The Cardio-VASCULAR System

- ○ Anatomy
- ○ Histology
- ○ Pathology
- ○ Pharmacology
- ● Physiology
- ○ Microbiology

Lec #: 4

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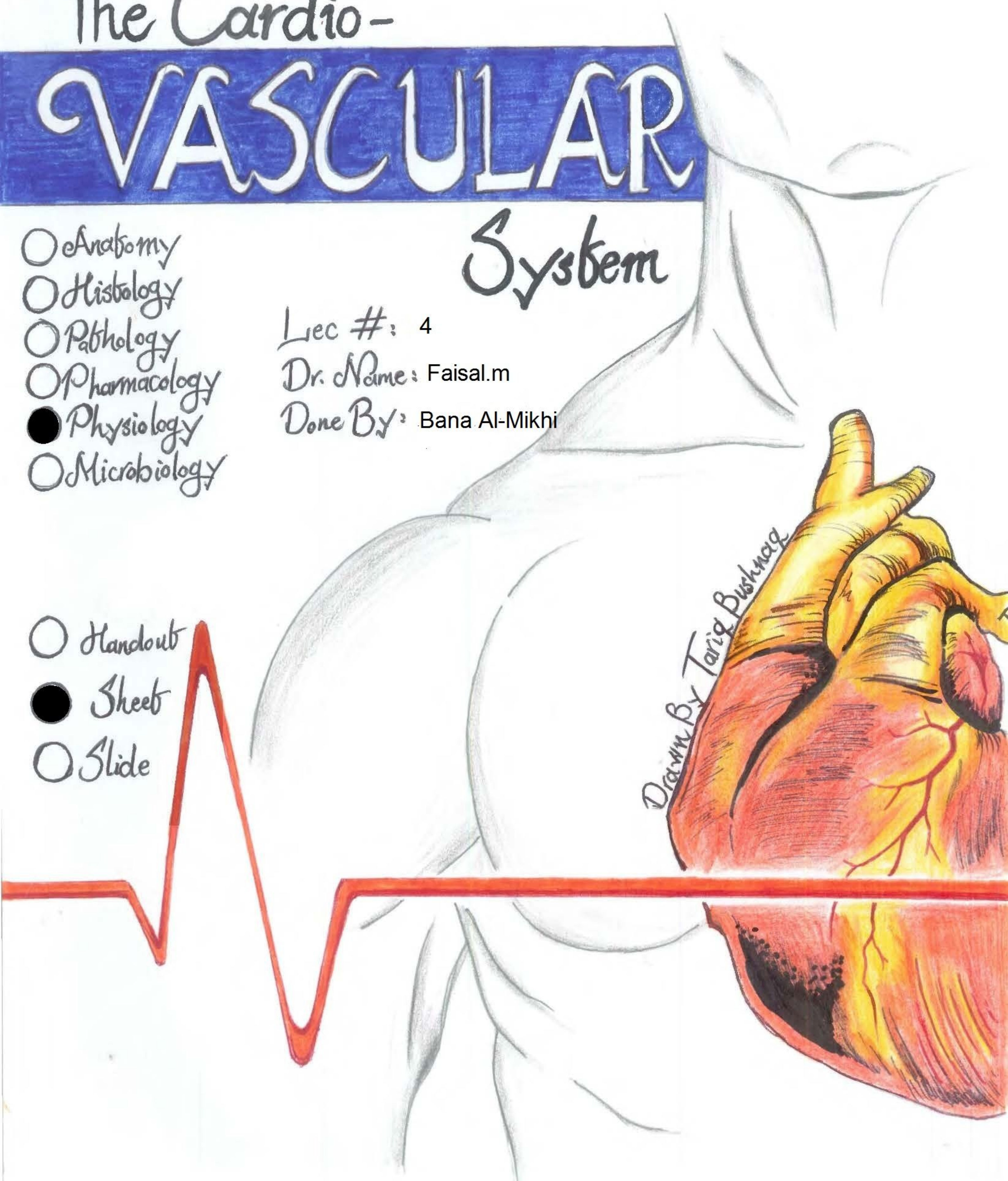
- ○ Handout
- ● Sheet
- ○ Slide



-This lecture is written according to section 1 recording with a little of information rearrangement.

