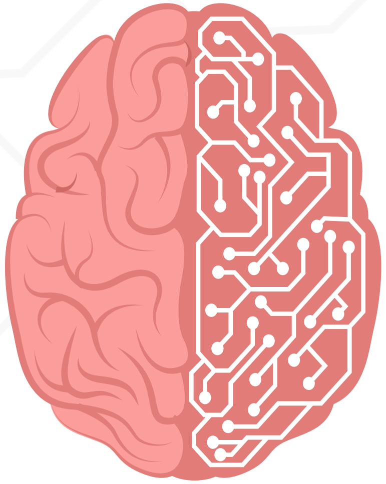
النادي الطلابي
كلية الطب



Physiology - CVS

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Electrocardiography – Normal 5

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Check this ninja nerd video يا نيرد

https://youtu.be/CNN30YHsJw0

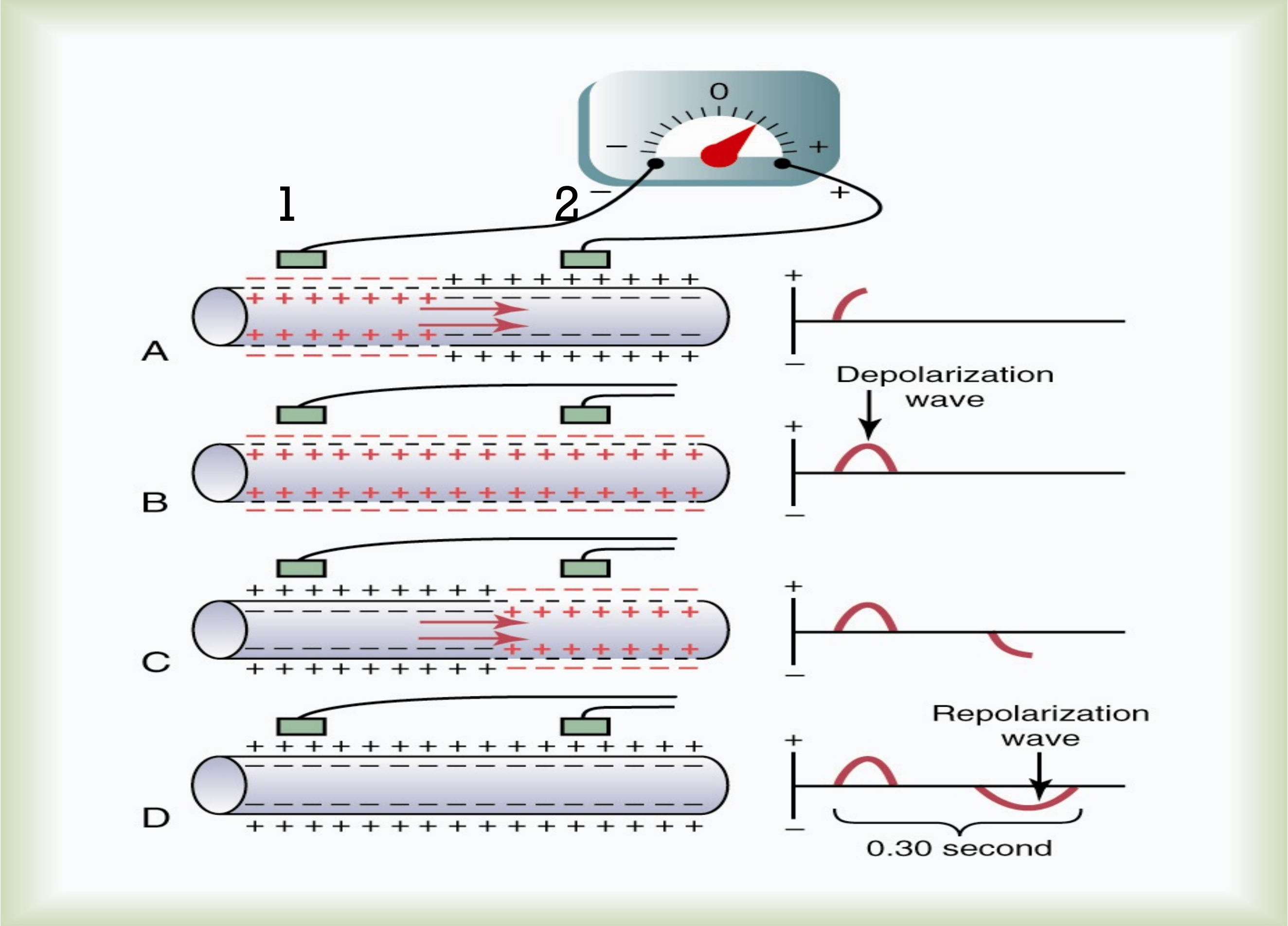
Take a deep breath and enjoy it!

If any patient comes with cardiovascular problems, we should do ECG because it's an important tool in diagnosing cardiovascular diseases

Objectives

1. Describe the different “waves” in a normal electrocardiogram.
2. Recall the normal P-R and Q-T interval time of the QRS wave There are 3 main waves (P, QRS, T).
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 named after the scientist who discovered it.

Depolarization and Repolarization Waves



Upward - positive (depolarization)
Downward - negative (repolarization)

ECG is an electrical recording of the electrical events in the heart. It will never tell you about the mechanical events that occur in the heart neither tell you about the systole or diastole.
The electrical changes are either depolarization or repolarization (of the atria or the ventricles)

- Note that no potential is recorded when the ventricular muscle is either completely depolarized or repolarized.

Explanation of the previous slide

A : We have 2 electrodes that are connected with a galvanometer. The depolarization starts from area 1 to 2, so there is a change in the electrical charges that occur on the surface and inside the strip of muscles.
In area 1 : the outside is negative, and the inside is positive .
So, there will be an electrical potential difference between electrode 1 and 2 and this difference increases by moving from 1 to 2 until we reach halfway of the stripes where the membrane potential difference is the MAX.
Pay attention that these 2 electrodes are on the surface!
When you exceed the halfway, there will still be a potential difference between side 1 and 2 but it's decreasing (downward) until the stripe of the muscle is completely depolarized (like in the B situation).

