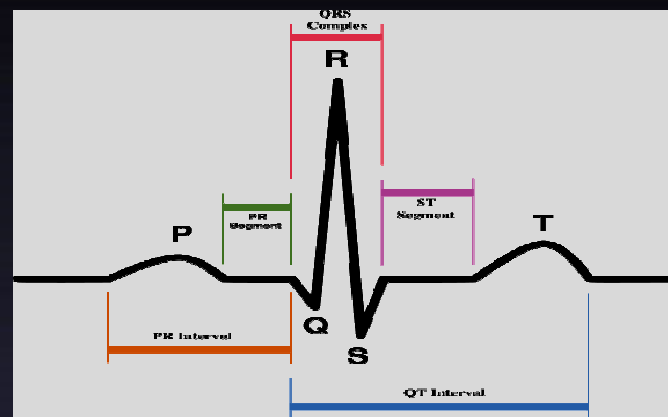




# ELECTROCARDIOGRAM (ECG)



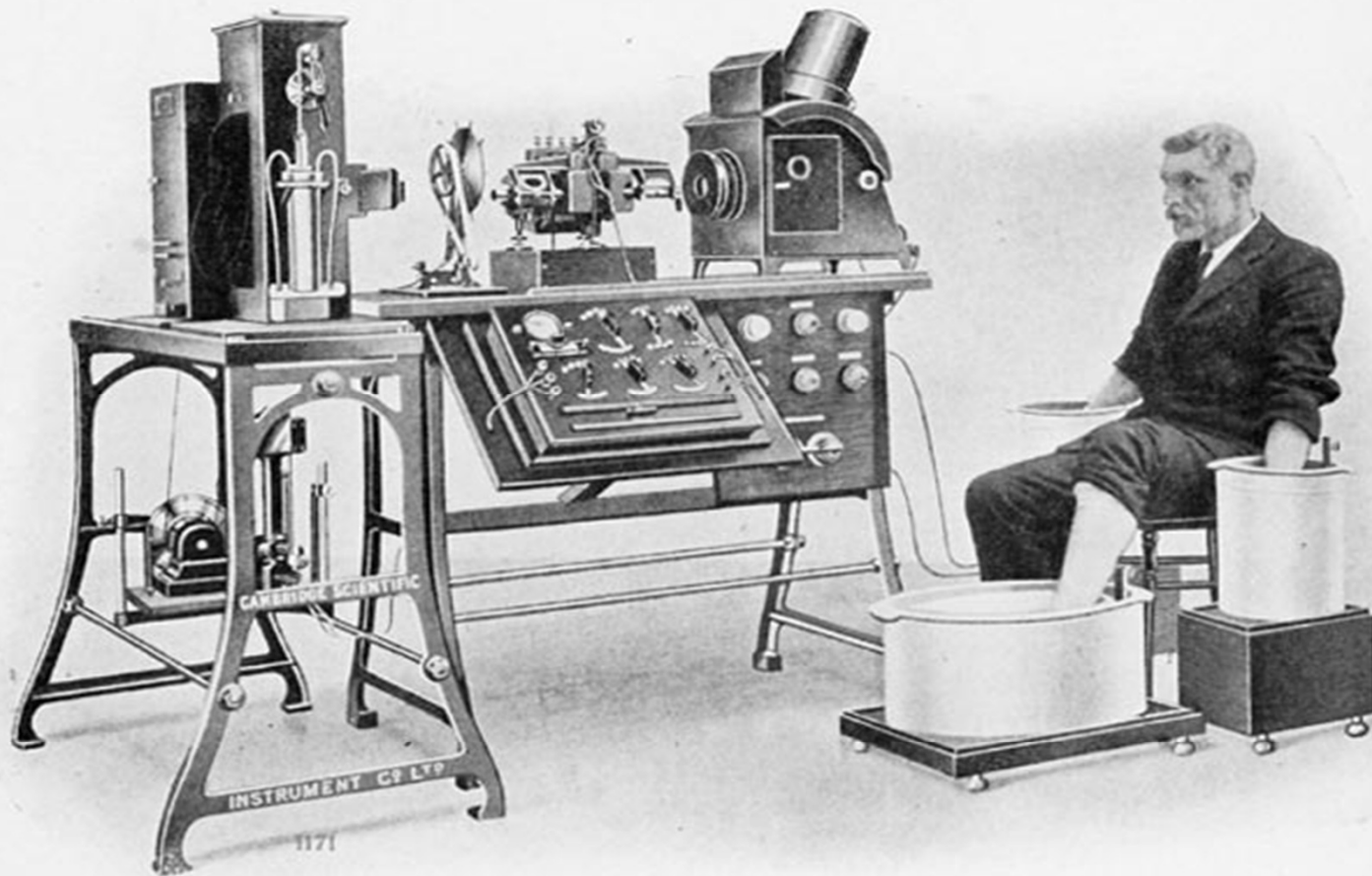
**Dr Syed Shahid Habib**  
**Professor & Consultant Clinical Neurophysiology**  
**Dept. of Physiology**  
**College of Medicine & KCUH**  
**King Saud University**

# OBJECTIVES

At the end of this lecture you should be able to:

- Define ECG & list 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

**Einthoven's original machine weighed 500 pounds and needed five operators**



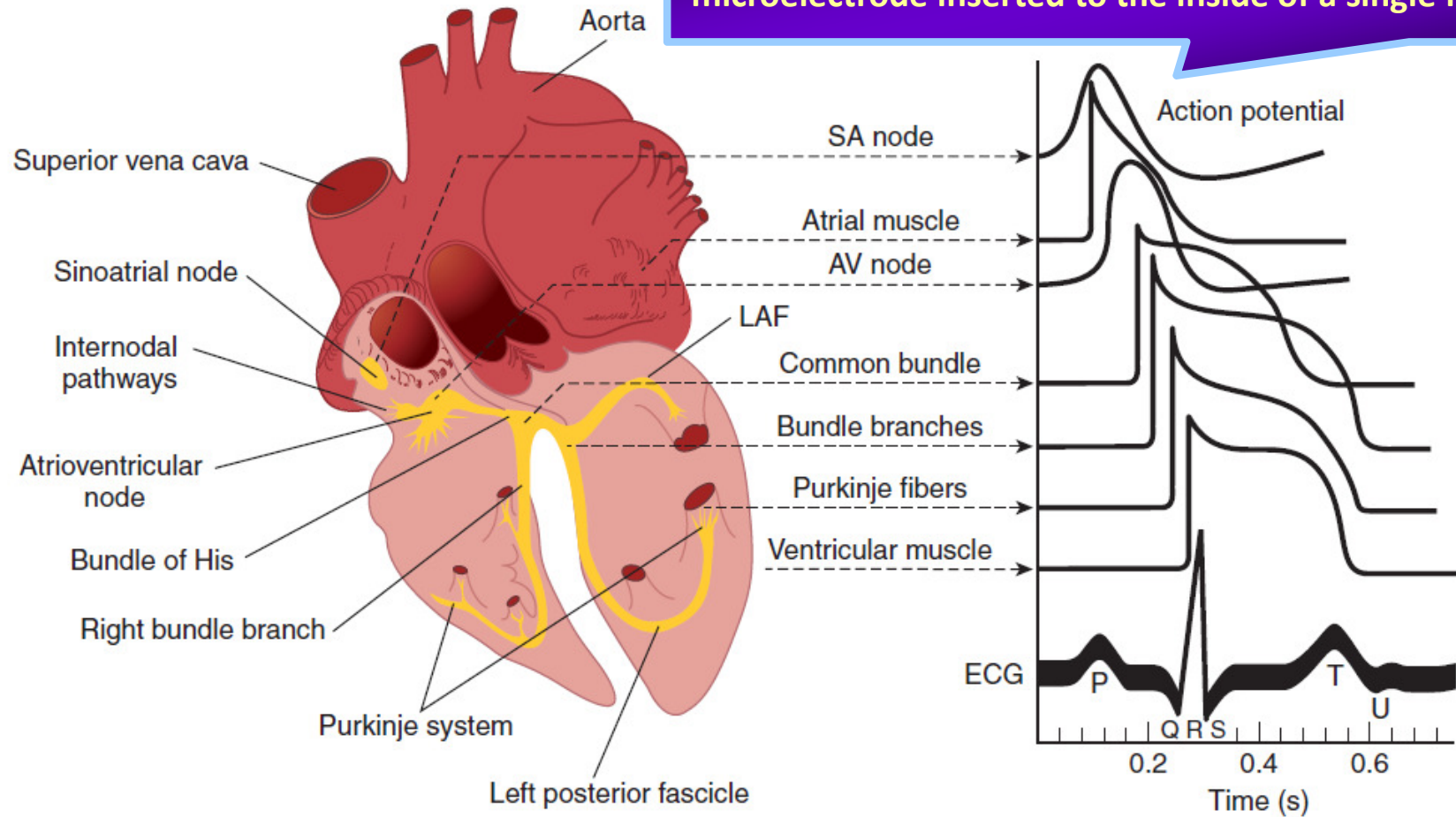
PHOTOGRAPH OF A COMPLETE ELECTROCARDIOGRAPH, SHOWING THE MANNER IN WHICH THE ELECTRODES ARE ATTACHED TO THE PATIENT, IN THIS CASE THE HANDS AND ONE FOOT BEING IMMERSSED IN JARS OF SALT SOLUTION