-Let's start with reviewing a few points on the previous lecture:

(1) We mentioned the effects of sympathetic and para-sympathetic effects on the conducting system of the heart:

- The sympathetic effect on:

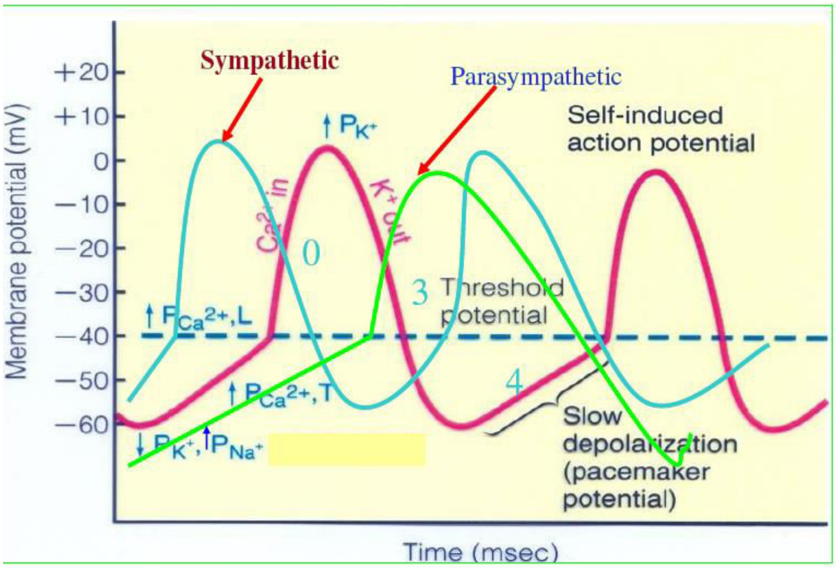
- SA node: increases the rate of diastolic depolarization leading to an increase in the heart out rate → positive **chronotropic** effect.
- AV node: increases conduction rate → positive **dromotropic** effect.
- Atrial contraction: increases stress/force of contraction → positive **inotropic** effect. (not so important; in case of atrial fibrillation "absent atrial contraction" the heart will still be functioning normally)
- Ventricular contraction: increases force of contraction → positive **inotropic** effect.

- It supplies all parts of the heart (atria, ventricles and all parts of the conduction system).
- increases the permeability of the cardiac cells to Na^+ and Ca^{++} through epinephrine and norepinephrine.

- para-sympathetic effect:

- It has no effect on the ventricles since it does NOT supply them. → Parasympathetic from Vagus nerves supplies mainly the atria, SA and AV nodes, very little supply to ventricles leading to a negative chronotropic effect WITHOUT an inotropic effect
- Increases the permeability of the cardiac cells to K^+ and decreases its permeability to Na^+ and Ca^{++} due to Ach release.

(2)



- This figure shows Normal(purple), Sympathetic(blue), Para-sympathetic(green)

- Note that the peak is the same in all cases, since action potential is an all-or-none process.

(3) Ventricular escape and over-drive suppression:

Suppose we have an extensive parasympathetic stimulation (extensive vagus nerve stimulation), this will lead to a decrease in the heart rate, but afterwards the heart would stop for about 15-30seconds.

After that the heart resumes its contraction with the purkinje fibers conduction rate (15-40 beats/min) although there is a persistent parasympathetic stimulation.

→ As previously mentioned, the conduction rate is different than the intrinsic rate, normally 70 impulses/min coming from the SA node will be conducted through the purkinje to the ventricular muscles, and the muscles will contract with a rate of 70beats/min.

Normally when the SA and AV nodes are intact, the purkinje fibers' intrinsic conduction will be suppressed; meaning that they'll conduct nothing by themselves (they'll work under the SA or AV node conduction rate) and this is referred to as **Over-Drive Suppression**.

-Why is there a resumption after 15-30 seconds?

This is called **Ventricular escape**, which means that the ventricles escape the parasympathetic effect.

-why is the intrinsic rate of purkinje not active to start with?!

