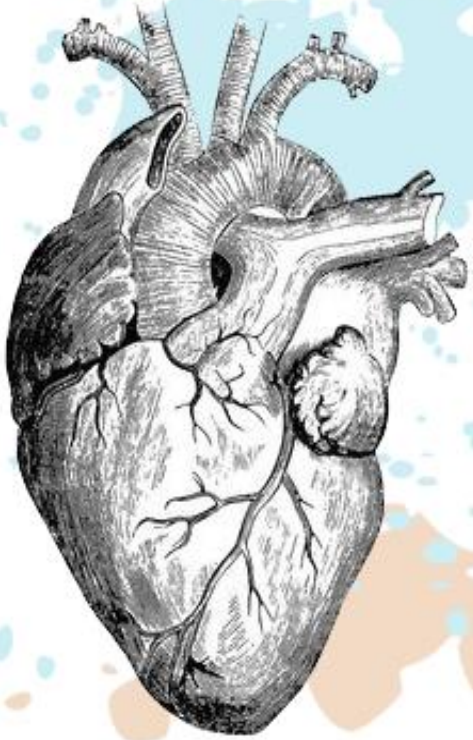


Very important

Extra information

Physiology

OF THE CARDIOVASCULAR SYSTEM

* Guyton corners, anything that is colored with grey is EXTRA explanation

Electrocardiogram (ECG)

Objectives :

- Enumerate uses of ECG.
- Explain basic ECG principles.
- Describe ECG leads and their application.
- Recognize ECG waves, intervals and segments.
- Determine rate and normal heart rhythm.
- Have some idea about ECG abnormalities in common clinical conditions.

Contact us : Physiology435@gmail.com

Uses of ECG

- **Definition:**

- ECG is a graphical representation of the sum of all the electrical activities of the heart usually recorded from the body surface.
- It can help the doctor to see if you have a heart muscle damage or any electrical problems in the heart.

Types of information we can obtain from an ECG:

- Heart rate.
- Heart rhythm. (Regular - Single p-wave precedes every QRS complex - P-R interval is constant and within normal range)
- Myopathies.
- Helps in the diagnosis of chest pain.
- Proper use of thrombolysis in treatment of MI* depend upon it.
- Electrolyte disturbance (i.e. hyperkalemia, hypokalemia)
- Drug toxicity (I.e. digoxin and drugs the prolong the QT interval)

*MI : Myocardial Infarction

ECG principle

The normal ECG:

The depolarization wave spreads through the heart → electrical current passes into the surrounding tissue → part of the current reaches the surface of the body.

The electrical potentials generated by these currents can be recorded from **electrodes** placed on the skin opposing the heart.

- A complete depolarized heart muscle → no wave deflection.
- A complete repolarized heart muscle → no wave deflection.
- During repolarization or depolarization → there will be a wave.

* Because of the potential difference.

ECG principle

- Methods for recording ECG :

1

Computer-based and electronic display

2

Pen recorder and a moving sheet

PHYSIOLOGY TEAM 435

ECG principle

Two electrodes needed:

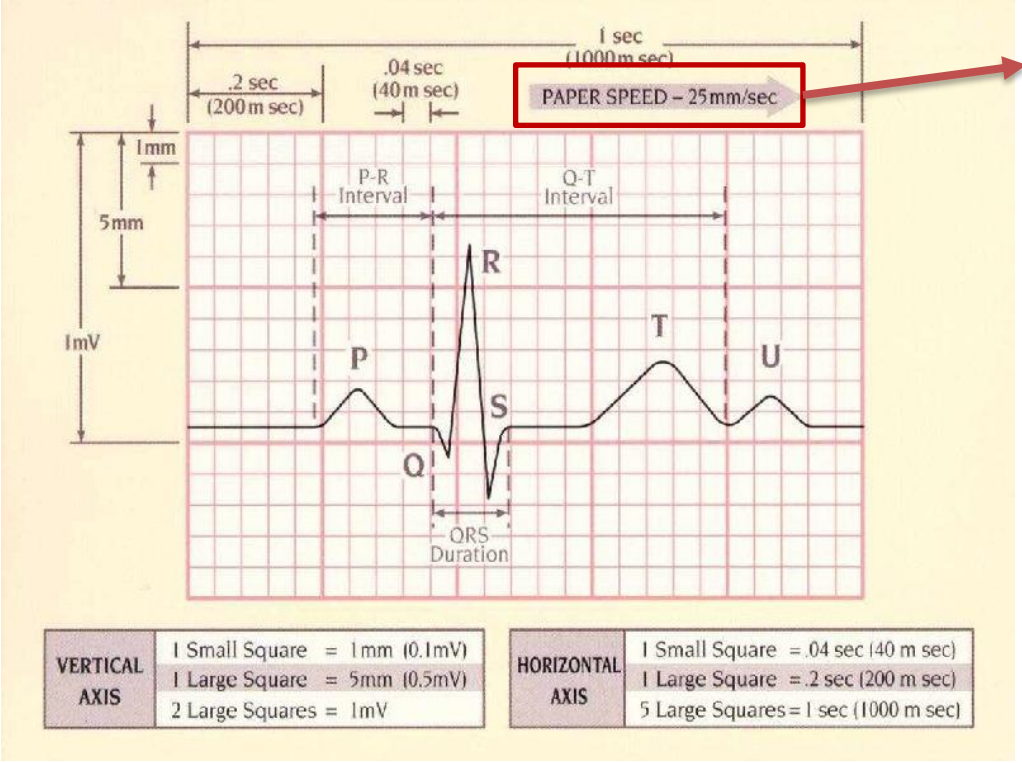
1- **Positive electrode** (mostly it is the active one and records the electrical activity).

2- **Negative electrode** (it closes the circle).

Effects of electrodes one the wave:

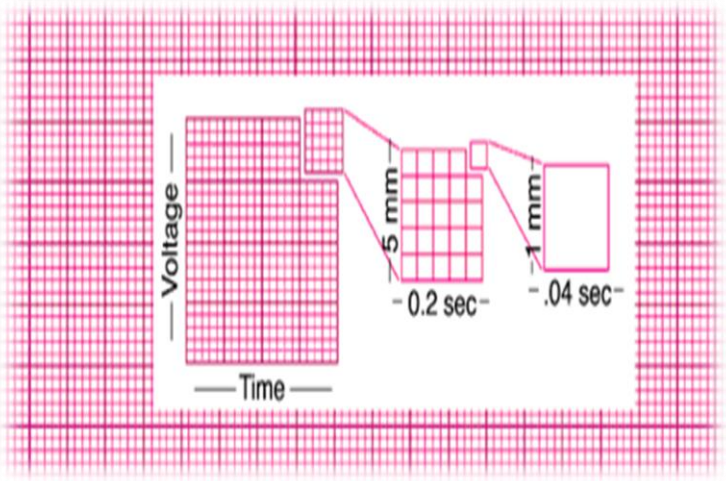
- If the **depolarizing signal** from the heart is going **towards** the active electrode(+ve) it will make an **upward wave.**
- If the **repolarizing signal** from the heart is going **towards** the active electrode(+ve) it will make a **downward wave.**
- If the **depolarizing signal** from the heart is going **away** from the active electrode(+ve) it will make a **downward wave.**
- If the **repolarizing signal** from the heart is going **away** from the active electrode(+ve) it will make an **upward wave.**

The ECG paper



VERTICAL AXIS	1 Small Square = 1mm (0.1mV)	HORIZONTAL AXIS	1 Small Square = .04 sec (40 m sec)
	1 Large Square = 5mm (0.5mV)		1 Large Square = .2 sec (200 m sec)
	2 Large Squares = 1mV		5 Large Squares = 1 sec (1000 m sec)

Note: it's important to know the paper's speed for example in this paper it's: **25mm/sec** if it became **50mm/sec** we have to double all the other measurements.