# Modern ECG Machines



**ECG** is the record of the algebraic sum of electrical activity i.e. action potentials generated by the heart during cardiac cycle

Monophasic action potentials recorded from a microelectrode inserted to the inside of a single fibers



The action potentials and ECG are plotted on the same time axis

# ECG PRINCIPLE

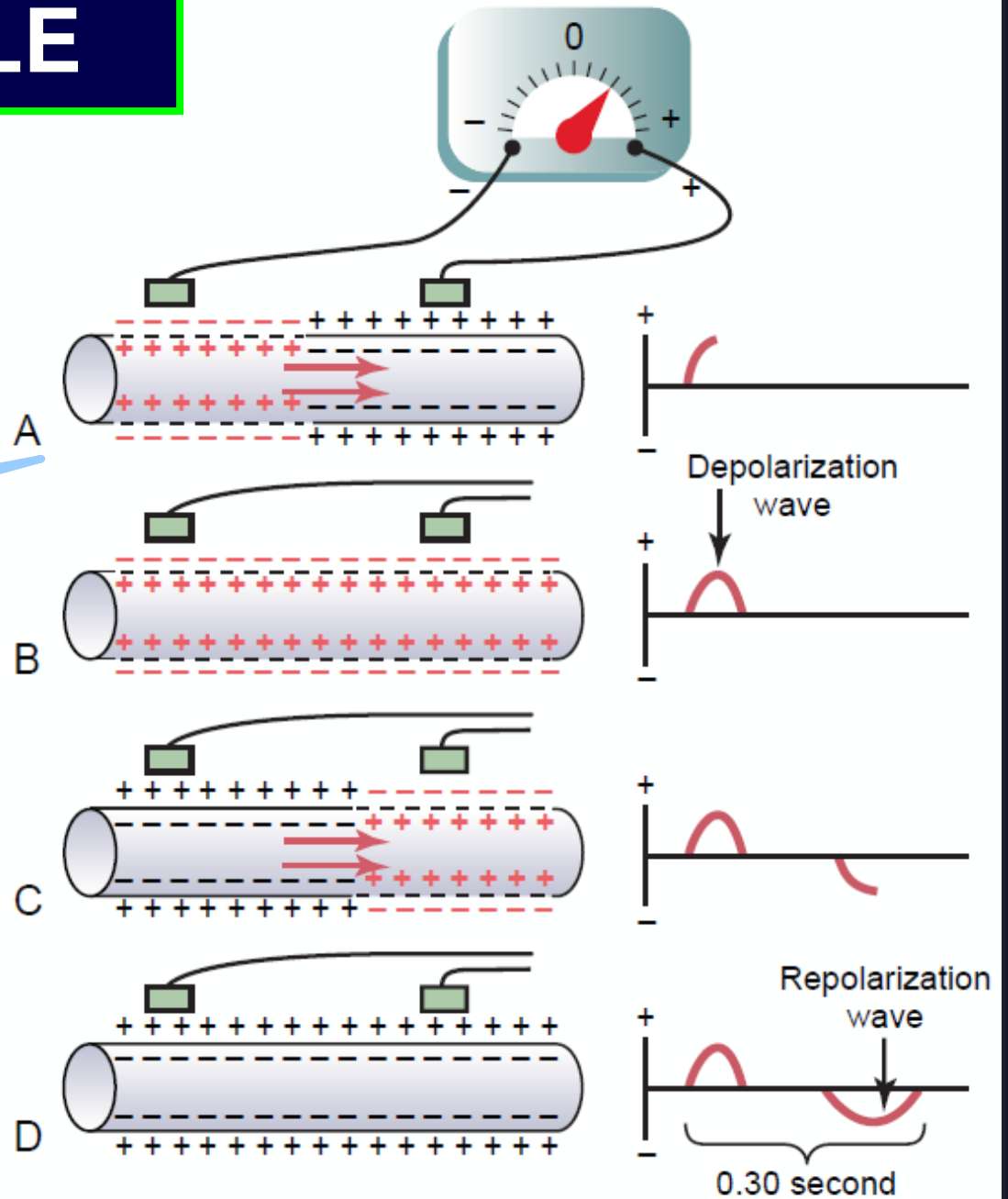
When the depolarization wave spread through heart, electrical currents pass into the surrounding tissue (body fluids are good conductors) and can be recorded from surface electrodes