Because it is suppressed by the higher rate that it receives from SA-node or AV-node. This is called: **Overdrive suppression.**

- If the AV-node is destroyed; a case known as heart block. We'll lose the connection between atria and ventricles, so the atria will be conducted by the SA node and the ventricles by the purkinje fibers.

(4) In slide number 31(with cover) the dr. read said the numbers are not for memorization.

In slide 32(with cover) he quickly reads the steps.

(5) Slide number 33(with cover), the speed of conduction is fastest in the purkinje (4m/s) because the ventricles must contract very fast at one time.

- Suppose we have an AV-bundle branch block, the impulse will be conducted from on cell to another of the ventricular muscles through gap junctions making their conduction rate slow (0.3-0.5 m/s) which is must lower that the normal speed (4 m/s).

- AV-node has the slowest conduction rate (0.05 m/s) causing **AV-delay** to insure that atrial contraction finishes before ventricular contraction begins since both contractions should not occur together.

- The dr. reads the steps in the slide.

(6) -Normal rate of discharge in sinus node is 70-80/min.; A-V node - 40-60/min.; Purkinje fibers - 15-40/min.

-Sinus node is pacemaker because of its faster discharge rate.

-Intrinsic rate of subsequent parts is suppressed by "Overdrive suppression".

- Ectopic pacemaker is anything beyond the pace of SA-node, anything that discharges higher or lower than SA-node whether it is from the atrium or ventricle.

- Ectopic pacemaker also occurs when transmission from SA node to AV node is blocked (A-V block), During sudden onset of A-V block/heart block, sinus node discharge does not get through, and next fastest area of discharge becomes pacemaker of heart beat (Purkinje system).

(7) Delay in pickup of the heart beat is the **"Stokes-Adams" syndrome**.

This occurs when there is pressure on the vagus nerve from a carotid aneurysm, leading to suppression of ventricular rate which causes a decrease in heart beat then heart stops for 15-30seconds then it resumes with purkinje's rate (ventricular escape). The syndrome comes and goes; it's not persistent.

Now let's start with a new topic: **Electrocardiography. تخطيط القلب**

- Electrocardiography means recording only the electrical changes of the heart and has nothing to do with mechanical changes (systole-diastole) or (contraction-relaxation) neither with sounds.

-what are the electrical changes that occur in the heart?

Depolarization and repolarization of atria, depolarization and repolarization of ventricles.

When we record these changes in the action potential, we put one electrode inside the cell and one outside the cell, but this is not possible upon ECG (ElectroCardioGraphy)

That's why we will record them from the surface of the body (hands, legs,...) using an instrument known as galvanometer that records voltage difference.

- What are the potential differences that occur in the heart?

resting = -90 maximum = +30 ⟶ difference = 120mV

This 120mV electrical potential is at the heart level, when it reaches the surface (arms/legs) it would almost be equal to 1-2mv due to resistance, this creates a problem upon measuring it.

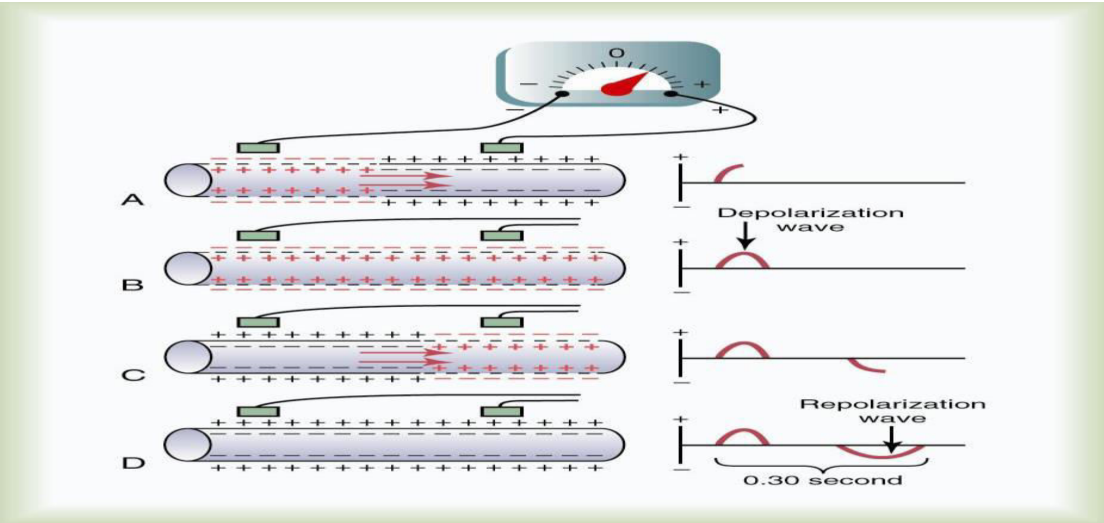
This problem is solved by using an <u>amplifier</u> with the galvanometer to increase the scale.