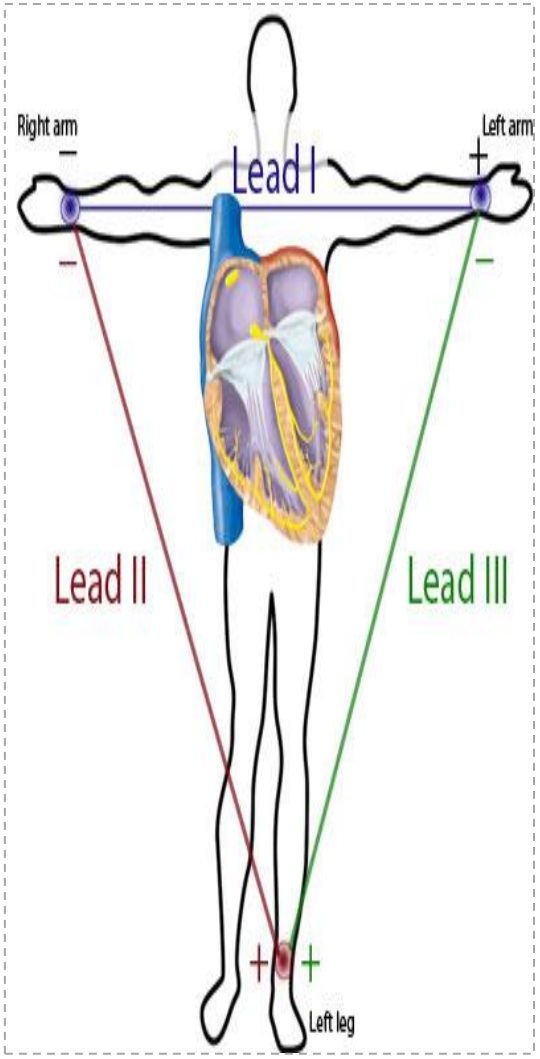
- **The vertical calibration lines: Voltage(millivolt)**
  10 small lines = **1** mV
- **The horizontal calibration lines:Time (seconds)**
  - 1 inch(25 small lines) = **1** second
  - Each inch is divided by **5** dark vertical lines
  - The interval between the dark lines= **0.2** second
  - thin line=**0.04** second

Einthoven's law & Triangle

Enthoven's Law:

- It states that if the electrical potential of any two of the three bipolar limb leads are known, the third one can be determined mathematically by summing the first two. **(note the +ve and -ve signs).**

- The sum of voltages in **Lead I** and **Lead III** is equal to the voltage in **Lead II**.



Enthoven's Triangle:

- drawn around the area of the heart

- The two apices at the upper part of the triangle represent the points at which the two arms connect electrically

- The lower apex is the point at which the left leg connects

ECG Leads

Leads are electrodes which measures the difference in electrical potential between either:

- Two exploring **(active)** electrodes attached to the surface of body, so it means the ECG is recorded from two electrodes. **(Bipolar leads)**
- One point on the body (exploring) and a virtual reference point (indifferent) electrode with zero electrical potential. **(Unipolar leads)**

The standard ECG has **12** leads :

- **3** standard limb leads **(Bipolar)**
- **3** Augmented limb leads **(Unipolar)**
- **6** Precordial (chest) leads **(Unipolar)**

	Limb leads	**Precordial leads**
Bipolar	I, II, III (Standard limb leads)	-
Unipolar (V leads)	aVR, aVL, aVF (Augmented limb leads)	V_1-V_6

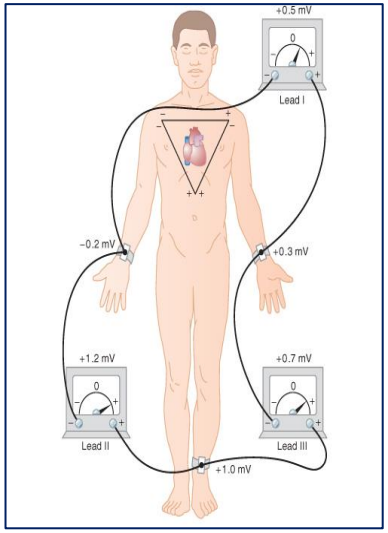
- The axis of particular lead represents the viewpoint from which it looks at the heart. That's why we need 12 leads for ECG so we can observe the heart functions from different angles.

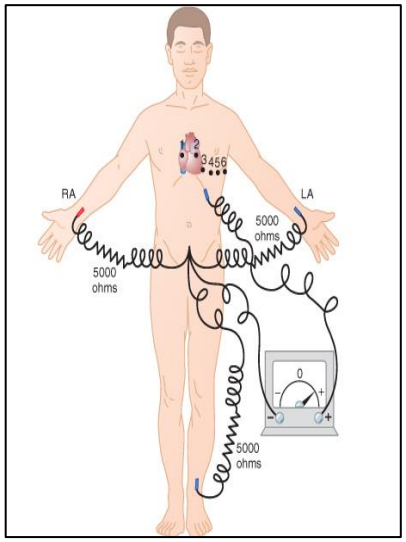
ECG leads

Bipolar limb leads:

"ECG is recorded by 2 electrodes"

Lead I: Right arm (-ve) **&** Left arm (+ve)
Lead II: right arm (-ve) **&** Left leg (+ve)
Lead III: Left arm (-ve) **&** Left leg (+ve)





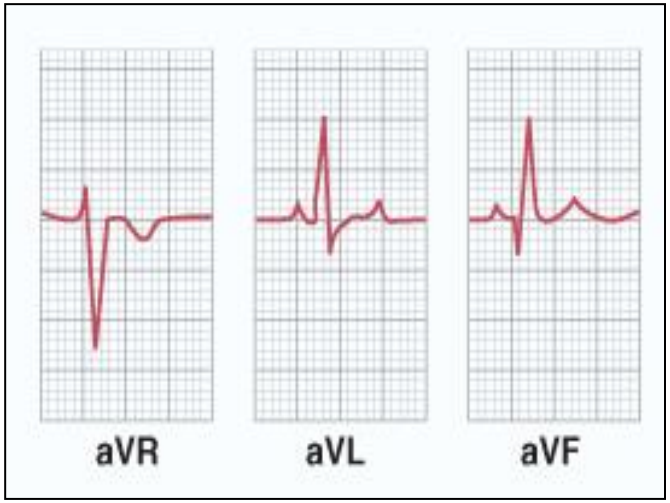
Augmented unipolar limb leads:

The two limbs are connected to the negative terminal of the ECG, and the third limb is connected to the positive.

- **aVR:** Attached to the Right arm.

[it's inverted because the current flow is in the opposite direction of the heart's potential].

- **aVL:** Attached to the Left arm.
- **aVF:** Attached to the Left leg.