Depolarization, is traveling from left to right

Depolarization completed

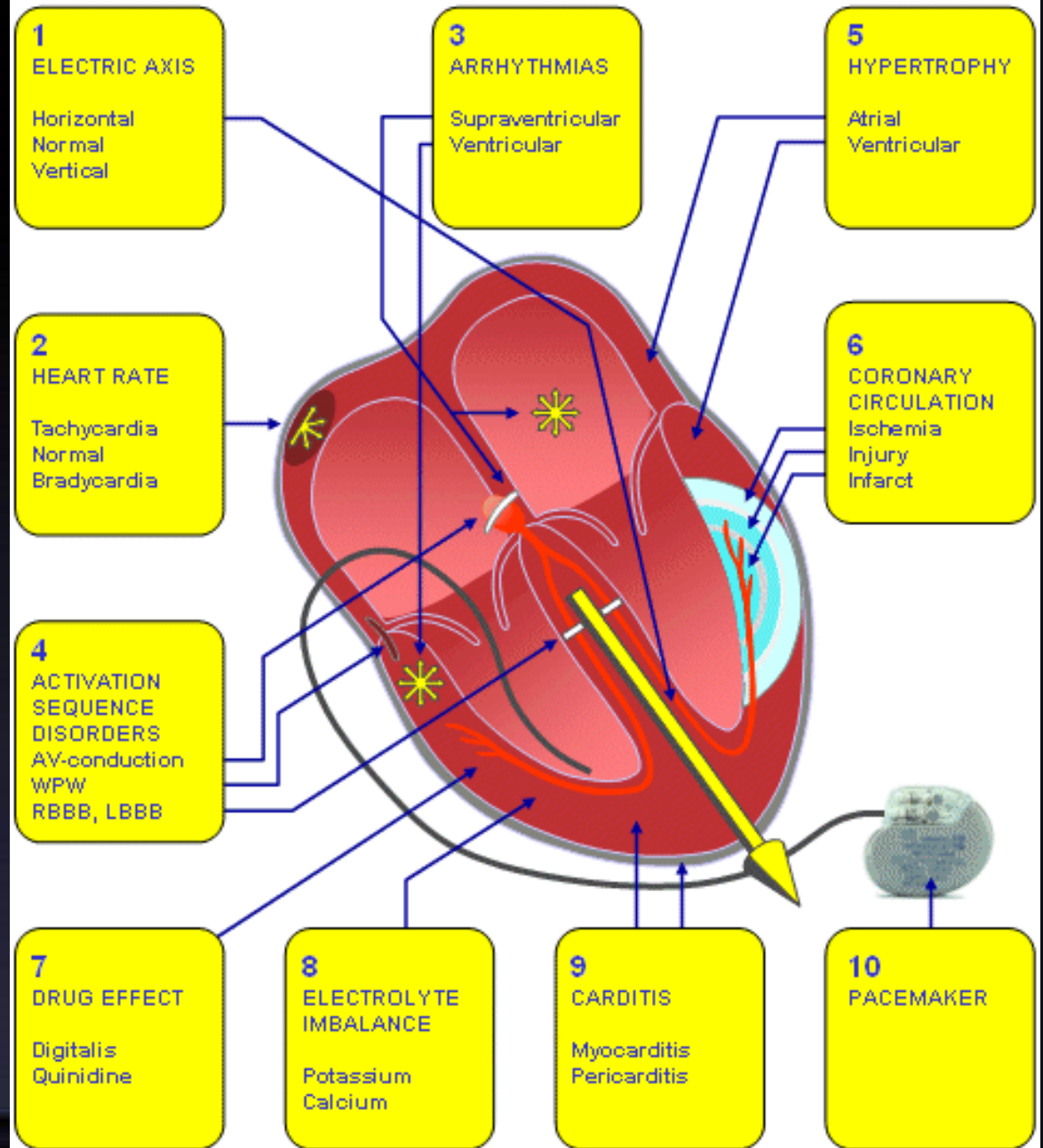
Repolarization, is traveling from left to right

Repolarization completed

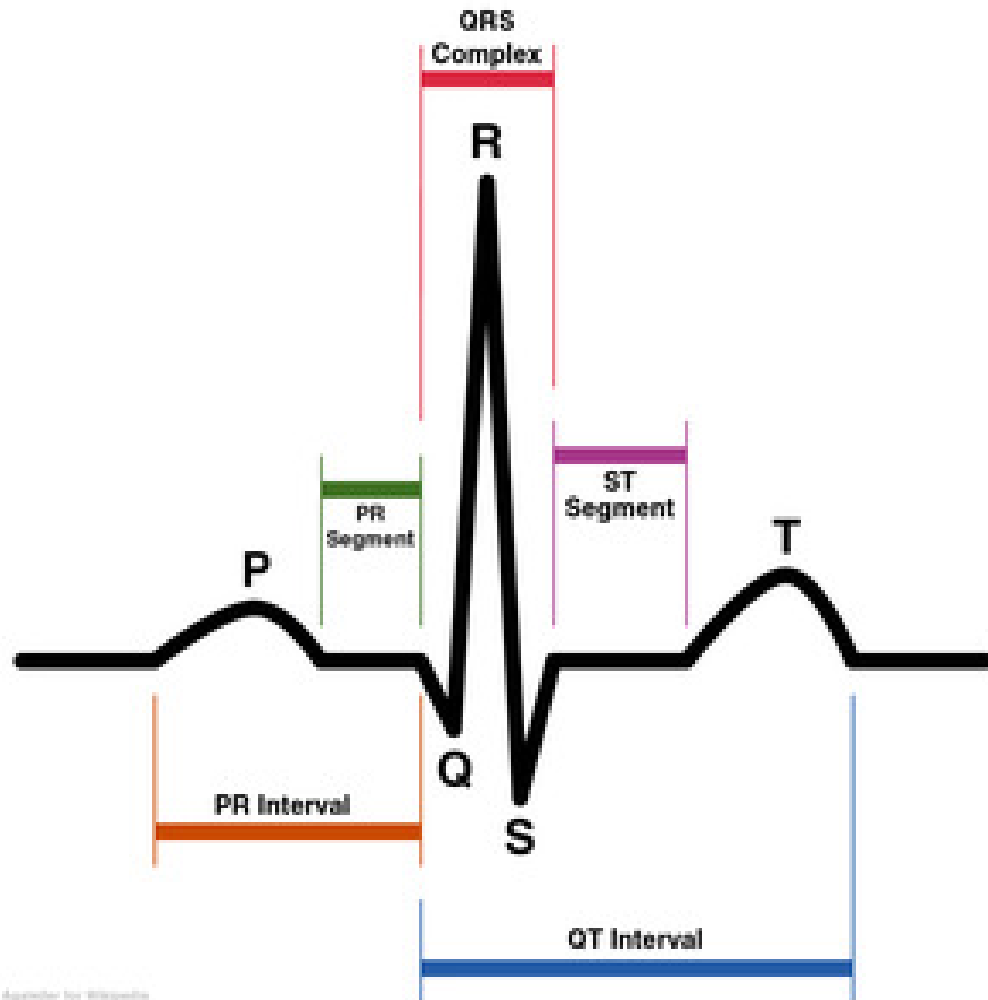


# What types of information can we obtain from an ECG?

- Heart rate
- Heart Axis
- Heart Rhythm
- Myopathies
- Carditis
- Chamber Hypertrophy
- Conduction defects
- Myocardial Ischemia/MI
- Electrolyte disturbances
- Drug toxicity (eg; digoxin)