So the instrument used is <u>Electrocardiograph</u> (galvanometer + amplifier).

Objectives:

1. Describe the different "waves" in a normal electrocardiogram (ECG) sometimes it is called EKG because the pioneers of this mechanism are German, and in deutsch language cardio is written with a K.
2. Recall the normal P-R and Q-T interval time of the QRS wave.
3. Distinguish the difference in depolarization and repolarization waves.
4. Recognize the voltage and time calibration of an electrocardiogram chart.
5. Point out the arrangement of electrodes in the bipolar limb leads, chest leads, and unipolar leads.
6. Describe Einthoven's law.

<u>-Depolarization and Repolarization:</u>



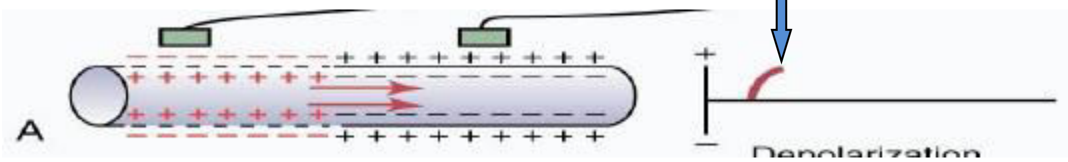
In the above figure: if we have a wave of depolarization in the muscle running from one point to another of the electrodes, there will be a potential difference.

If the whole membrane is depolarized or repolarized then there will be NO potential difference because it will have the same charge, and the galvanometer records **zero**.

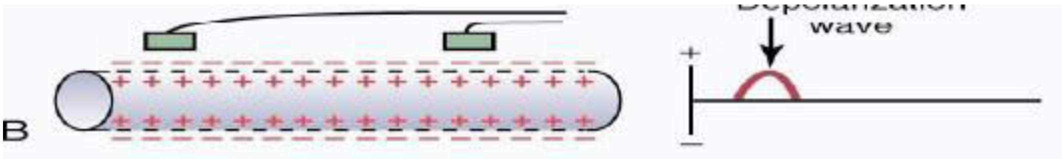
when the wave of depolarization starts (in figure A) the membrane will start to become negative outside and positive inside at one side, and on the other side it will be the opposite which creates a potential difference that will be recorded by the galvanometer.

- upon reaching the midway, maximum potential difference is recorded and then it will start dropping once again.

midway - max. potential difference then it will start decreasing.



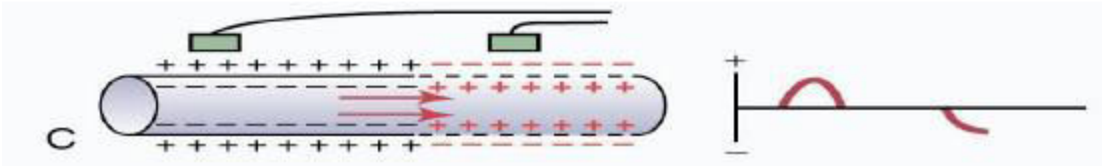
- In figure B, the whole membrane is depolarized, and as we have mentioned this means that we don't have a potential difference.