B : When the stripe of the muscle is completely depolarized, there will be no potential difference between area 1 and 2 (all the surface is negatively charged). So, there's no current going from 1 to 2. We have an iso-electric line = no ups and downs, just a straight, forward line. There is no potential difference.

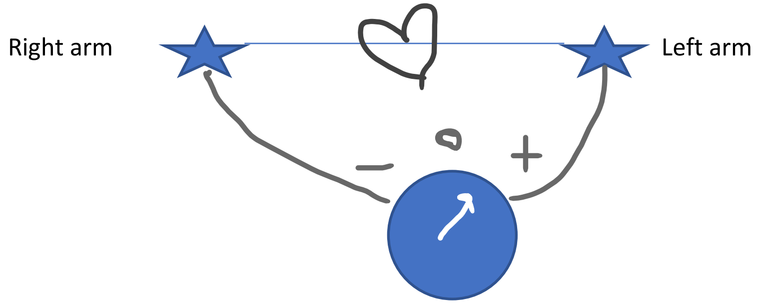
Memorize this → depolarization is an upward deflection.

C : Repolarization. If repolarization comes from 1 and goes to 2, repolarization means that the charges are becoming positive at side 1 while it is still negative at side 2. (the opposite of A).
The current that is going from 1 to 2 is in the reverse direction, and there is a potential difference between 1 and 2 but this potential difference is going in the other direction. The arrow of the galvanometer will be to the other side compared to that in figure A. So, when we record this potential difference, there will be a downward deflection until the repolarization is almost halfway in the muscle, and what we record here is the maximum potential difference.
When we exceed the halfway, the potential difference starts to decrease until it is completely repolarized, when it is completely repolarized it goes to the isoelectric line.

When the muscle is completely repolarized/depolarized, it is isoelectric.
We can denote that a downward deflection is a repolarization, and an upward deflection is depolarization, it is internationally accepted.

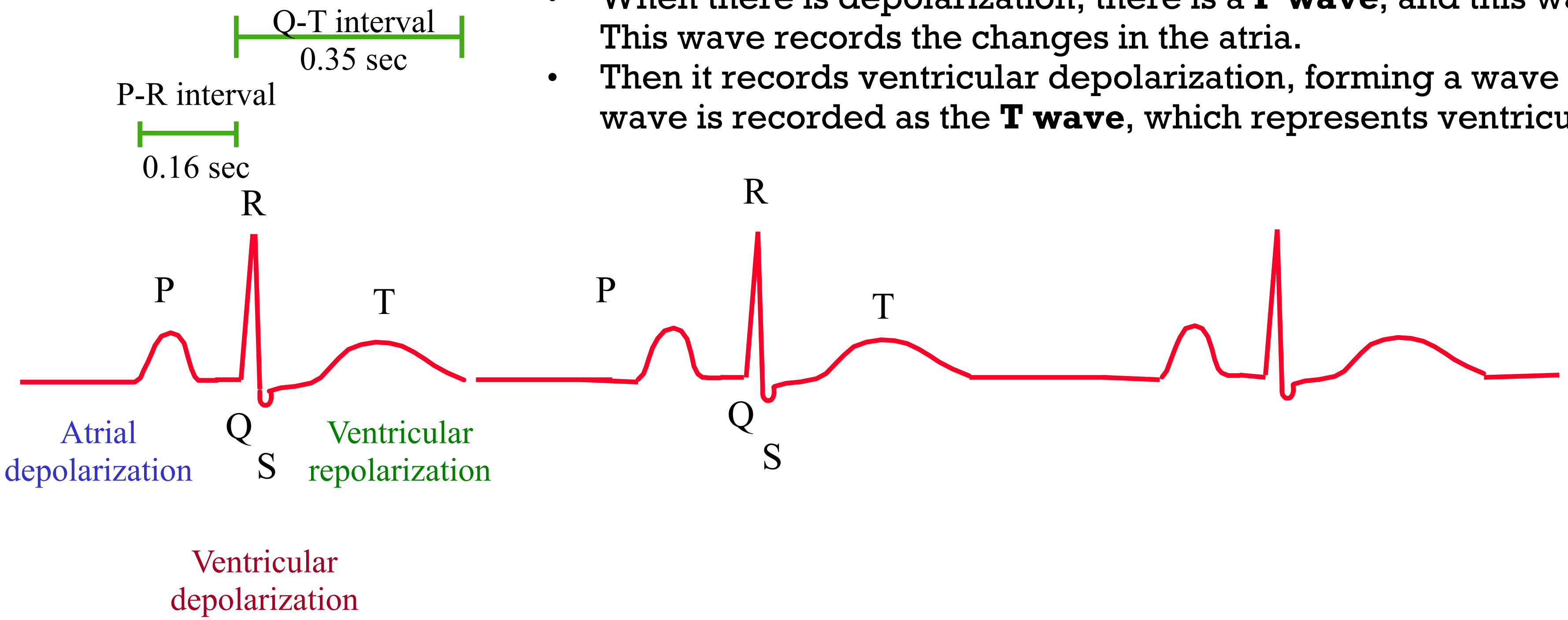
Intro to the upcoming slide

- In normal ECG, we put one electrode for example on the right arm, and the other electrode on the left arm. The pointer of the galvanometer will point to the change in the potential difference as the wave of depolarization moves from one area to another across the heart, where there is depolarization.
- We can catch these electrical changes when we put the electrodes on the right and left arms but remember that the potential difference that occurs during the cardiac action potential starts from -90mv then we have a depolarization until let's say 20mv. So, the potential difference is around 110 mv during the action potential in the heart.
- If you want to see this action potential in the arms, you know the electricity from the heart, since the heart is connected to electrical conductors that (couldn't catch this idk).
- So, this electricity will be conducted to the arms, but the potential difference that is 110mv in the heart is much less when you catch it in the surface of the hand which might reach 1 or 2 mv maximum.