# ECG Waveforms



**3 waves:  
(Deflections)**

- P- wave
- QRS complex
- T- wave

**3 segments:  
(isoelectric record only)**

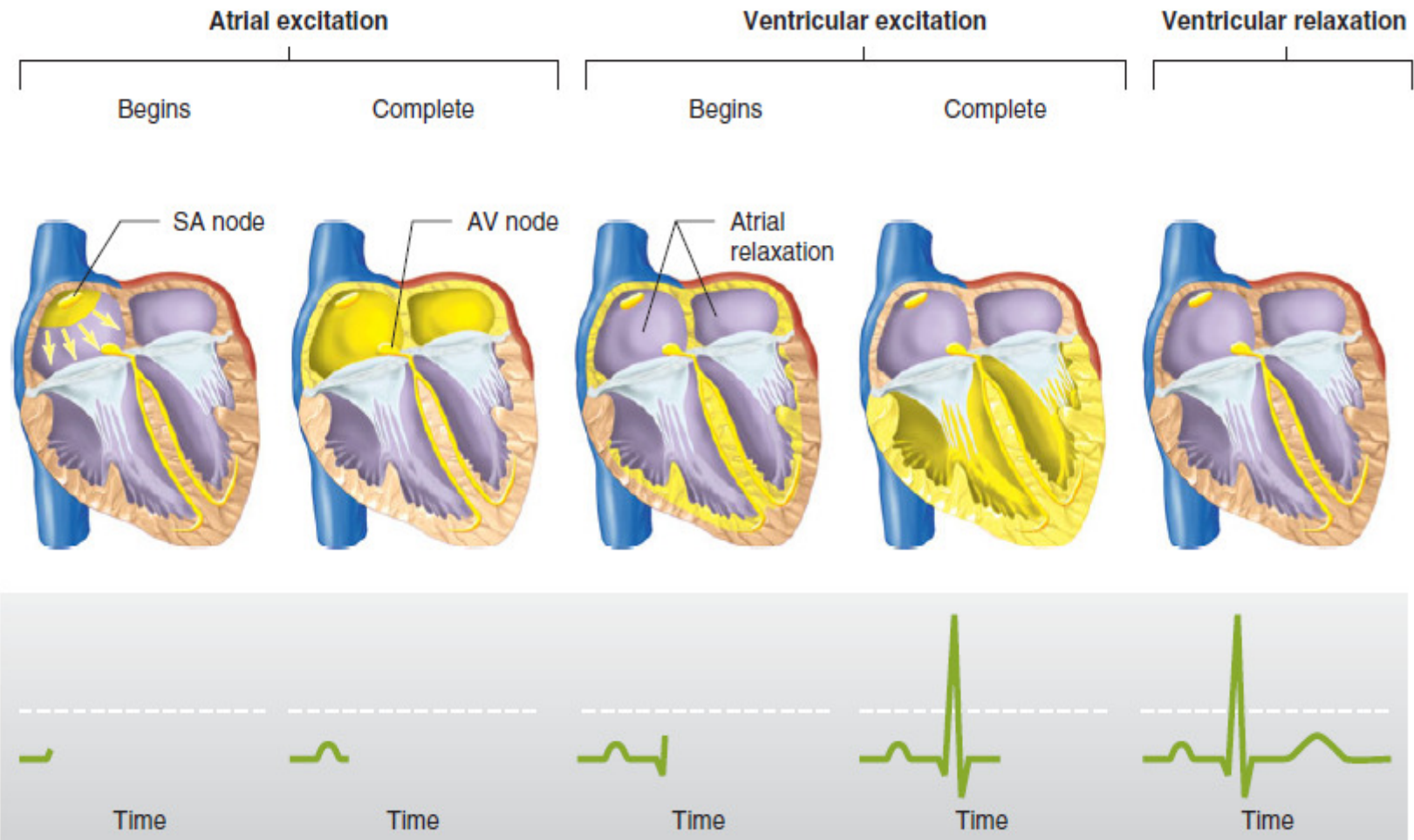
- ST segment
- TP segment
- PR segment

**3 time intervals:  
(include waves only)**

- P-R interval
- Q-T interval
- R-R interval



# SEQUENCE OF CARDIAC EXCITATION



Anatomical position of electrical activity with Corresponding electrocardiogram

# ECG Waveforms

## P- wave

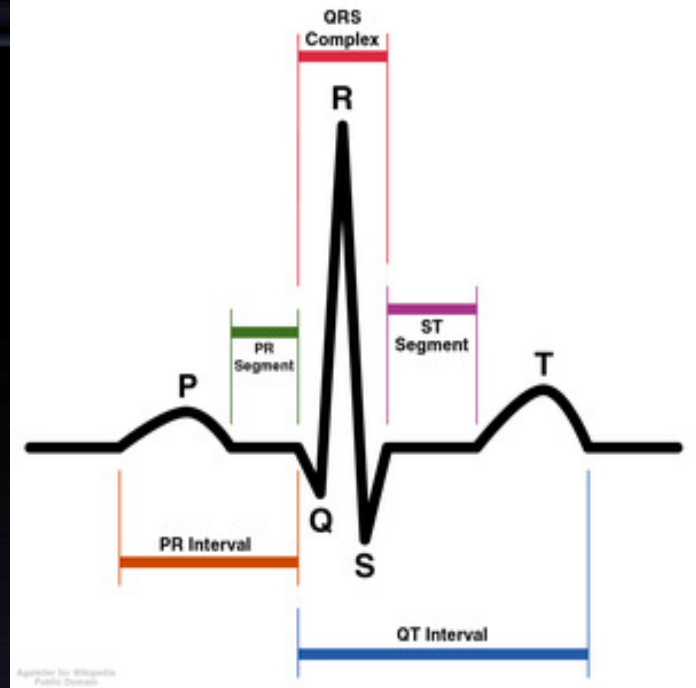
- Due to atrial depolarization
- P-wave is recorded before onset of atrial systole
- Atrial repolarization occurs at the same time with ventricular depolarization. But, since ventricular depolarization wave is giant, it masks the atrial repolarization wave