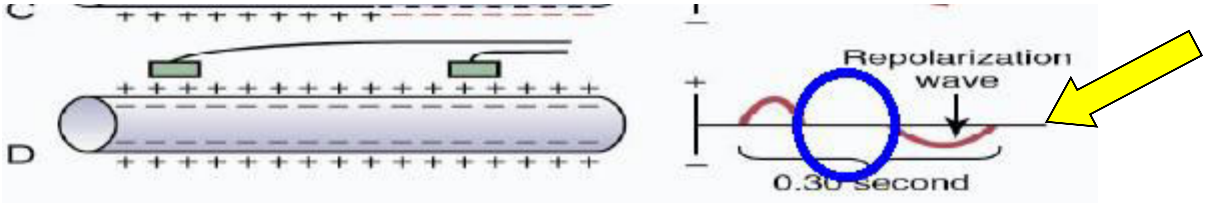
-NOTE: it has been agreed upon that a wave of **depolarization** is an upward reflection, and a **repolarization** wave is a downward reflection.

* Explanation (not important): The current between the two electrodes will always go from negative to positive, in case of depolarization the membrane on the proximal end will start to depolarize and become positive inside and negative outside but the distal membrane will still be resting (negative inside and positive outside) so the current will move in a certain direction. However in case of repolarization the proximal membrane will start to repolarize and become negative inside and positive outside and the distal membrane will still be depolarized (positive inside and negative outside) so the current will be moving in the opposite direction of the previous case, that's why we have upward and downward reflections. (don't be confused by the arrows of the figures as they're not very specific)*

-In figure C, repolarization is occurring : positive outside and negative inside which means the membrane potential is reversed and the galvanometer records the other way around.



- In figure (D): complete repolarization and back to zero.



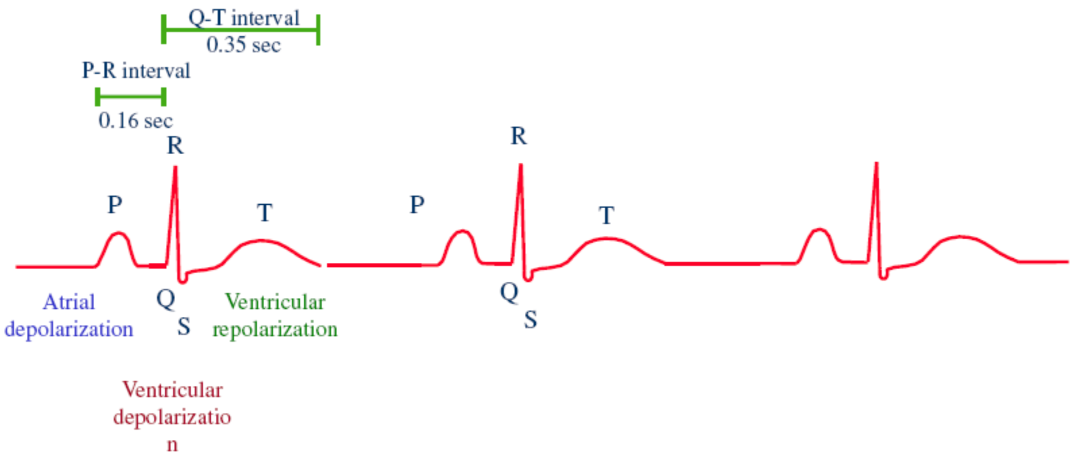
What is the cause of the space? (pointed by the blue circle)

→ this is when the membrane is completely depolarized during <u>plateau</u>.

- note that the line pointed by the yellow arrow is called **<u>isoelectric line</u>**.

* depolarization and repolarization of ventricles occur at all parts of the ventricle at almost the same time due to purkinje fibers.

When recording ECG we must record four waves: depolarization of ventricle, repolarization of ventricle, depolarization of atrium, repolarization of atrium, we will get the following recording:

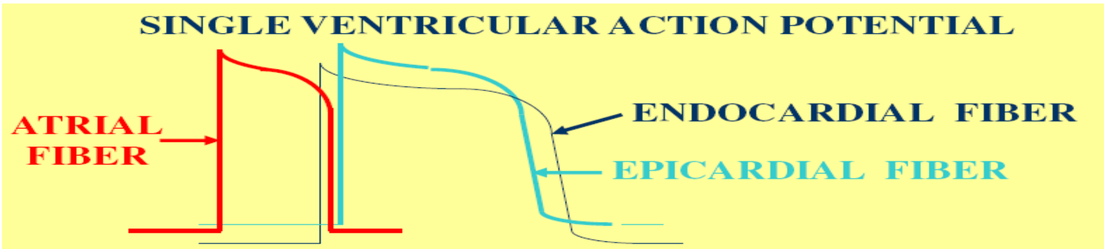


First wave P, then QRS, and T. (no specific reason for this naming, only because they started with P and continued alphabetically)

P = atrial depolarization.
QRS = ventricular depolarization.
T = ventricular repolarization.