Normal EKG

- So how can we see these in the ECG? We can see this by putting some amplifiers. The ECG machine is basically a galvanometer with amplifiers to amplify the difference between the depolarization and the repolarization.
- When there is depolarization, there is a **P wave**, and this wave is due to atrial depolarization. This wave records the changes in the atria.
- Then it records ventricular depolarization, forming a wave called **QRS complex**, and a third wave is recorded as the **T wave**, which represents ventricular repolarization.



- During each cycle (each beat), we record depolarization of the atria then depolarization of the ventricles then ventricular repolarization.
- There should be an atrial repolarization, but this occurs during the ventricular depolarization, so it is masked and doesn't show up.
- The ventricular repolarization is an upward deflection although it is a repolarization (we have mentioned earlier that repolarization is a downward deflection), BUT this is in the case of the repolarization moving from 1→ 2 but if it occurs the other way around (from 2→1), the repolarization will appear as an upward deflection and this is what we see in the ECG, since ventricular repolarization occurs from the pericardium to the endocardium.
- NOTE: the depolarization occurs from the endocardium to the pericardium.
- When the cycle continues, the heart continues to depolarize and repolarize and so on.

Explanation

- The recording of the action potential is called monophasic recording, where we put one electrode inside the cell and the other one outside the cell. It is called this way because it is all on one side, (the waves are all in one direction).

- But in the ECG, we call this type of recording biphasic recording, there are waves up and waves down, and biphasic recording occurs when the two electrodes are on the surface.

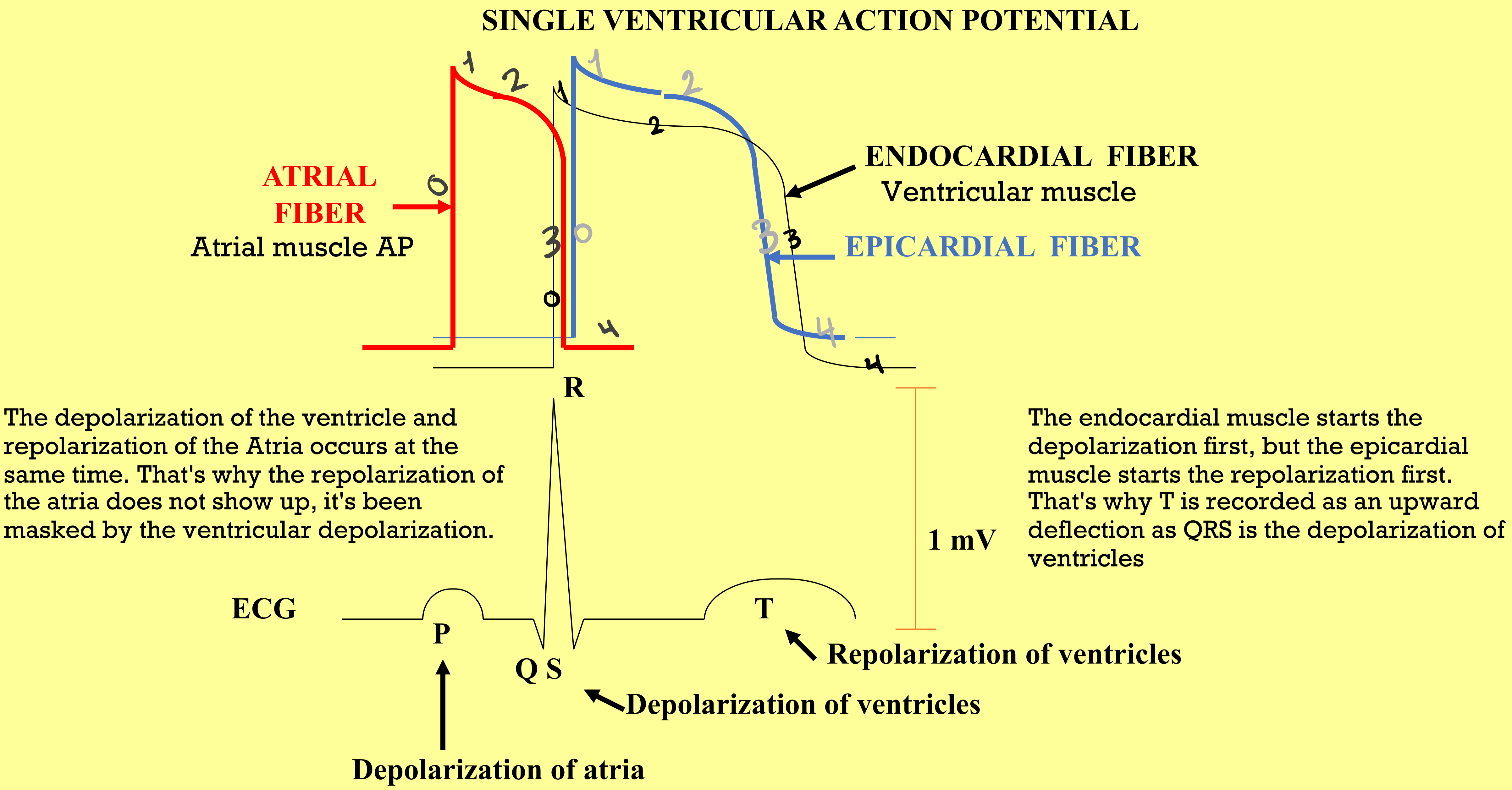
- Normal ECG is PQRST, and the repetition of this recording is called the cardiac cycle. From one R to the next R is called the cardiac cycle, it can be from any letter to the next and it should be the same, but we use the standard measure from R to R because it is more definite and obvious, since it has a very sharp peak.

- How many cycles per minute is the same as the number of heart beats, so the heart beats normally as the same number of cardiac cycles that occur in one minute.