## QRS complex

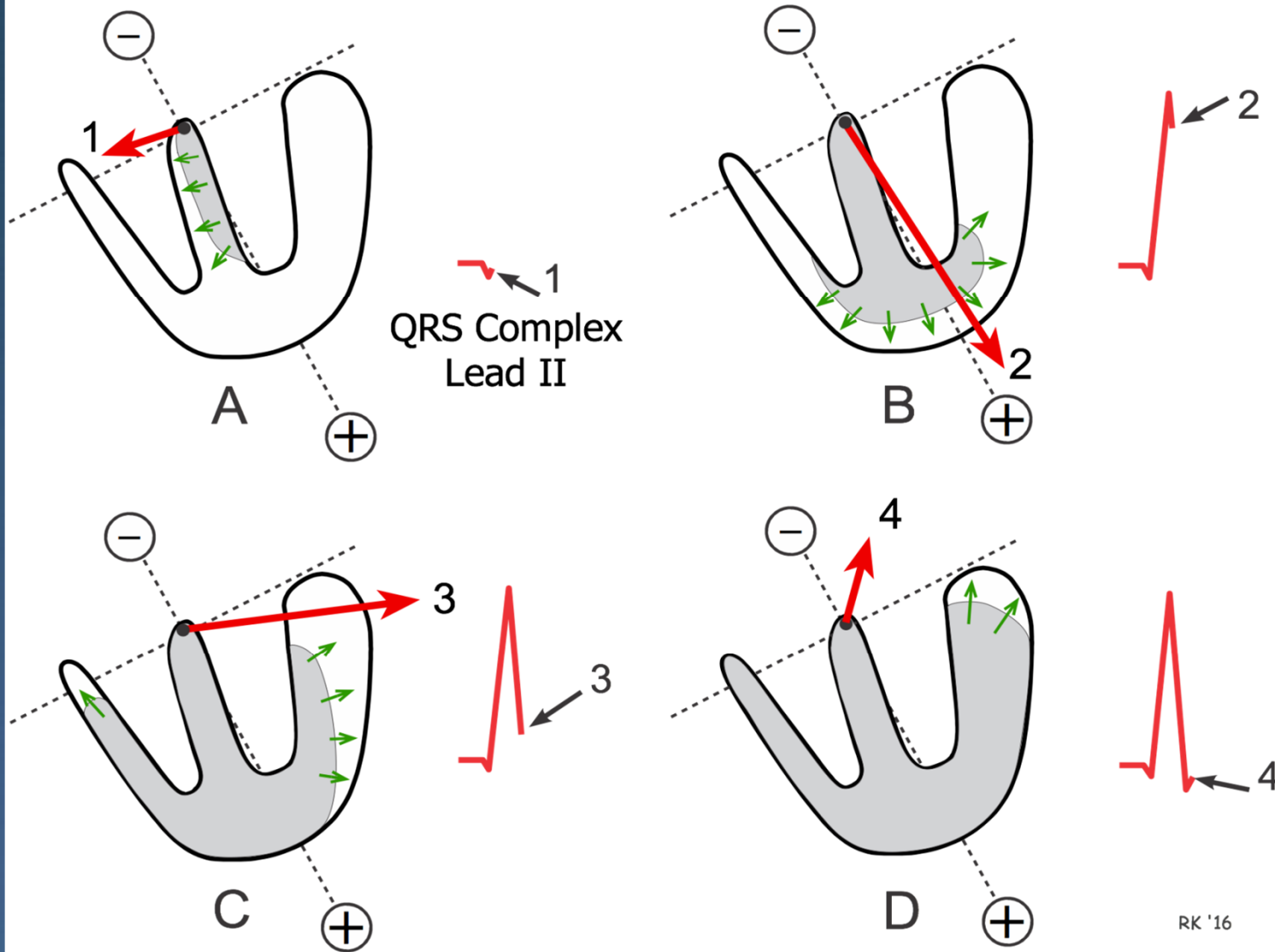
- Due to ventricular depolarization
- Q-wave due to depolarization of interventricular septum
- R-wave due to depolarization of ventricles
- S-wave due to depolarization of base of the heart
- QRS complex is recorded before the onset of ventricular systole

## T- wave

- Due to ventricular repolarization
- T-wave is recorded before the onset of ventricular diastole



# Pattern of Excitation of Ventricles to Produce QRS Complex in ECG

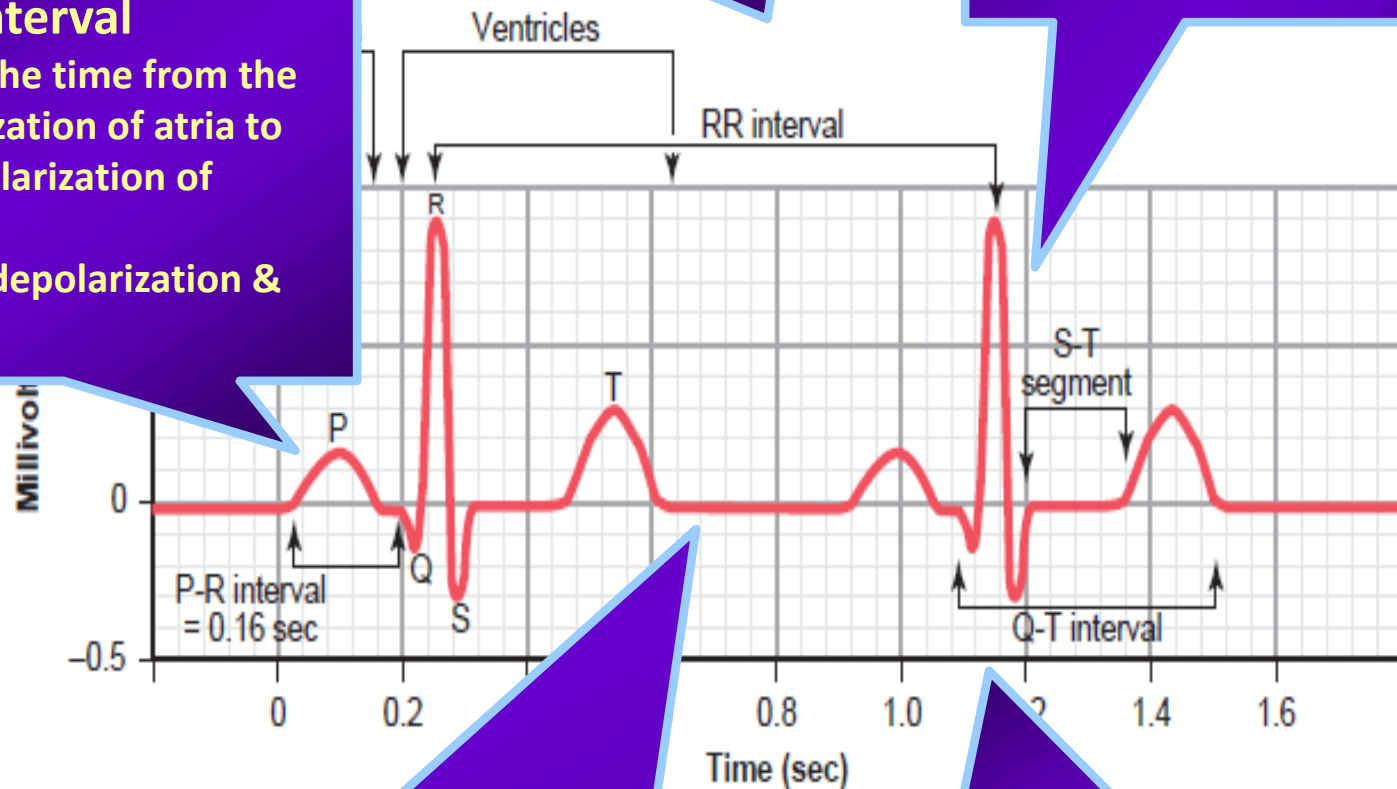


## R-R interval

The interval between two successive R-waves. Used to measure Heart rate

## P-R interval

- P-R interval is the time from the initial depolarization of atria to the initial depolarization of ventricles.
- denotes atrial depolarization & AV delay.



## S-T segment

During this segment all ventricular muscles are completely depolarized,

## T-P segment

Time interval from end of ventricular repolarization till next atrial depolarization. It represents ventricular filling.

## Q-T interval

Indicates Vent Depolarization & Repolarization

# Causes of ECG Waves

ECG Wave	Cause	Represent
<b>P- wave</b>	<b>Atrial depolarization</b>	Time of electrical impulse from SA node to spread through atrial muscle. Duration = 0.08 –0.1 sec Precedes atrial contraction by $\approx$ 0.01 - 0.02 sec
<b>QRS complex</b>	<b>Ventricular depolarization</b>	Measured from beginning of Q wave till end of S wave. Consists of 3 waves: <b>Q wave: (-ve):</b> Produced by depolarization of interventricular septum. <b>R wave: (+ve):</b> Produced by depolarization of ventricular wall. <b>S wave: (-ve):</b> Produced by depolarization of the base of the heart. Duration $\leq$ 0.1 sec. Precedes ventricular contraction by $\approx$ 0.02 sec. Occurs after P-wave by $\approx$ 0.12-0.2 sec = PR interval
<b>T- wave</b>	<b>Ventricular repolarization</b>	Occurs during latter part of systole, before the onset of diastole. Ventricular repolarization progresses from apex to the base of the heart. Duration = 0.27 sec.