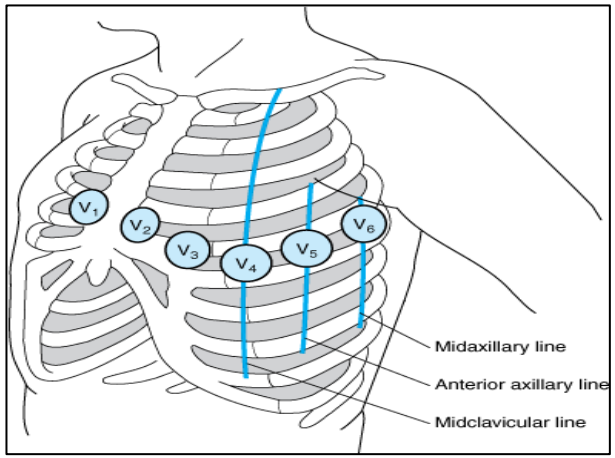


Chest leads

Recorded from the anterior surface of the chest :

Lead placement:

- **V1:** 4th intercostal space right sternum.
- **V2:** 4th intercostal space left sternum.
- **V3:** midway between **V2** and **V4.**
- **V4**: 5th intercostal space on the *midclavicular line*.
- **V5:** between **V4** and **V6** on the anterior axillary line.
- **V6:** on the *midaxillary line* lateral to **V4** and **V5**.

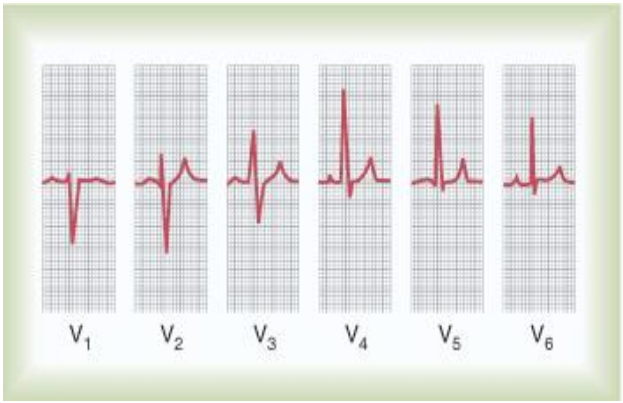


V1 and V2:

the QRS complex is mainly negative, because the chest leads are nearer to the base of the heart.

V3, V4, V5, and V6:

the QRS complex is mainly positive, because the chest leads are nearer to the apex of the heart.



ECG waveforms

- **P wave:** Atrial depolarization.

- **PR interval:** Impulse from atria to ventricles and AV nodal delay, shortens as heart rate increases.

Duration: 0.12-0.2 (average: 0.18)

- **QRS complex:** Ventricular depolarization. (By purkinje fibers)

Duration: 0.08-0.1

- **ST segment:** Isoelectric and shows the period between ventricular depolarization and repolarization.(Plateau portion)

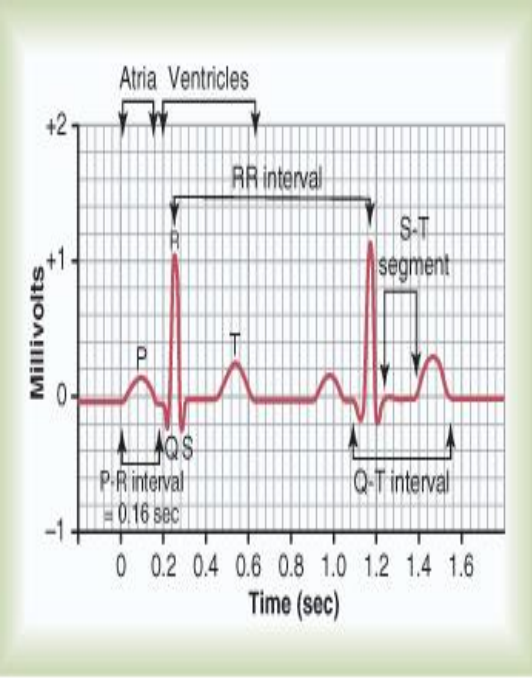
Duration: 0.32

- **T wave:**

Ventricular repolarization (usually in the same direction as QRS).

- **QT interval:** It spans the onset of depolarization to the completion of repolarization of the ventricles.

Duration: 0.4-0.43. (can be lower depending on heart rate).

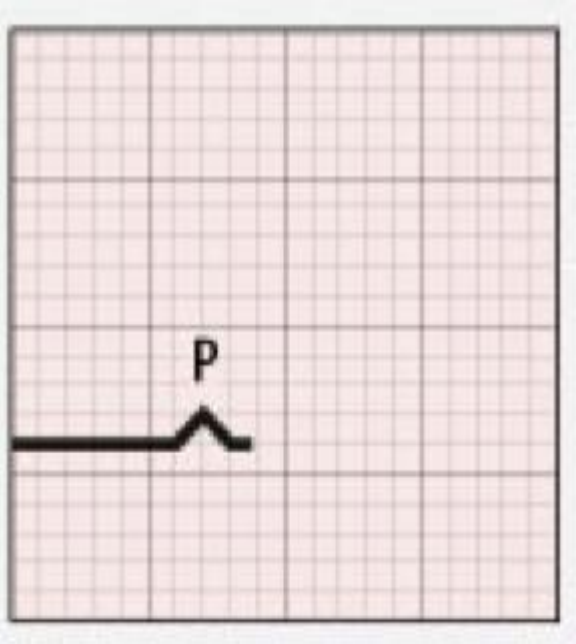


Note: The repolarization wave of of the atrium is hidden in the QRS complex, but it may appear in some diseases.

Parts of ECG

The P Wave :

- Atrial depolarization generates a *'P wave'* on the ECG
- After that the impulse travels to the AV node.
- Note the AV node famous for keeping the impulse for a little while and this called the AV nodal delay causing no depolarization or Repolarization so it makes an *isometric line.*



Parts of ECG

QRS complex :

After the impulse goes to bundle of His and after that goes to bundle branch, *the first part which depolarize in the ventricle is the septum* and the depolarization comes from the left bundle branch so that means that the direction of the depolarization is away from active electrode so it make a negative wave called the **Q wave**

The T wave :

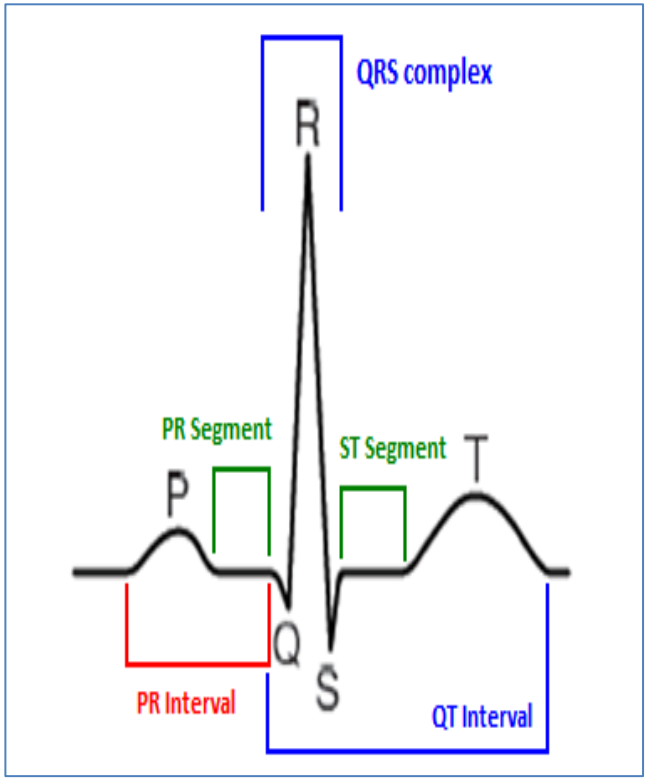
It is a Repolarization of the ventricles it happens from outside to inside that means it is away from the active electrode it will make a positive wave

Parts of ECG

P-R interval

It is the time between the beginning of the *P wave* and the beginning of the *QRS complex*.