- T wave and QRS are upward deflections, because

1. The depolarization and repolarization don't start from the same point.
2. Depolarization → from endocardium to pericardium - from the base of the heart to the apex.
3. Repolarization → from pericardium to endocardium - from the apex of the heart to the base.

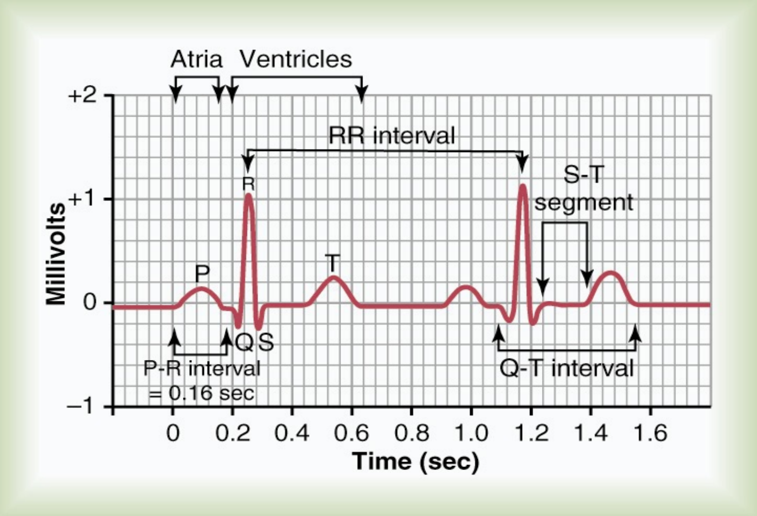
Thus, it might be an intrinsic property of the cardiac muscle AP.


SINGLE VENTRICULAR ACTION POTENTIAL
ATRIAL FIBER
Atrial muscle AP
ENDOCARDIAL FIBER
Ventricular muscle
EPICARDIAL FIBER
0
1
2
3
4
R
The depolarization of the ventricle and repolarization of the Atria occurs at the same time. That's why the repolarization of the atria does not show up, it's been masked by the ventricular depolarization.
1 mV
The endocardial muscle starts the depolarization first, but the epicardial muscle starts the repolarization first. That's why T is recorded as an upward deflection as QRS is the depolarization of ventricles
ECG
P
Q S
T
Repolarization of ventricles
Depolarization of ventricles
Depolarization of atria

Standardized EKG's

look at the x axis on the ECG, we record the time in term of (sec) and in the Y axis we record the voltage in (mv)

- Time and voltage calibrations are standardized

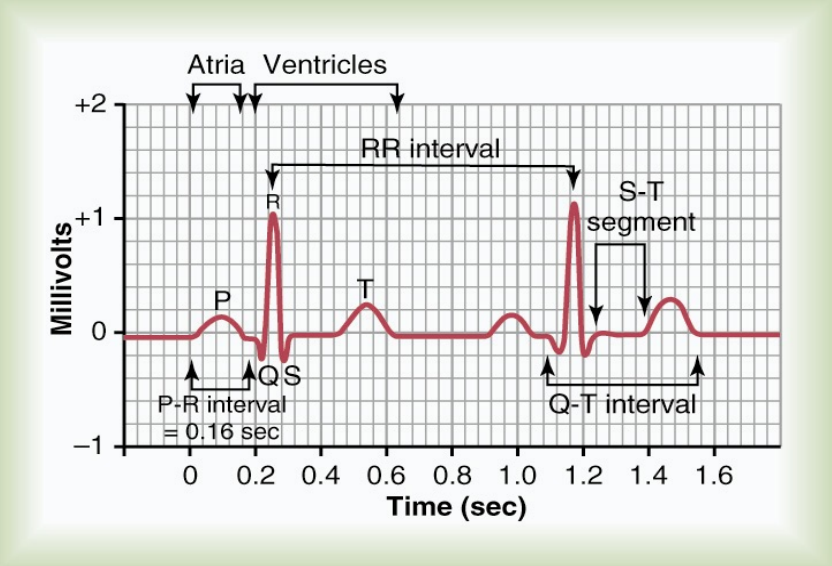


We put a heat sensitive squared paper under the pointer of the electrocardiograph, the squares in X axis are for time (sec) and in Y axis for voltage in (mv).

We have a hard line every 5 squares, and the speed of machine is 25 mm/sec, which means that there are 25 small squares every sec, so each square is 1/25 sec (0.04 sec).
And every big square is 0.2 sec

On the contrary, every 10 small squares in the Y axis are 1 mv.

From R to R, we have one cycle which is called an Interval (any Interval should have a wave in between)
The first interval (PR), in fact it is PQ, but Q doesn't show up most of the time. It's between the beginning of P to the beginning of R or Q, remember that P is the depolarization of the atria so it's an interval that gives you the time between the atrial depolarization and ventricular depolarization (the time of the conduction of the depolarization from the atria to the ventricles.
The second Interval (QRS) is between the beginning of Q to the end of S, the time taken for the depolarization of the ventricles.
The third Interval (QT) is between the beginning of Q to the end of T, it gives the time of ventricular depolarization and part of the ventricular repolarization.



What do we mean by segments?
It's an iso-electric line.
1. PR segment : between the end of P to the beginning of R.
2. ST segment : from the end of S to the beginning of T.
3. TP segment

We care about the time in the intervals (normal on abnormal), and in the segments we care abound deflection (depressed or elevated)

The deflection (depression or elevation) of segments is very important because it's a contradiction of ischemia ذبحة صدرية of the heart muscle (decreased blood flow) and this might end with infarction احتشاء في عضلة القلب (No blood flow).