**Atrial repolarization occurs at the same time with ventricular depolarization. But, since ventricular depolarization wave is giant, it masks the atrial repolarization wave**

# CARDIAC VECTORS

Electrical forces can be represented in the form of 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.

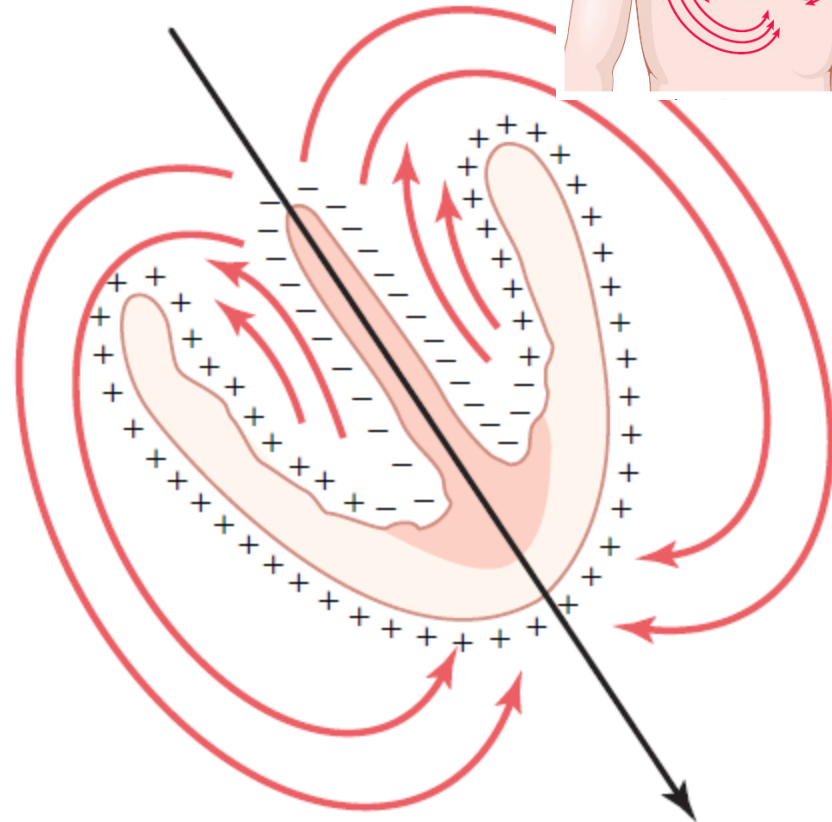
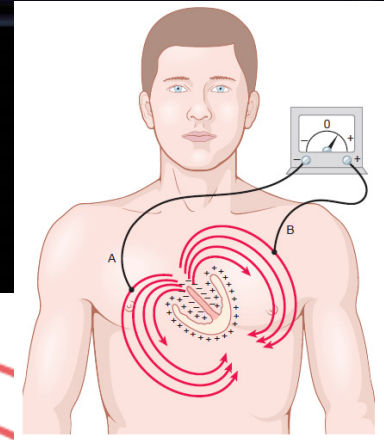


Figure 12-1

Mean vector through the partially depolarized ventricles.

# DEPOLARIZATION OF THE ATRIA—THE P WAVE

The area in the atria that also becomes repolarized first is the sinus nodal region, the area that had originally become depolarized first. Therefore, the atrial repolarization vector is backward to the vector of depolarization

In a normal ECG, the atrial T wave 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

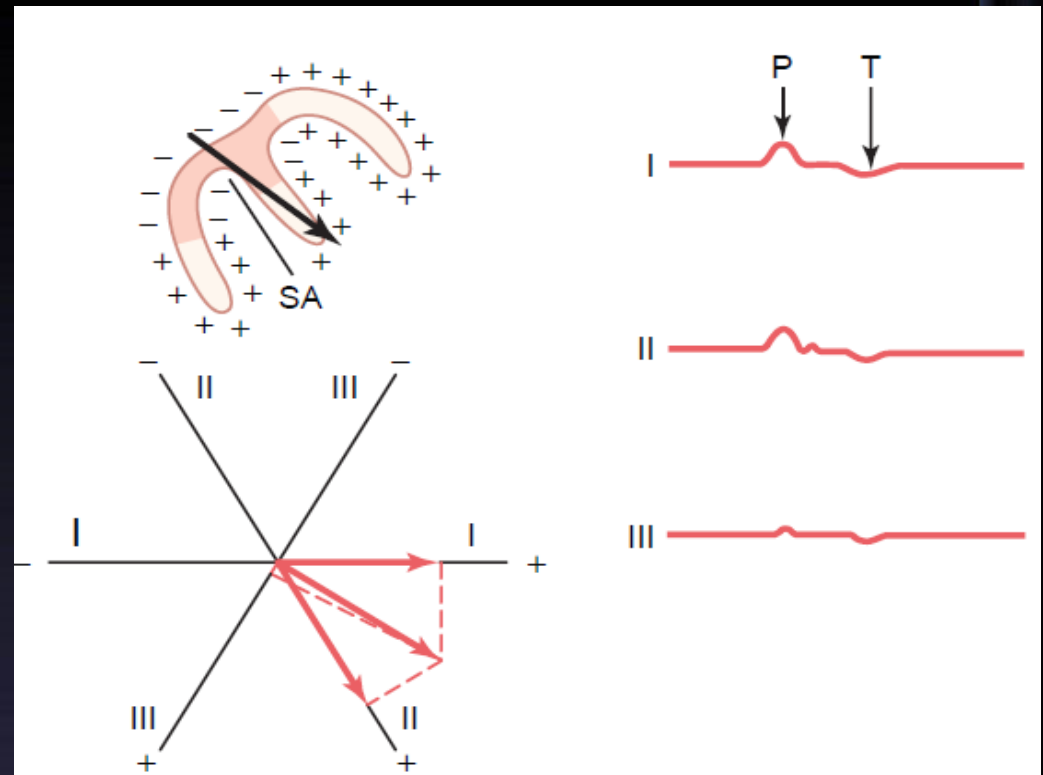


Figure 12-9

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.

## **VECTORS THAT OCCUR AT SUCCESSIVE INTERVALS DURING DEPOLARIZATION OF THE VENTRICLES—THE QRS COMPLEX**

- **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.**
- **It spreads through the ventricular muscle to the outside of the heart**
- **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.**