- It is the interval between the beginning of electrical excitation of the atria and the beginning of excitation of the ventricles
- The P-R interval is about 0.16 second

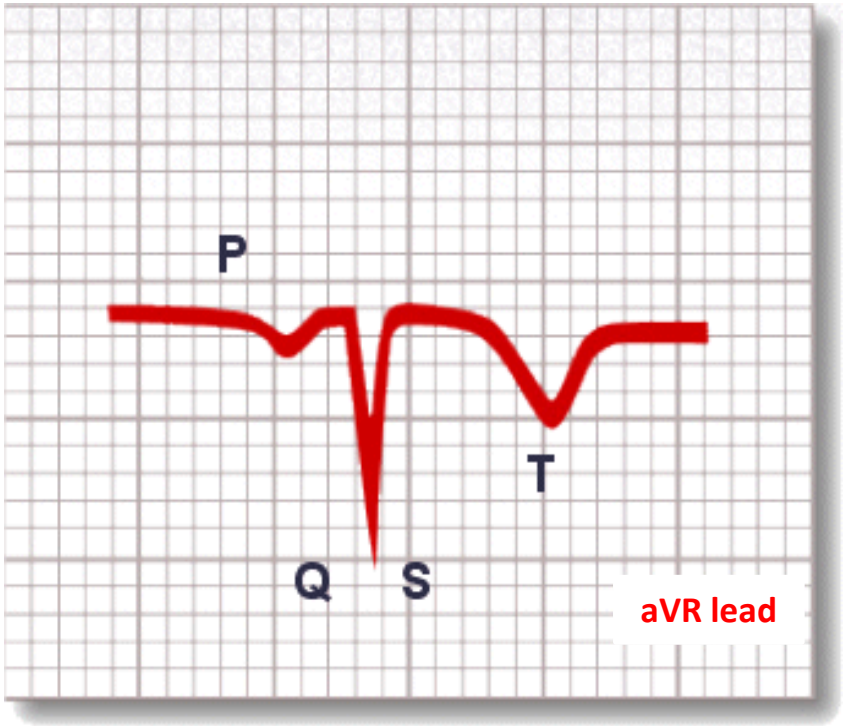


Q-T interval

- Contraction of the ventricles last from the beginning of the Q wave to the end of the T wave
- Q-T interval is the time from the beginning of the Q
- wave to the end of the T wave.
- Q-T interval is about 0.35 second

Cardiac Vectors

- A vector is an arrow that points in the direction of the electrical potential generated by the current flow, with the arrowhead in the positive direction
- The length of the arrow is proportional to the voltage of the potential.



If the voltage of the lead is down it means the direction of flow towards that lead is negative like aVR .

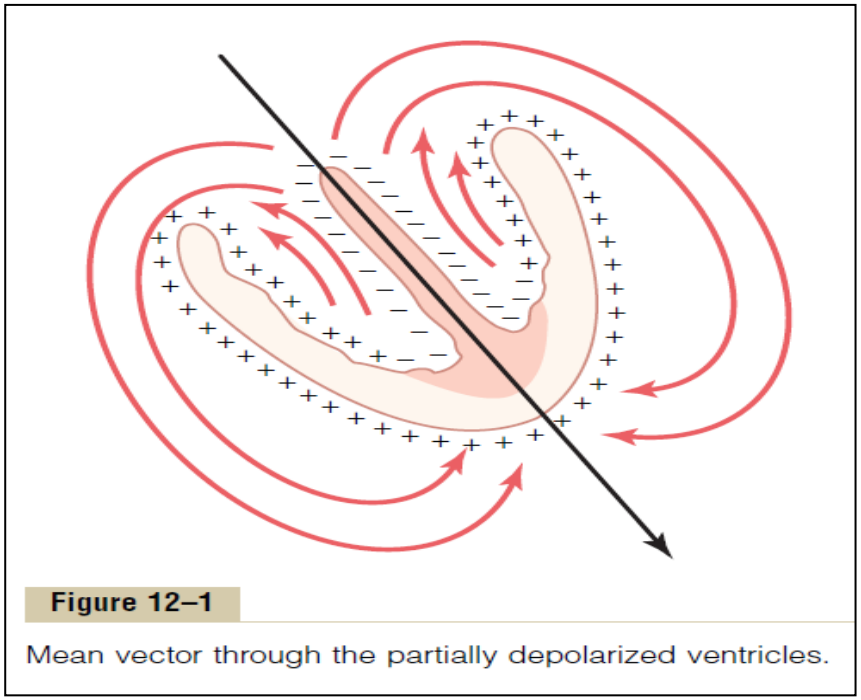


Figure 12–1

Mean vector through the partially depolarized ventricles.

- **Depolarization from the base to the apex of the heart**
- The length of the arrow depends on the amount of current and this happened when the deflection is high on ECG, so if there is a higher deflection in the lead it indicate more current flows in the direction of this lead.

REPOLARIZATION OF THE ATRIA

- In a normal ECG, the T wave of atrial repolarization appears at about *the same time that the QRS complex of the ventricles appears.* Therefore, it is almost always totally obscured by the large ventricular QRS complex.

Doctor Shahid's explanation

- The (T wave) of atrial repolarization is hidden behind the QRS complex. The flow of the current in repolarization is the same of depolarization direction of current but the charge is different.