How can we calculate the heart rate from ECG?
From R to R, it's one cardiac cycle → 20 small squares, each small square is 0.04 sec, so 0.04*20= 0.8 sec, so if each cardiac cycle is 0.8, how many cycles would we have in 1 min?
60/0.8 = 75 per min
The heart rate of this person if his cardiac cycle is 0.8 is 75 bpm -beats per min-

Take a break and read this note:)

We can call the ECG an EKG because the first people who invented the electrocardiogram were Germans, and in their language, cardiology is written "kardiologie", and Americans use EKG more than ECG because they want to keep the advantage for the Germans, so it's fine to call it EKG :)

BUT if the cycle is 15 small squares *0.04 then we have 0.6 sec. If each cycle is 0.6 sec, the heart will be 60/0.6=100 bpm

Note : the speed of machine is 25mm/sec, so if we have a 25 small squares cycle, the cycle will be 25*0.04=1 sec.
60/1=60 bpm

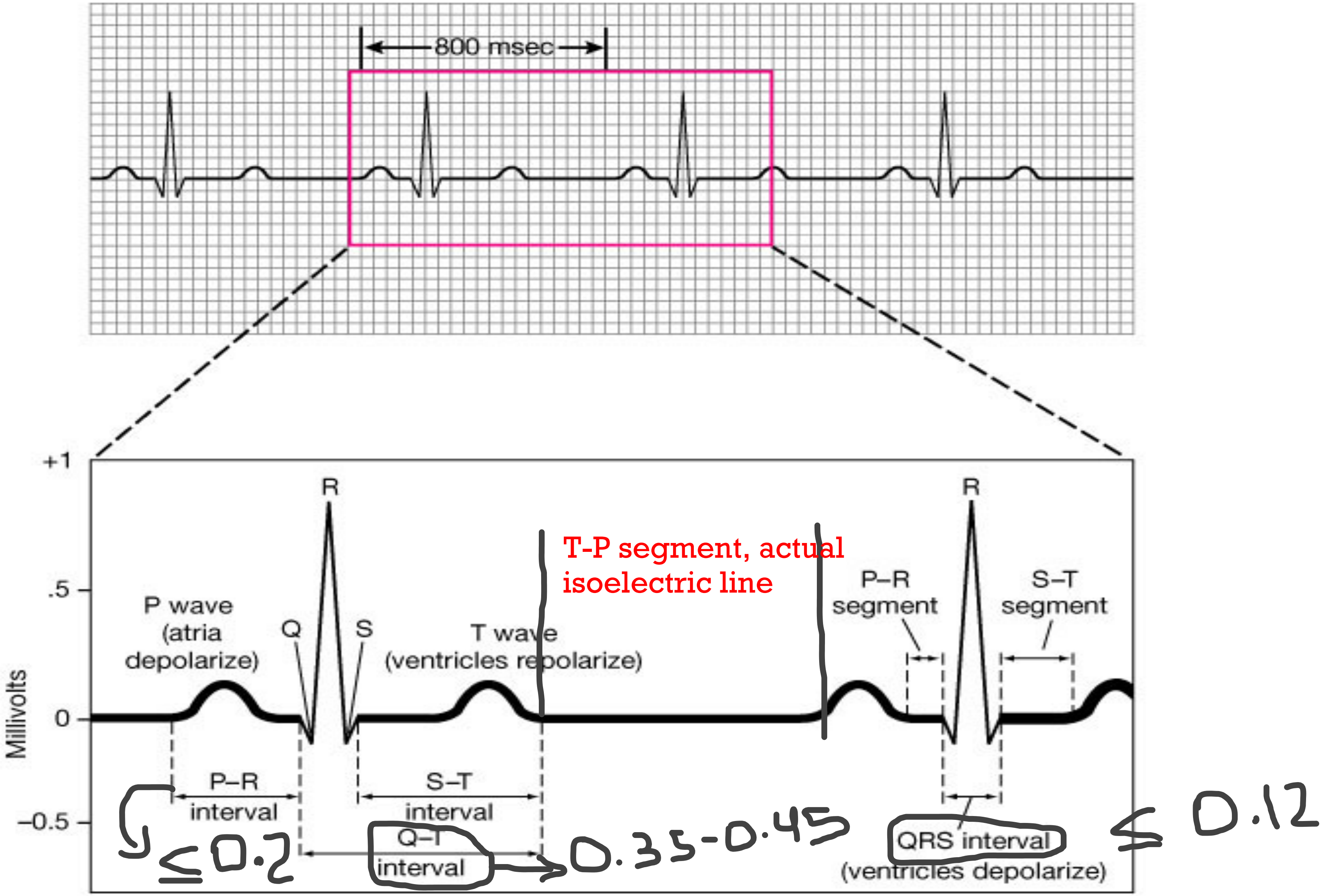
As you see from these 3 examples, whenever the cardiac cycle time is increasing, the heart rate is decreasing and vice versa, so the heart rate is inversely proportional to the time of the cardiac cycle.

For teaching purposes, we can say that the cardiac cycle is 0.8 sec and in this case the heart rate is 75 bpm, but in reality, the normal heart rate is 60-100 bpm

Electrocardiogram

- Record of electrical events in the myocardium that can be correlated with mechanical events و This means that to have a mechanical change we must have first electrical change.
- **P wave**: depolarization of atrial myocardium(electrical).
  - Signals onset of atrial contraction(atrial systole, mechanical)
- **QRS complex**: ventricular depolarization
  - Signals onset of ventricular contraction(ventricular systole)
- **T wave**: repolarization of ventricles
- **PR interval** or PQ interval: 0.16 sec
  - Extends from start of atrial depolarization to start of ventricular depolarization (QRS complex) contract and begin to relax
  - Can indicate damage to conducting pathway or AV node if greater than 0.20 sec (200 msec), so the normal range of PR interval is lower than or equals to 0.2 sec, if it is more than 0.2 there must be a damage somewhere.
- **Q-T interval**: time required for ventricles to undergo a single cycle of depolarization and repolarization, and it usually equals half the time of cardiac cycle.
  - Can be lengthened by electrolyte disturbances, conduction problems, coronary ischemia, myocardial damage