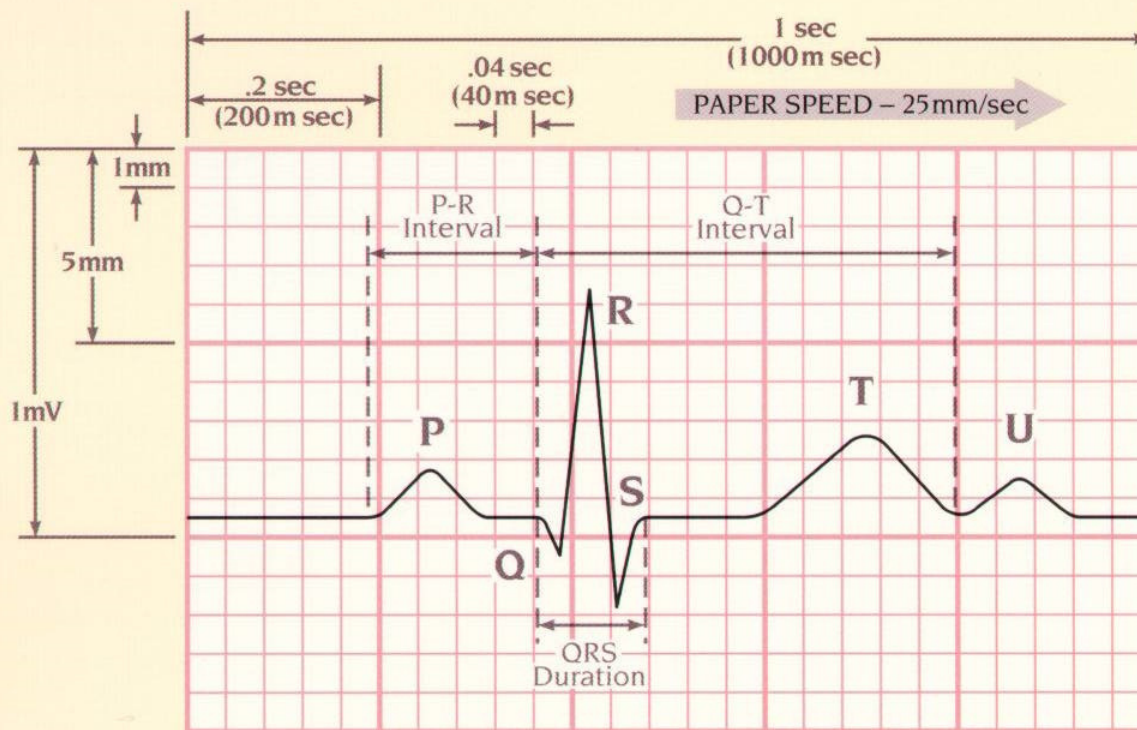


**ELECTROCARDIOGRAM  
DURING VENT  
REPOLARIZATION  
THE T WAVE**

Because the septum and endocardial areas of the ventricular muscle depolarize first, it seems logical that these areas should repolarize first as well, but actually it is NOT so!!!!!!!!!!

- The greatest portion of ventricular muscle mass to repolarize first is the entire outer surface of the ventricles, especially near the apex of the heart because the septum and other endocardial areas have a longer period of contraction than do most of the external surfaces of the heart so **endocardial areas, conversely, normally repolarize last.**
- Therefore, 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, which is also the polarity of most of the normal QRS complex.

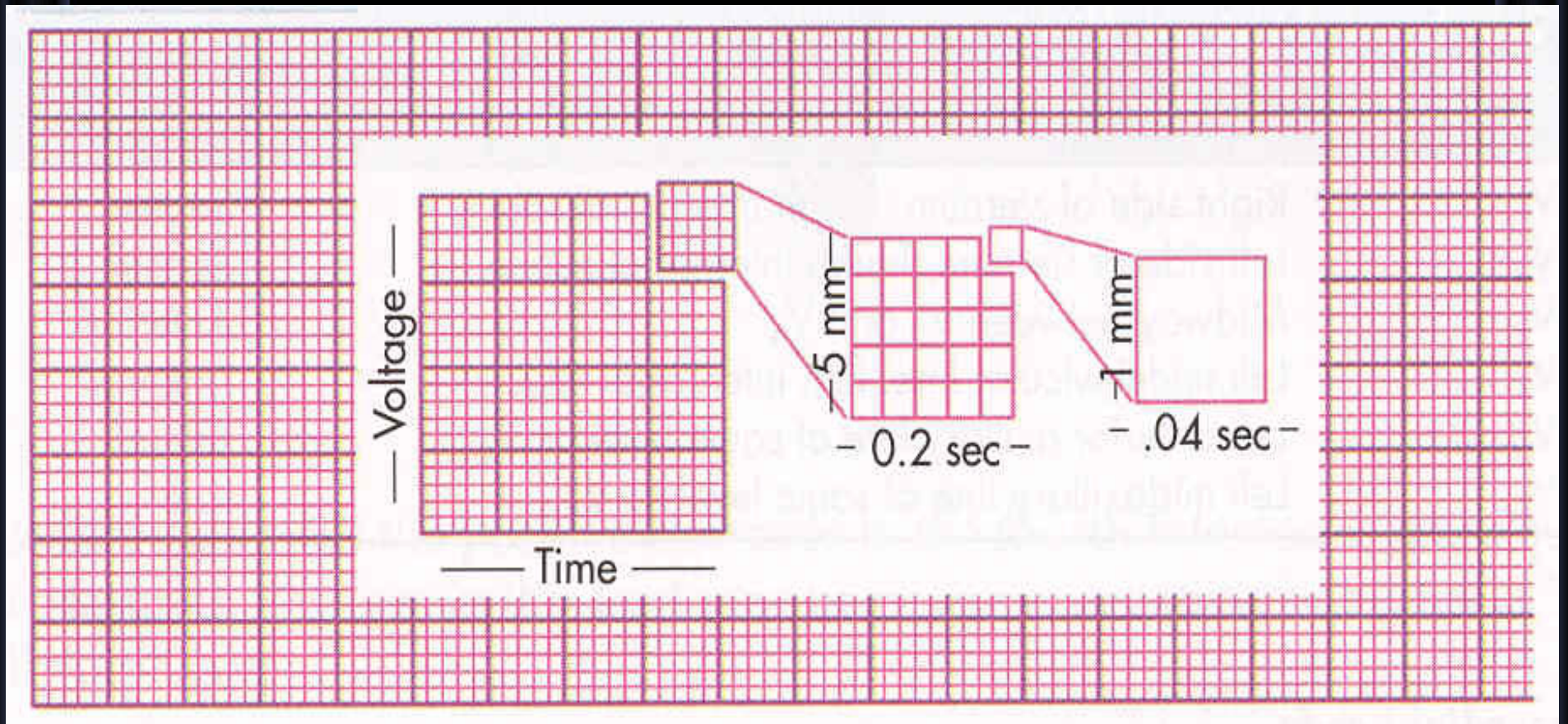
# The ECG Paper



<b>VERTICAL AXIS</b>	1 Small Square = 1mm (0.1mV)
	1 Large Square = 5mm (0.5mV)
	2 Large Squares = 1mV

<b>HORIZONTAL AXIS</b>	1 Small Square = .04 sec (40 m sec)
	1 Large Square = .2 sec (200 m sec)
	5 Large Squares = 1 sec (1000 m sec)

# The ECG Paper



**TABLE 29–2 ECG intervals.**

Intervals	Normal Durations		Events in the Heart during Interval
	Average	Range	
PR interval <sup>a</sup>	0.18 <sup>b</sup>	0.12–0.20	Atrioventricular conduction
QRS duration	0.08	to 0.10	Ventricular depolarization
QT interval	0.40 <sup>c</sup>	to 0.43	Ventricular action potential
ST interval (QT minus QRS)	0.32	...	Plateau portion of the ventricular action potential

<sup>a</sup>Measured from the beginning of the P wave to the beginning of the QRS complex.

<sup>b</sup>Shortens as heart rate increases from average of 0.18 s at a rate of 70 beats/min to 0.14 s at a rate of 130 beats/min.