When the ECG shows a straight line, this indicates heart arrest (death)

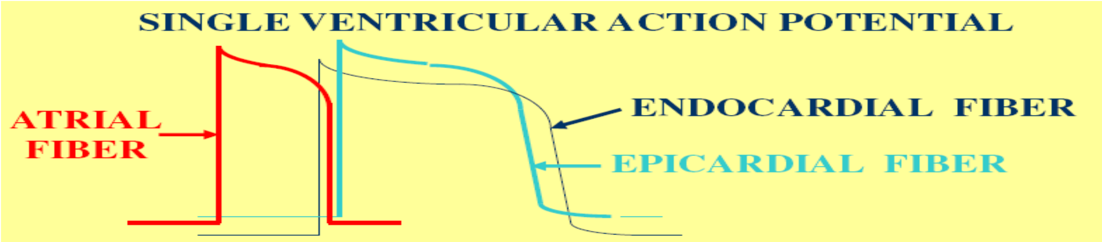
When measuring from P to P or R-R interval is called **cardiac cycle** (you can start from Q or R)
-Now, upon looking at the ECG two distinctive points must have come to your mind
1- Missing atrial repolarization wave:
It occurs at the same time at the ventricular depolarization to the extent that it is masked by it so it does not appear.



In the figure you can see that phase 3 of atrial fiber action potential is occurring at the same time of phase 0 of ventricular action potential.

2- Ventricular repolarization "T" is an upward elevation where it is supposed to be downward reflection:
This can be explained by two possibilities:
(a) in normal ECG the depolarization and repolarization start and end at the same direction but what happens at the heart is that the **depolarization** occurs from **endocardium to epicardium** (base to apex) whereas the **repolarization** occurs from **epicardium to endocardium** (apex to base)

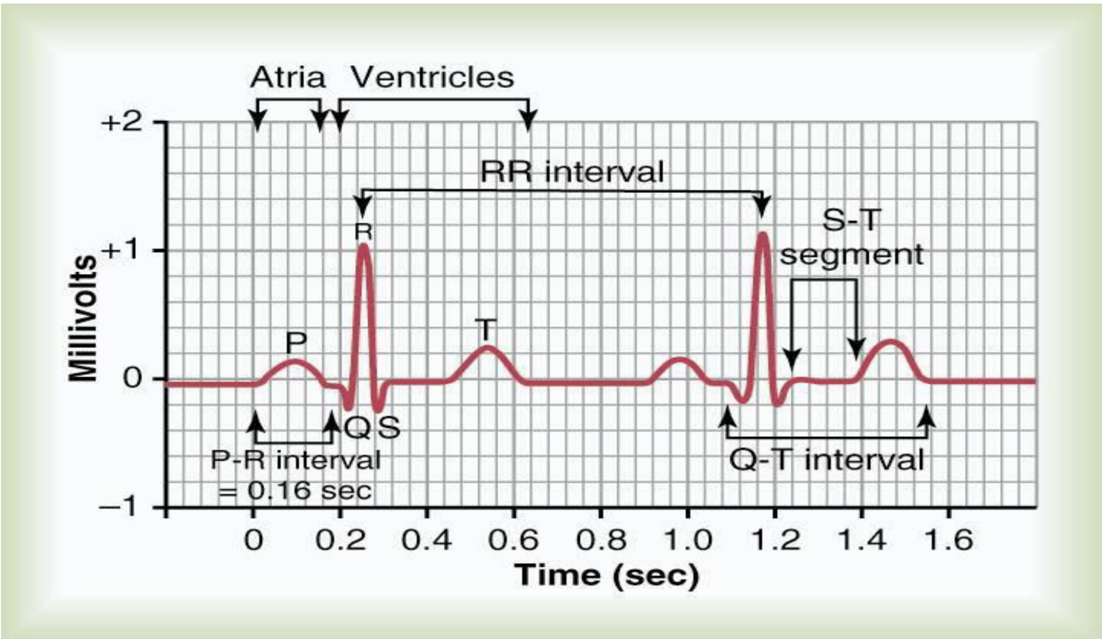
because of this change in direction (will be further explained), the ventricular repolarization "T" is an upward elevation.