Electrocardiogram



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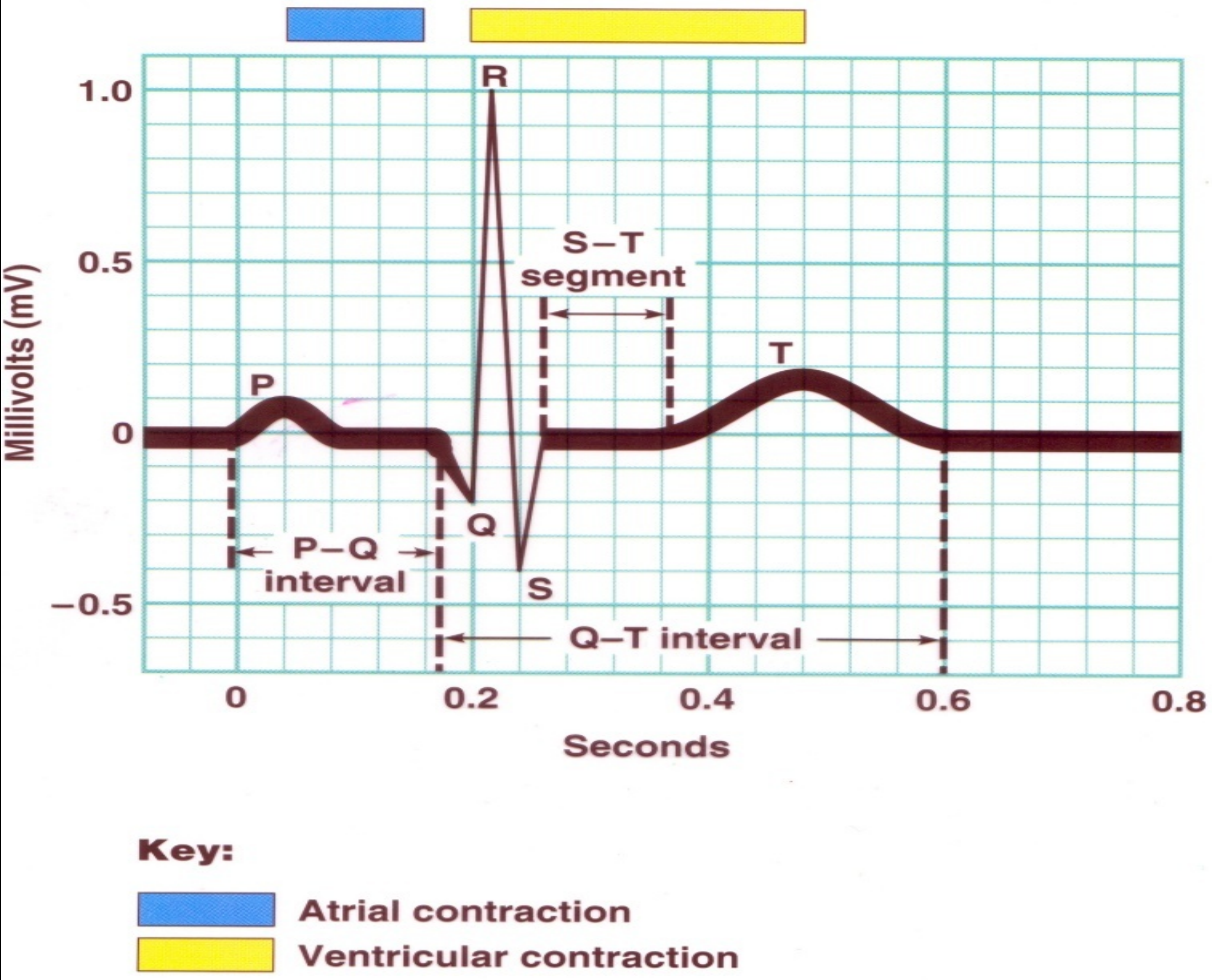
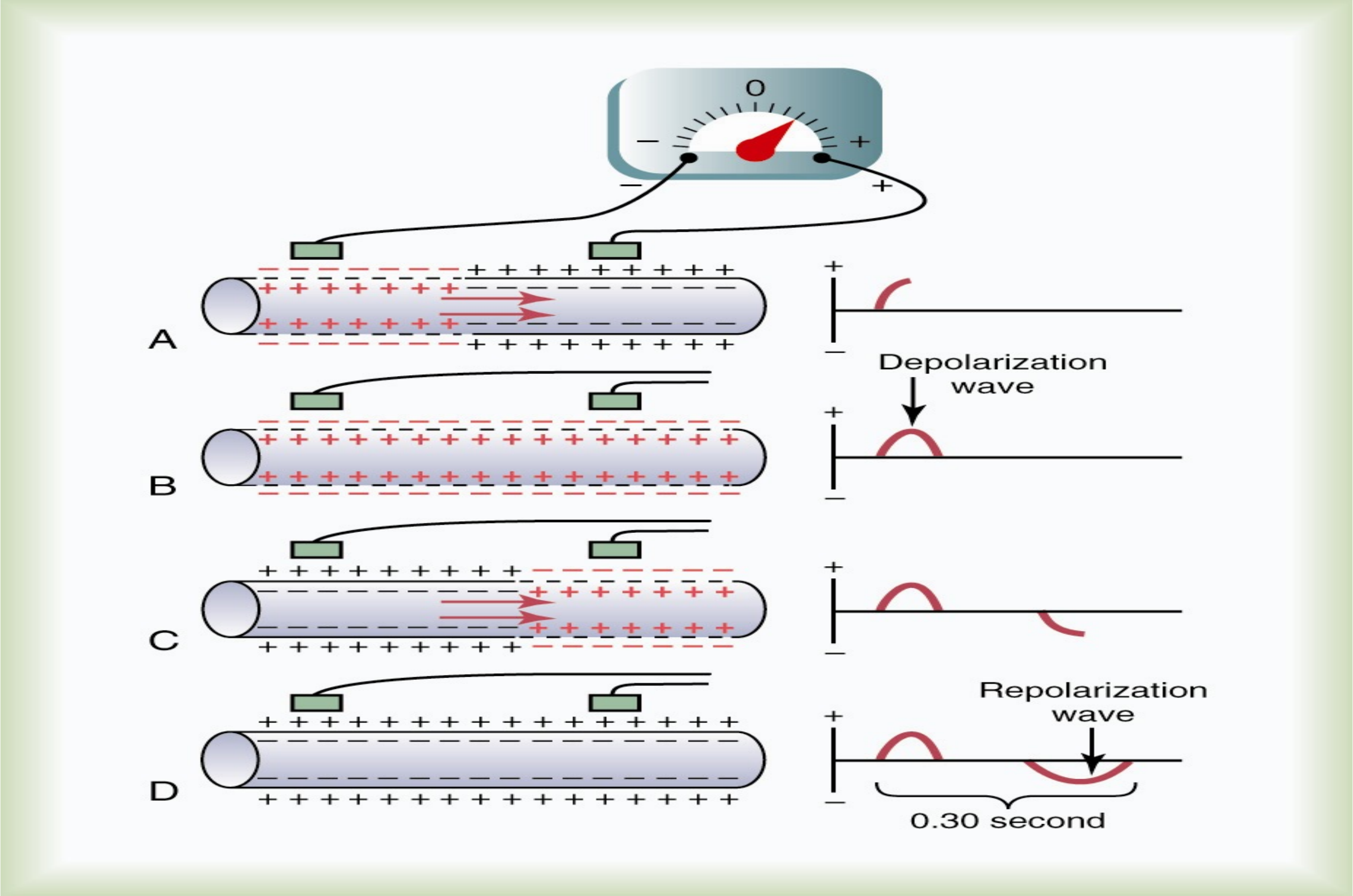