Atria= Depolarization= +ve in
Repolarization= +ve out

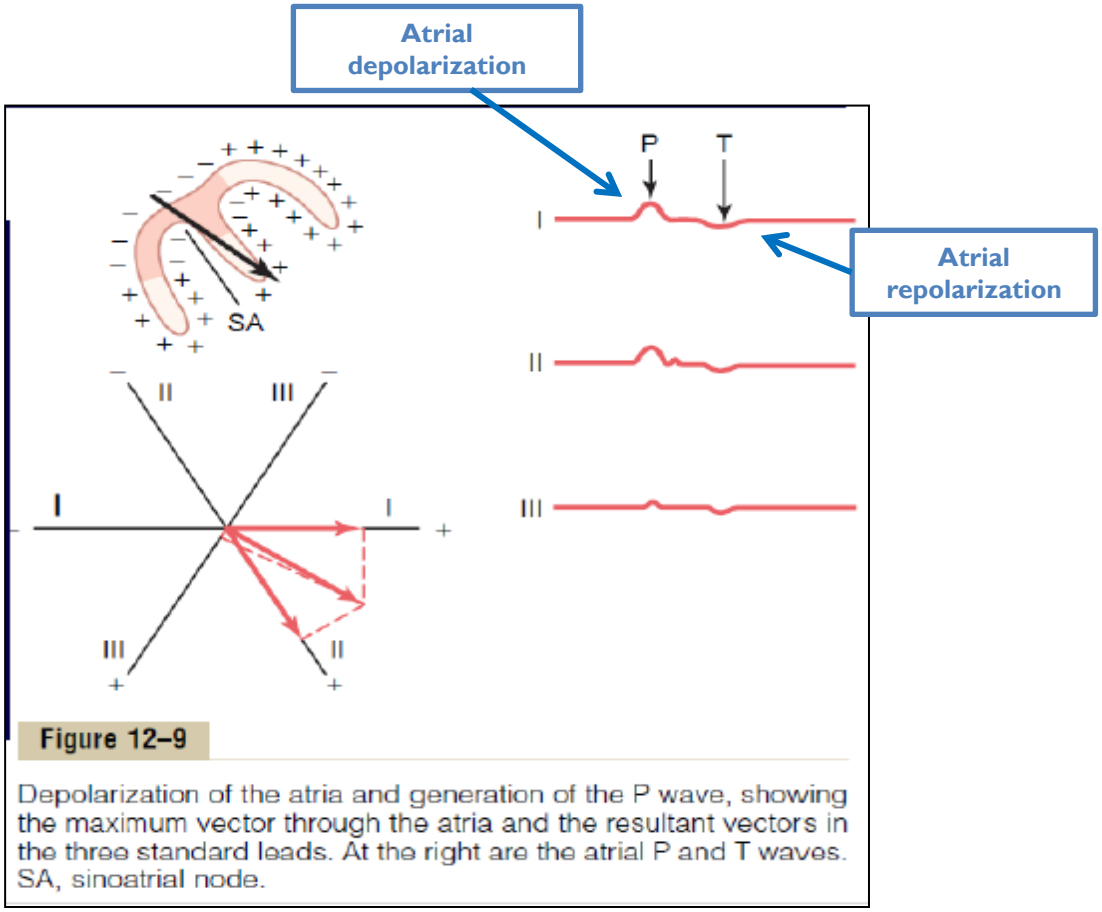


Figure 12–9

Depolarization of the atria and generation of the P wave, showing the maximum vector through the atria and the resultant vectors in the three standard leads. At the right are the atrial P and T waves. SA, sinoatrial node.

DEPOLARIZATION OF THE VENTRICLES

Before going to the next slide please understand this:

- In the left ventricle the net flow of the current is from the base to the apex (same in atria).
- The vector at the beginning is slightly negative which represent the Q wave (slight – ve deflection) and then becomes positive which represent the R wave (prominent + ve deflection)and finally goes negatively by representing the S wave(- ve deflection). Together QRS complex makes ventricular depolarization.

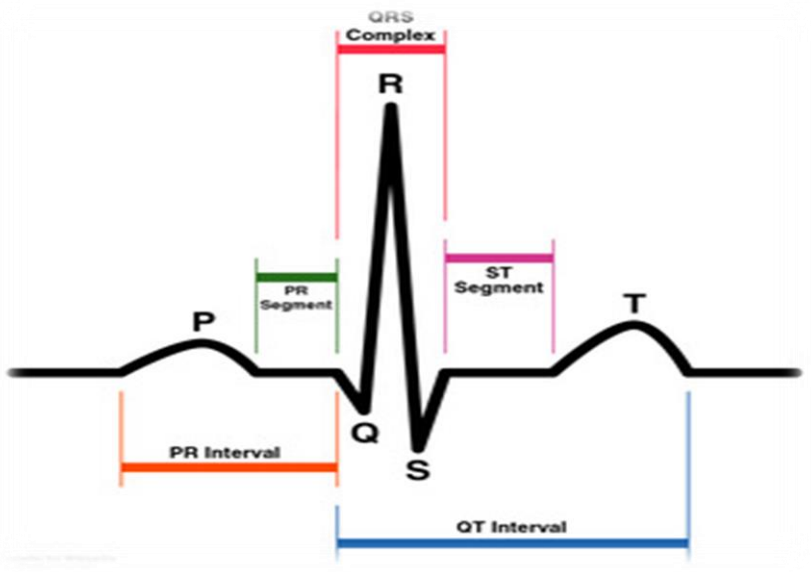
Doctor's Shahid explanation

Q wave : normally it is not present in ECG or it will appear in range of less than 0.04 sec in lead, but when it is prominent, it is abnormal.

Q wave :indicate the initial depolarization of the left side of the septum and this what makes the slight negative deflection.

S wave: caused by the change of the direction of the vector at the end of depolarization

S wave : it is the depolarization of the most lateral side of the left ventricle.



*More in the next slide

DEPOLARIZATION OF THE VENTRICLES

- 1.In normal ventricles, current flows from negative to positive, from the base of the heart toward the apex The first area that depolarizes is the ventricular septum
- 2.When the cardiac impulse enters the ventricles through the atrioventricular bundle, the first part of the ventricles to become depolarized is the left endocardial surface of the septum.
- 3.It spreads through the ventricular muscle to the outside of the heart *(current flows from the electronegative inner surface of the heart to the electropositive outer surface)*

- Q wave is caused by initial depolarization of the left side of the septum before the right side, which creates a weak vector from left to right for a fraction of a second before the usual base-to-apex vector occurs.