in the above figure you can notice that the epicardial fiber action potential is shorter than that of endocardial fiber, leading to an earlier repolarization of epicardium.

(b) Following depolarization is ventricular contraction increasing intraventricular pressure affecting the endocardial area more since it is nearer (highest pressure); this leads to changing the electrolyte environment to the extent that it delays repolarization.

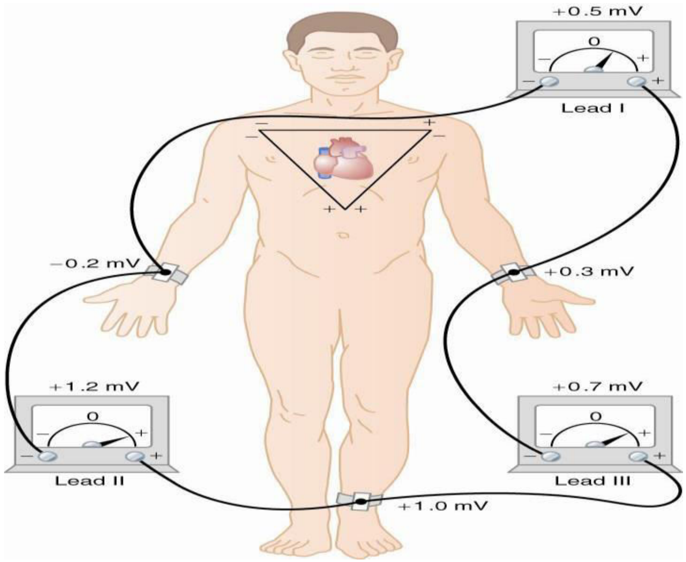
- Standardized ECG:



X-axis : time (sec)
Y-axis : Voltage (mv)

- The squares are approximately 1millimeter. Every 5 small squares we will have a thicker line (separate line)
- The speed of the machine=25mm/sec.
-what is the time for each small square? 0.04second (the machine's speed is 25mm/sec and each square is 1mm so 1/25 = 0.04)
Now, since we have each 5squares together, then the time between two thick lines must be 0.04 * 5 = 0.2 second

- Each cardiac cycle (R-R interval) = heart beat
From that we can calculate the heart rate.
Supposing we measured R-R interval and found that it is 1 second, then what is the heart rate? (1beat * 60 seconds) = 60beats/min



Supposing we measured R-R interval and found that it is 0.6 seconds, what is the heart rate? 100 beats/min (each heart beat occurs in 0.6 seconds so in 60 seconds '1min' = 60/0.6)

For teaching purposes, we consider each R-R interval is 0.8seconds and consequently the heart rate equals 75beats/min

-**<u>we conclude that: when the cardiac cycle decreases, the heart rate increases.</u>**

-If we want to have a full picture of the heart we must take different views, and that is why we record from 3 leads:
(Lead 1) Right Arm (negative electrode) and Left Arm (positive electrode)
(Lead 2) Right Arm (negative electrode) and Left Foot (positive electrode)
(Lead 3) Left Arm (negative electrode) and Left Foot (positive electrode)

To make it easier for you to memorize this, remember that:
Right arm is ALWAYS a negative electrode
Left foot is ALWAYS a positive electrode

By taking different measuring sites the voltage changes BUT the heart rate remains the same.

- you can see it on the right foot (earth), to discharge the electrostatic electricity.
- We call the leads bipolar because we connect them to two parts.
- If someone recorded them oppositely the recording will be reversed.