Notice that P-Q intervals refers to atrial depolarization,
and this interval is relatively long, why? Because we have a delay in the conduction between the atria and ventricles because of the AV node, to make sure that the atria contracts first and then ventricles, so normally they don't contract together, but we can have atrial and ventricular diastole together.

Depolarization and Repolarization Waves



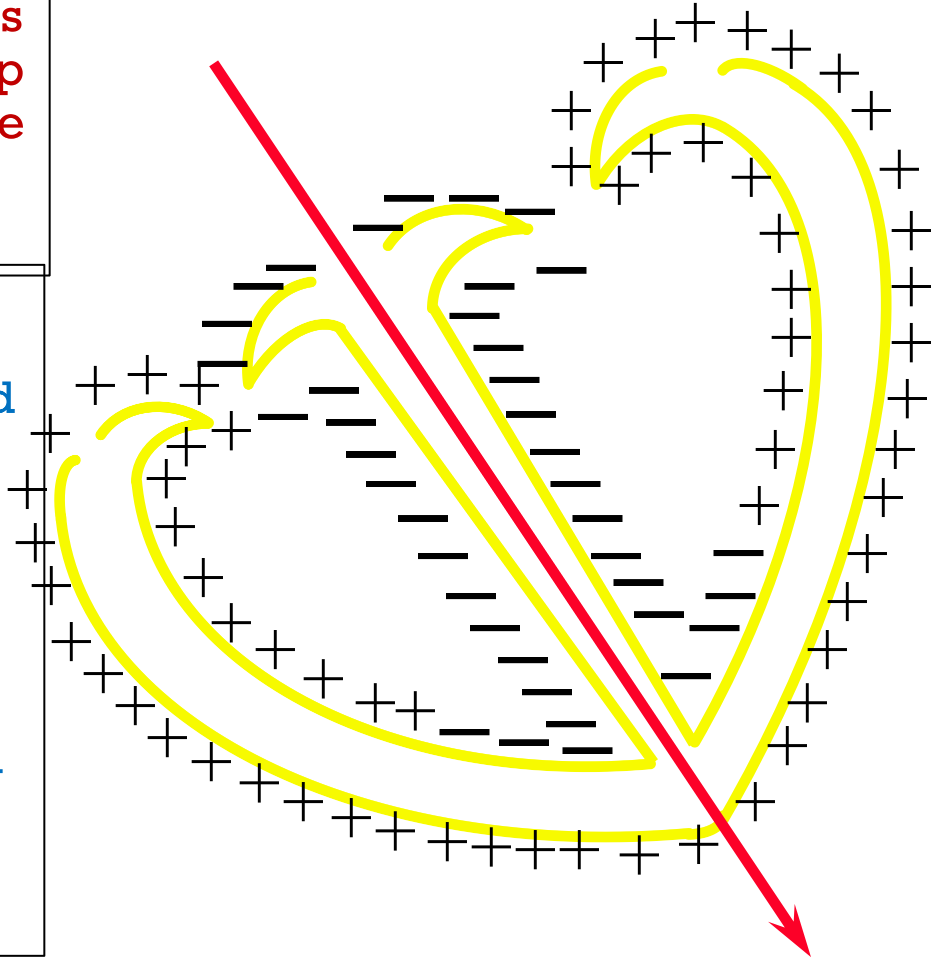
- Note that no potential (isoelectric line) is recorded when the ventricular muscle is either completely depolarized or repolarized.

Flow of Electrical Currents in the Chest Around the Heart

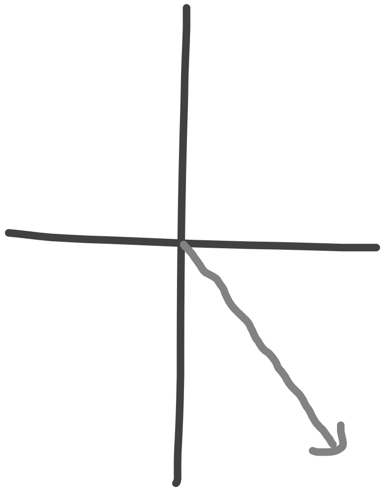
Mean Vector Through the Partially Depolarized Heart

1-The depolarization will start from the ventricular septum, and continues to both ventricles at the same time because of gap junctions, so the charges will be reversed (positive inside, negative outside)

2- We will have a vector due to the flow of currents, from the depolarized area to the polarized area. We have many vectors in many directions , so we must record a mean vector, and this mean vector is instantaneous, meaning that it depends on the instant you measure it. Remember, when depolarization occurs, we are going to record the QRS wave, and this denotes **mean electrical vector** on certain plane.



