents:**
    a. Depolarization of right ventricle

    b. Depolarization of both atria

    c. Depolarization of left ventricle

    d. Atria to ventricular conduction time
3. **In normal ECG one of the following waves is not represented, which one is that?**
    a. Depolarization of atria
    b. Repolarization of atria
    c. Depolarization of ventricles
    d. Repolarization of ventricles

♥ Answers:

1. A
2. D (Lead I is isoelectric and since aVF is positive, you know the axis is +90 degrees).
3. B
4. B