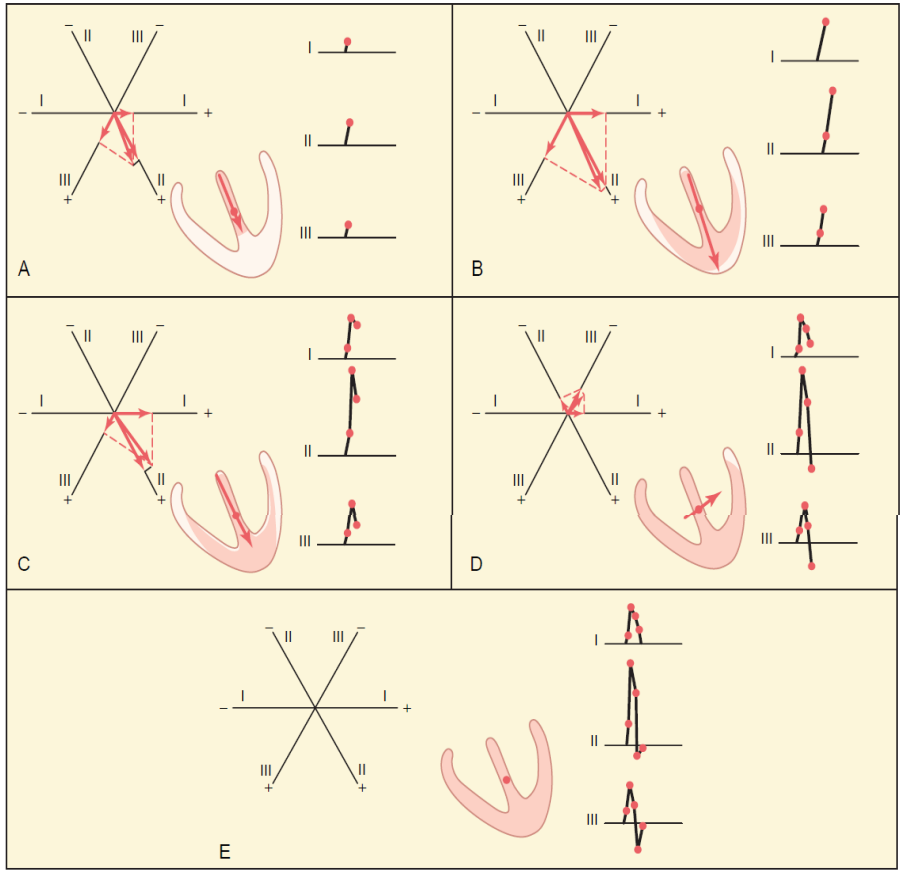


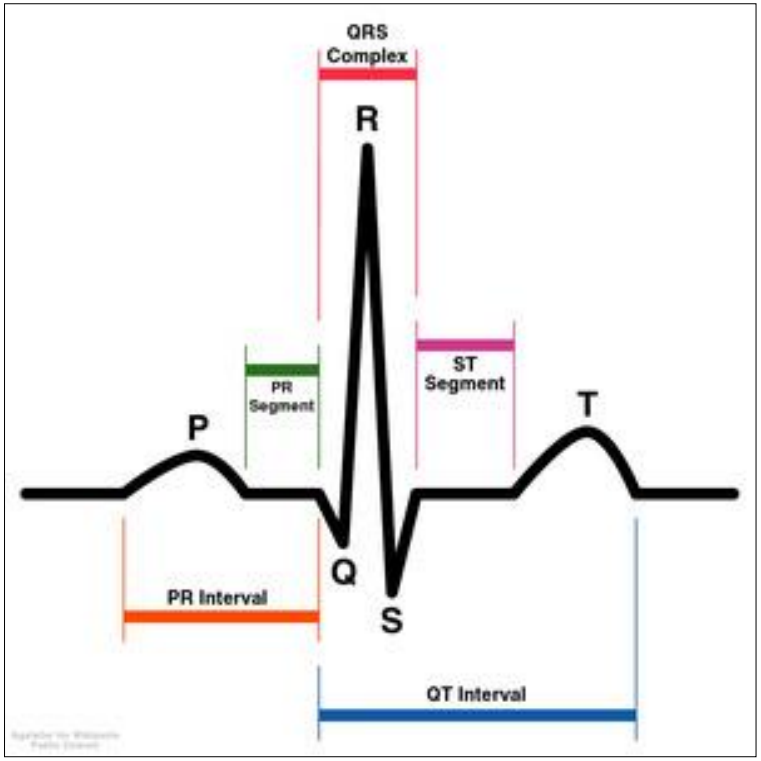
Figure 12–7

Shaded areas of the ventricles are depolarized (–); nonshaded areas are still polarized (+). The ventricular vectors and QRS complexes 0.01 second after onset of ventricular depolarization *(A);* 0.02 second after onset of depolarization *(B);* 0.035 second after onset of depolarization *(C);* 0.05 second after onset of depolarization *(D);* and after depolarization of the ventricles is complete, 0.06 second after onset *(E).*

Shaded(مظللة) areas of the ventricles are depolarized (−); nonshaded areas are still polarized (+). The ventricular vectors and QRS complexes onset of ventricular depolarization

Repolarization of the ventricle

- The T wave is the Repolarization of the ventricles which happens from outside(outer surface of the heart) to inside(inner surface of the heart) that means it is away from the active electrode and it will make a positive wave.



Doctor's Shahid explanation
In case of the ventricle repolarization , the repolarization start from the epicardium (outer surface) to the endocardium (inner surface) therefore it goes away from the electrode and therefore it gets its positive deflection on the ECG recording which is not the same on atrial repolarization.

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Summary

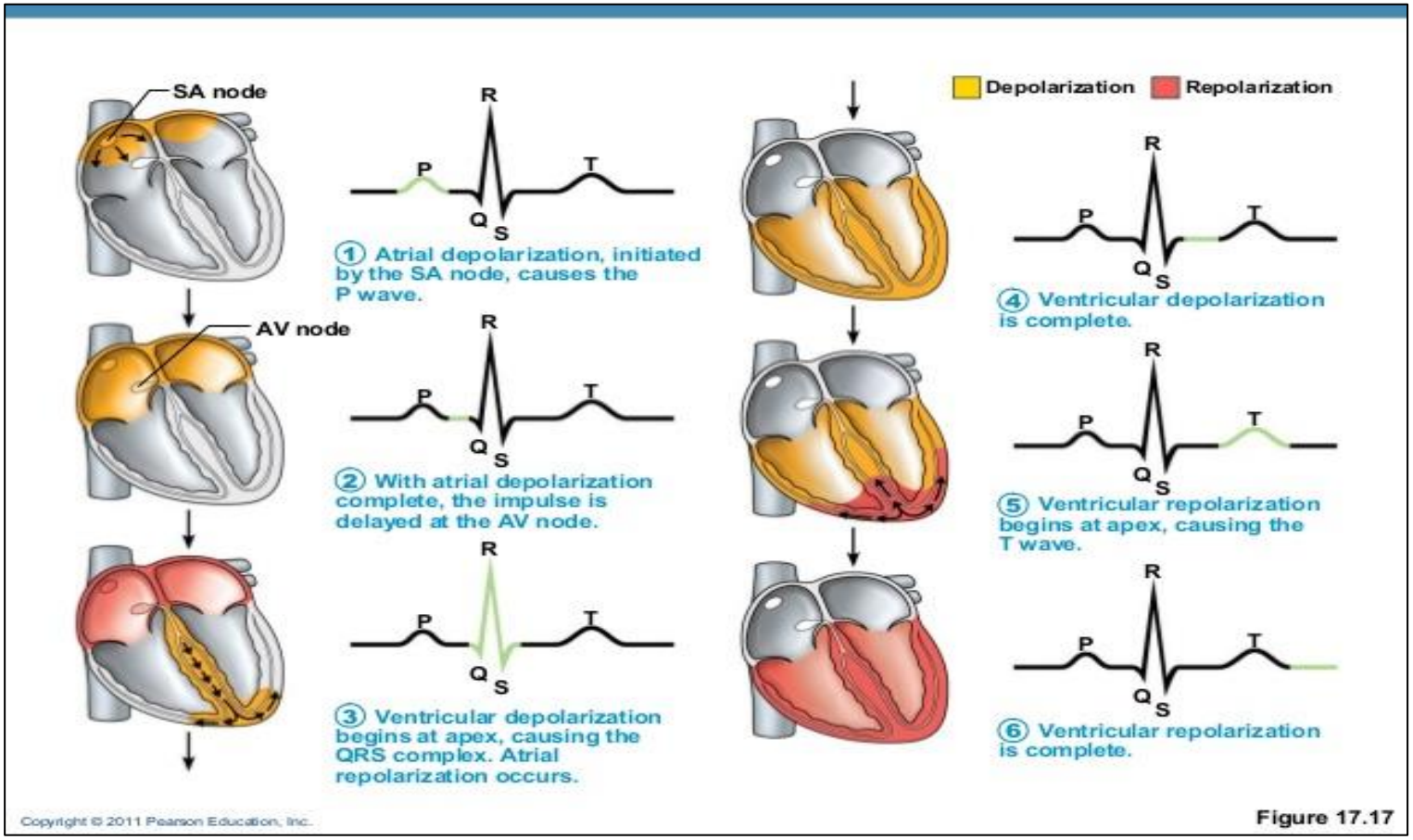


Figure 17.17

Cardiac Vectors

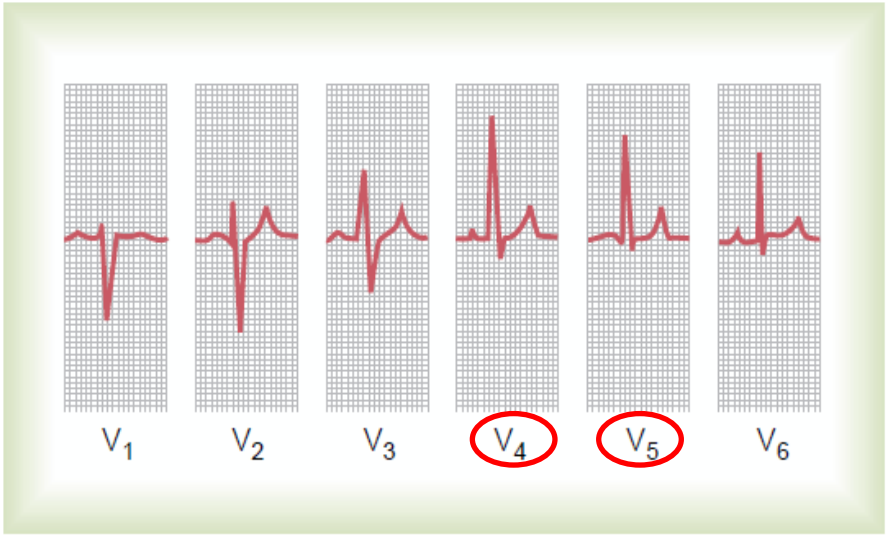


Figure 11–9

Normal electrocardiograms recorded from the six standard chest leads.