3-Regarding the direction of depolarization (vector), it is from right to left and anterior, in other words, it is directed downward to the left.



Flow of Electrical Currents in the Chest Around the Heart (cont'd)

- Ventricular depolarization starts at the ventricular septum and the endocardial surfaces of the heart, so the wave of depolarization is from the endocardium toward the epicardium.
- The average current flows positively from the base of the heart to the apex.
- At the very end of depolarization the current reverses from 1/100 second and flows toward the outer walls of the ventricles near the base (S wave)

- (to understand this piece of information you must remember that the depolarization wave comes from the atrium toward the ventricular septum, the depolarization of the septum is represented by the letter Q, and its direction is to the right, that's why Q is a downward deflection, then the depolarization wave will reach the ventricles, which will is referred to as R, its depolarization wave is is downward and to the left, so it is an upward deflection, then the depolarization wave will reach the base of left ventricle, this wave is referred to as S, and this depolarization wave's direction is upward and to the right, so it's downward deflection.) **the info written in green in this slide is for better understanding, not said by the doctor.**

EKG Concepts

- The P wave immediately precedes atrial contraction.
- The QRS complex immediately precedes ventricular contraction.
- The ventricles remain contracted until a few milliseconds after the end of the T repolarization wave.
- The atria remain contracted until the atria are repolarized, but an atrial repolarization wave cannot be seen on the electrocardiogram because it is masked by the QRS wave.

EKG Concepts (cont'd)

- The P-Q or P-R interval on the electrocardiogram has a normal value of 0.16 seconds and is the duration of time between the beginning of the P wave and the beginning of the QRS wave; this represents the time between the beginning of atrial contraction and the beginning of ventricular contraction.

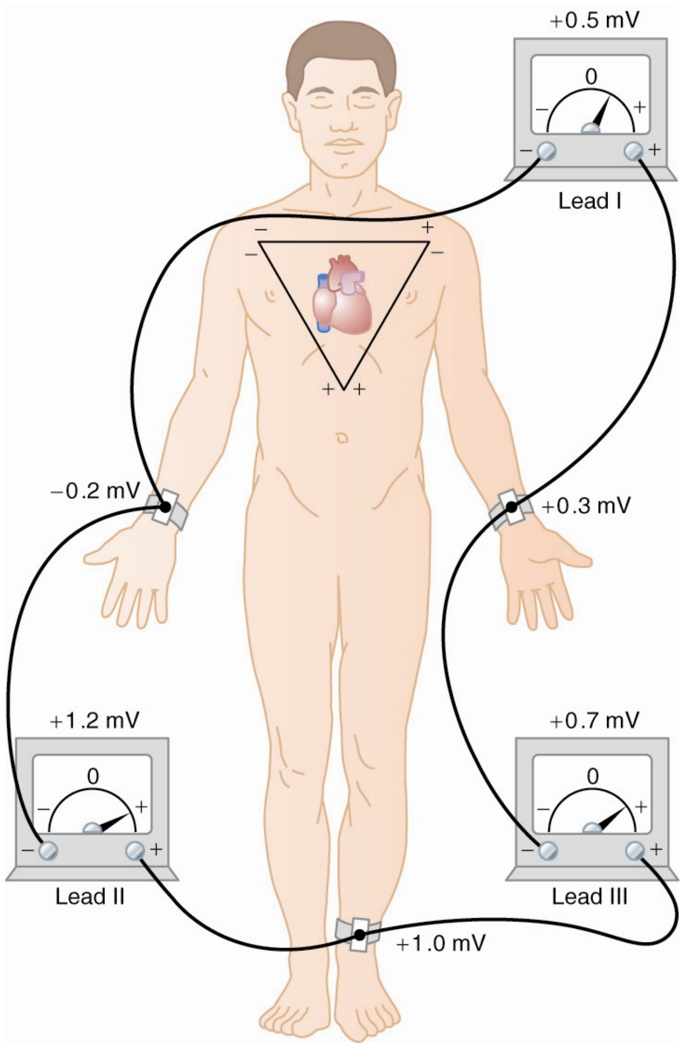
EKG Concepts (cont'd)

- The Q-T interval has a normal value of 0.35 seconds and is the duration of time from the beginning of the Q wave to the end of the T wave; this approximates the time of ventricular contraction, remember, Q-T interval is half of the cardiac cycle.
- The heart rate can be determined with the reciprocal of the time interval between each heartbeat, and the heart rate is inversely proportional to the time of heartbeat.

Bipolar Limb Leads

- Bipolar means that the EKG is recorded from two electrodes on the body.

Focus on the figure, you will notice that we have an electrocardiogram with 2 electrodes, depending on where we put those electrodes, we will have different leads, **lead1 is between right arm(negative electrode) & left arm(positive electrode)**, **lead2 is between right arm(negative electrode) & left leg(positive electrode)**, **lead3 is between left arm(negative electrode) & left leg(positive electrode),** but why do we put them like that? To make sure that the potential difference is positive depending on the movement of the vector(downward to the left).



Bipolar Limb Leads (cont'd)

- Lead I - The negative terminal of the electrocardiogram is connected to the right arm, and the positive terminal is connected to the left arm.
- Lead II - The negative terminal of the electrocardiogram is connected to the right arm, and the positive terminal is connected to the left leg.

Bipolar Limb Leads (cont'd)

- Lead III - The negative terminal of the electrocardiogram is connected to the left arm, and the positive terminal is connected to the left leg.
- Einthoven's Law states that 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
- Kirchoff's second law of electrical circuits
  LI+LII+LIII=0

Einthoven's triangle