Doctor's Shahid explanation

Why the maximum deflection is in V4 and V5?

Because the net current flow toward the V4,V5 is at the maximum stage and it is known as :

(normal progression of R wave).

Girls slides

V1 and V2: QRS are mainly negative because the chest leads are nearer to the base of the heart.

V3,V4 and V6 are mainly positive because the chest electrode are nearer to the apex.

HEXA AXIAL Diagram

Doctor's Shahid explanation

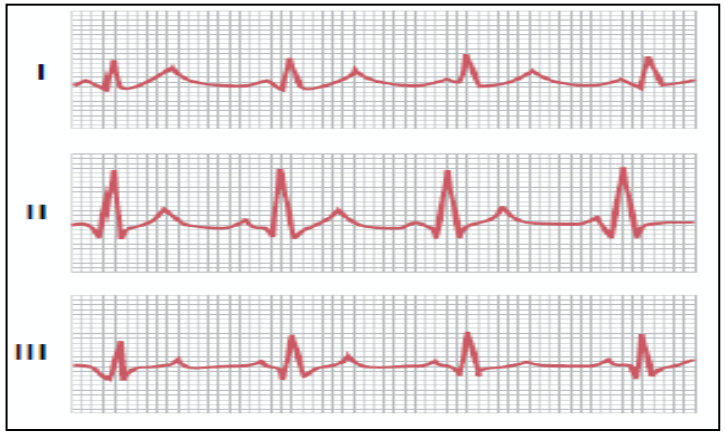
Normal heart axis:

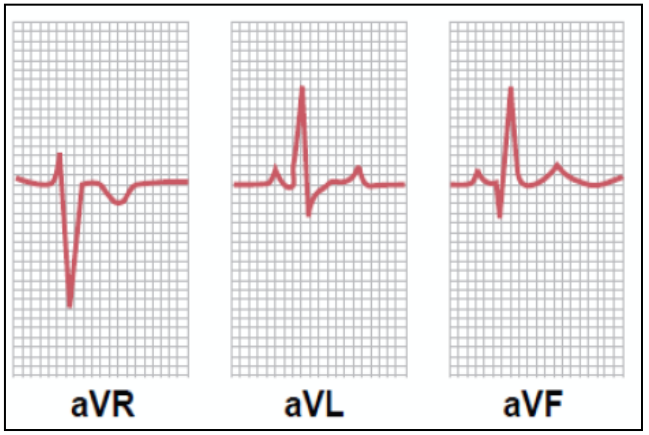
It is between -30 to +90

If its more than +90= Right axis deviation(RAD).

If it is less than -30= left axis deviation(LAD).

lead	Angle
aVF	90
aVL	30
aVR	210
I	0
II	60
III	120





HEXA AXIAL Diagram- cont.

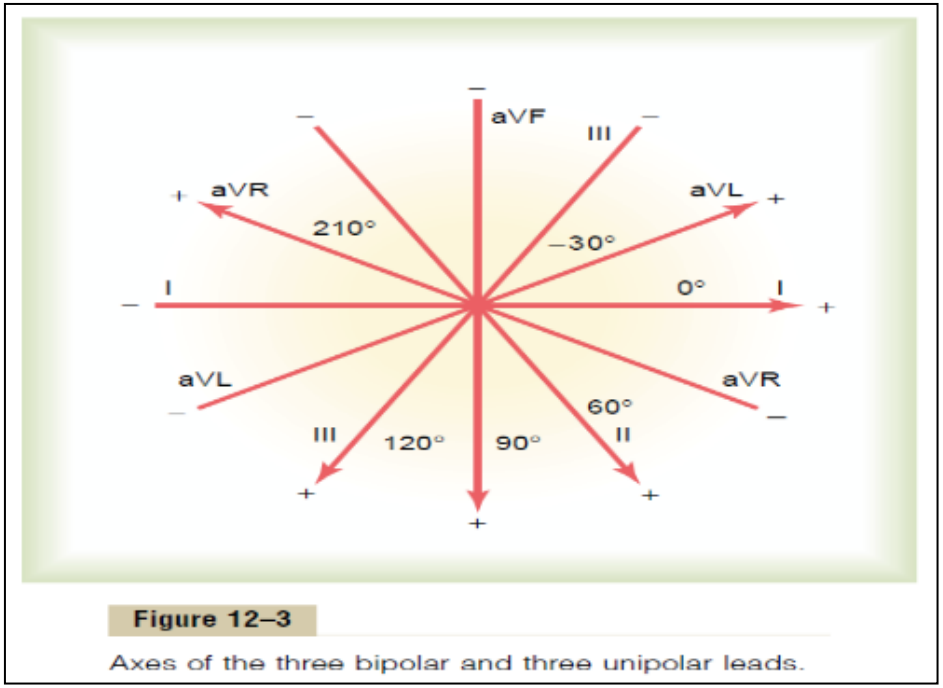
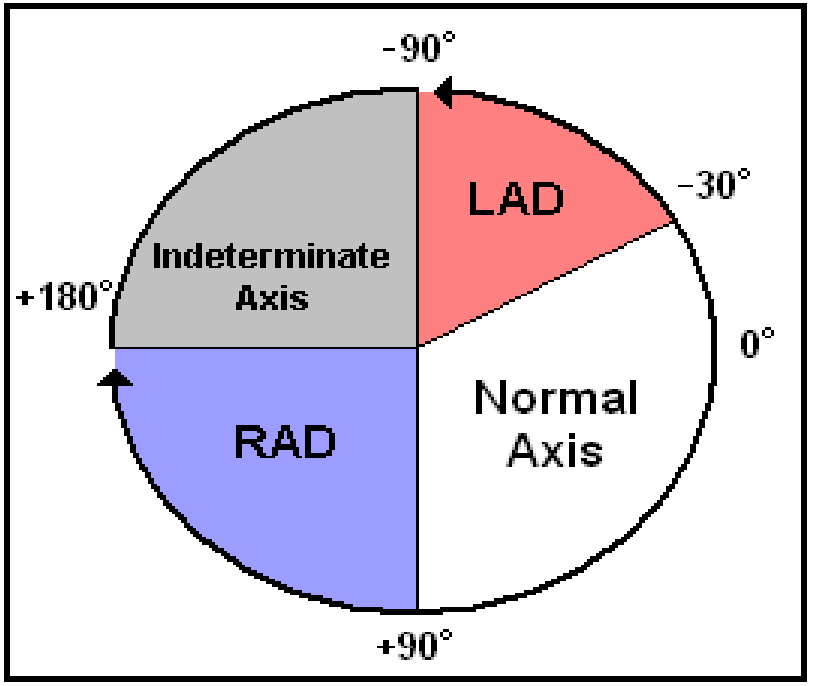


Figure 12–3

Axes of the three bipolar and three unipolar leads.



Mean Cardiac Electrical Axis

- When the vector in the heart is in a direction almost perpendicular to the axis of the lead, the voltage recorded in the ECG of this lead is very low.

- Conversely, when the heart vector has almost exactly the same axis as the lead axis, essentially the entire voltage of the vector will be recorded.

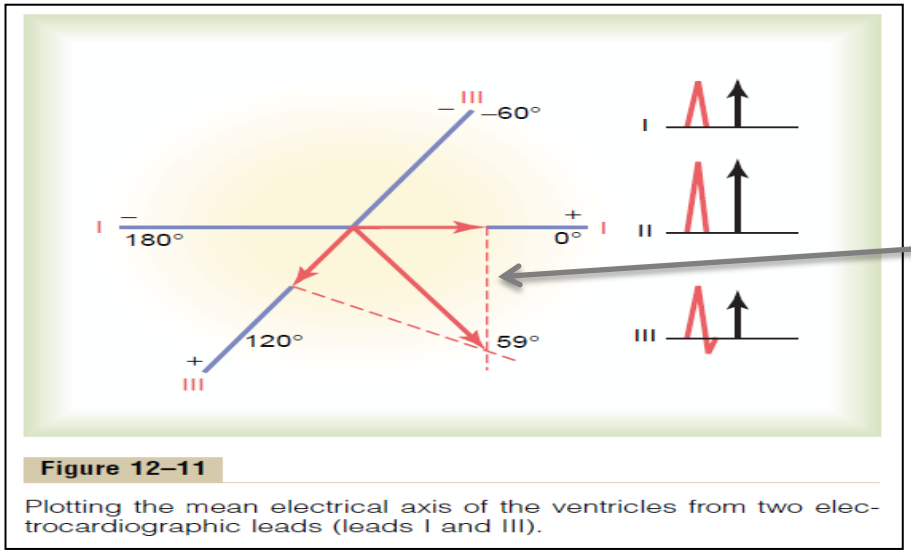


Figure 12–11

Plotting the mean electrical axis of the ventricles from two electrocardiographic leads (leads I and III).

The perpendicular line between the two leads

U-WAVE

- The U wave is a wave on an electrocardiogram that is not always seen. It is typically small, and, by definition, follows the T wave of ventricular repolarization. U waves are thought to represent repolarization of the papillary muscles or Purkinje fibers.
- Normal U waves are small, round and symmetrical and positive in lead II. It is the same direction as T wave in that lead.

Prominent U waves are most often seen in:

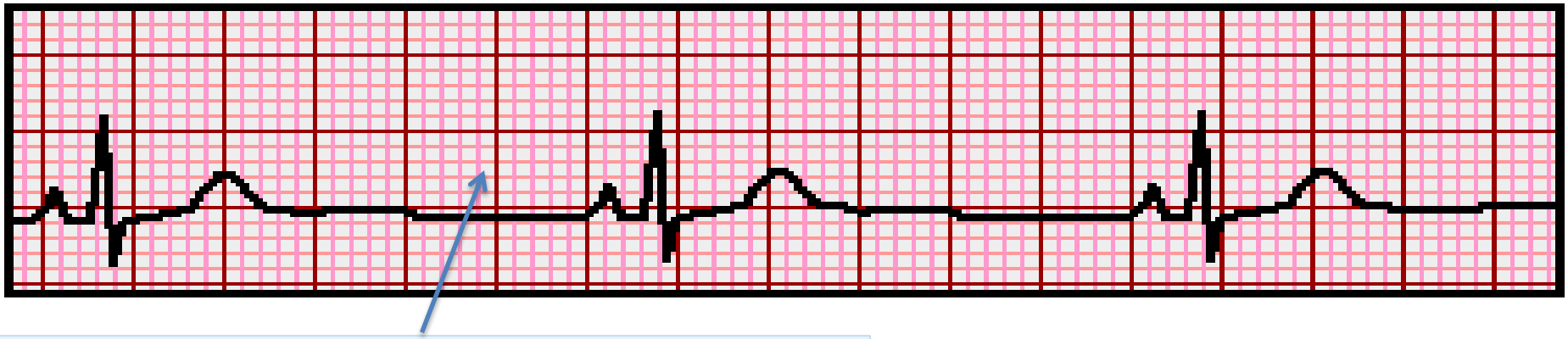
1. **hypokalemia, or may be hypercalcemia**
2. **the setting of intracranial hemorrhage**
3. **congenital long QT syndrome**
4. **Class 1A and 3 antiarrhythmics**
5. **Thyrotoxicosis**
6. **Epinephrine**
7. **exposure to digitalis**

U-WAVE

Determining the heart rate

To determine the heart rate ,take the number of "smallest boxes moved by the machine per minute" i.e. (1500) , and divide by the number of boxes between adjacent "R"-"R" waves.(progression R wave). Or dividing number of big boxes by 300.

H.R. = 1500 / total small squares between the 2 "R-R" waves
Or = 300 / total big squares between 2 "R-R" waves



Number of the small boxes between the adjacent R-R=30

Equation:
(1500 / 30) = 50 bpm

The number of the small boxes between the adjacent R-R indicate the normality from the abnormality

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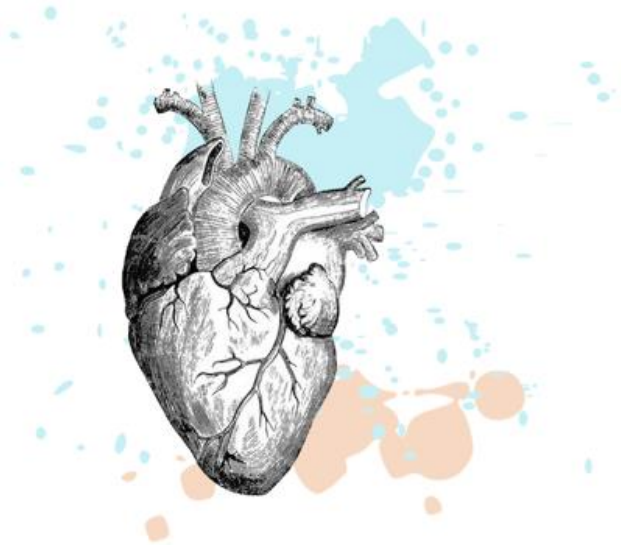
Videos :

- ECG Interpretation - Cardiac Electrical Activity
- ECG Interpretation - Generation
- Cardiac Conduction System and Understanding ECG, Animation.

Physiology
OF THE CARDIOVASCULAR SYSTEM

Physiology Leaders :

Khawla Alammari
Nojood Alhaidri
Rawaf Alrawaf



Girls team :

- Atheer Alnashwan
- Asrar Batarfi
- Afnan Almalki
- Alhanouf Aljlaoud
- Deema AlFaris
- Elham Alzahrani
- Johara Almalki
- Lojain alsiwat
- Malak Alsharif
- Monirah Alsalouli
- Nora AlRomaih
- Nurah Alqahtani
- Nouf Alabdulkarim
- Nora Albusayes
- Nora Alsomali
- Norah Alakeel
- Reem Alageel
- Rawan Aldhuwayhi
- Reham Al-Obaidan
- Samar AlOtaibi
- Shamma Alsaad

Boys team :

- Abdullah Aljaafar
- Omar Alotaibi
- Abdulrahman Albarakah
- Adel Alshehri
- Abdulaziz Alghanaym
- Abdulmajeed Alotaibi
- Khalil Alduraibi
- Hassan Albeladi
- Omar Alshehri
- Saleh Alshawi
- Abdulaziz Alhammad
- Faisal Alabdulatif
- Abdulnasser Alwabel
- Saad Almutairy