<sup>c</sup>Can be lower (0.35) depending on the heart rate

## ECG Leads

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

- 1. Two exploring (Active) electrodes attached to the surface of body (bipolar leads)**
- 2. One point on the body (Exploring) and a virtual reference point (Indifferent) electrode with zero electrical potential (unipolar leads)**

# Summary of ECG Leads

	Limb Leads	Precordial Leads
<b>Bipolar</b>	<b>I, II, III</b> (standard limb leads)	-
<b>Unipolar (V leads)</b>	<b>aVR, aVL, aVF</b> (augmented limb leads)	<b>V<sub>1</sub>-V<sub>6</sub></b>

# ECG Leads

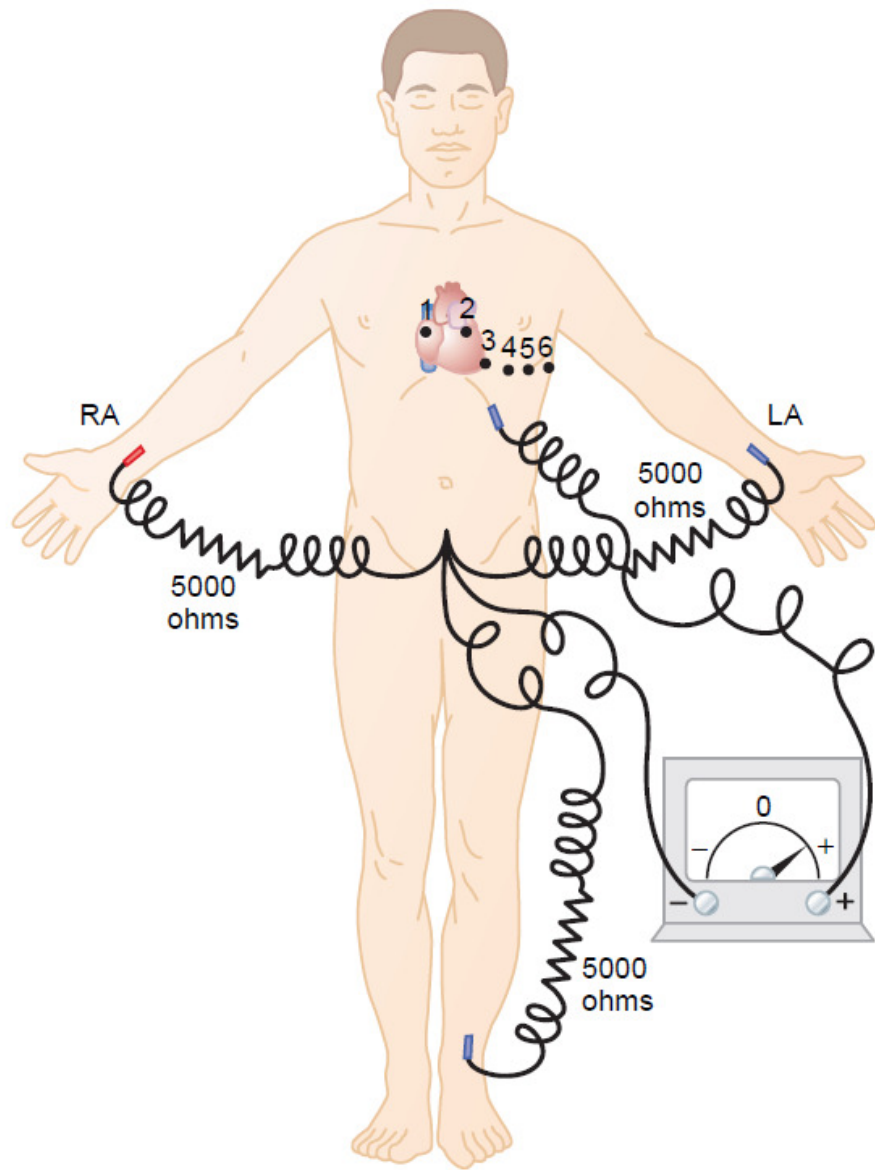
The standard ECG has 12 leads

3 Standard Limb Leads (Bipolar)

3 Augmented Limb Leads (Unipolar)

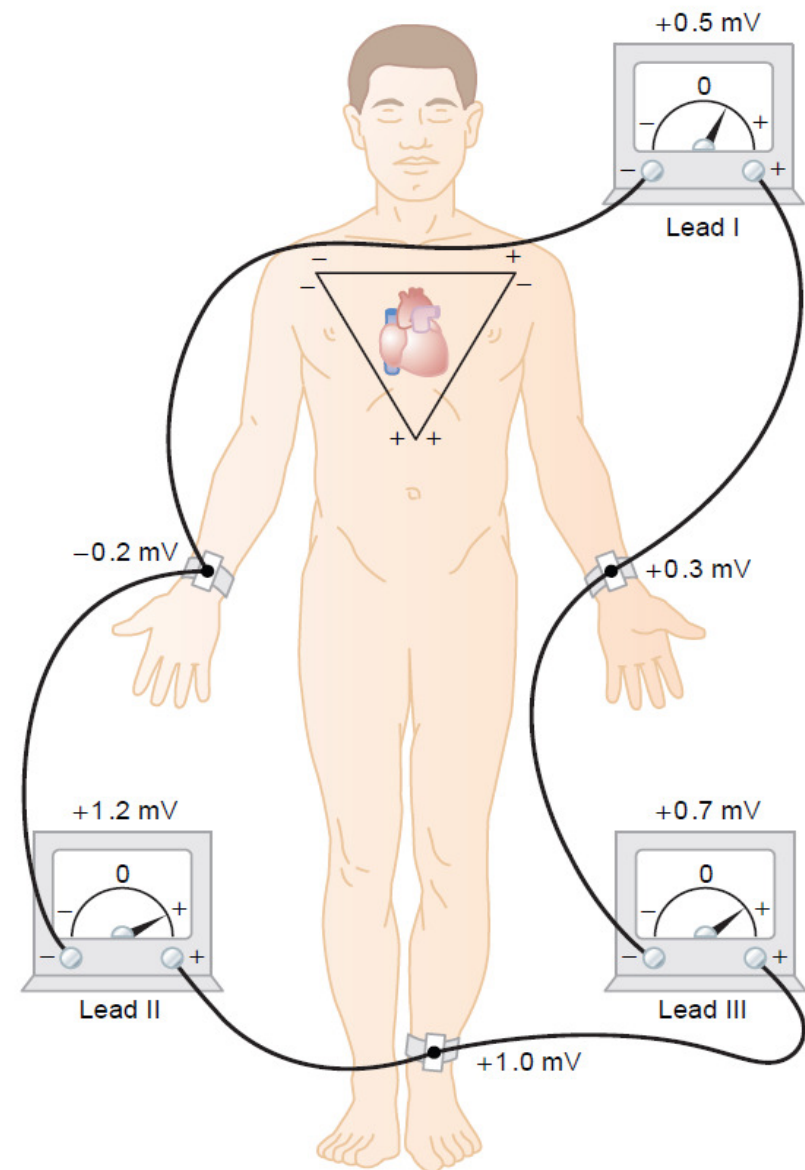
6 Precordial (chest) Leads (Unipolar)

The axis of a particular lead represents the viewpoint from which it looks at the heart.



**Figure 11-8**

Connections of the body with the electrocardiograph for recording chest leads. LA, left arm; RA, right arm.

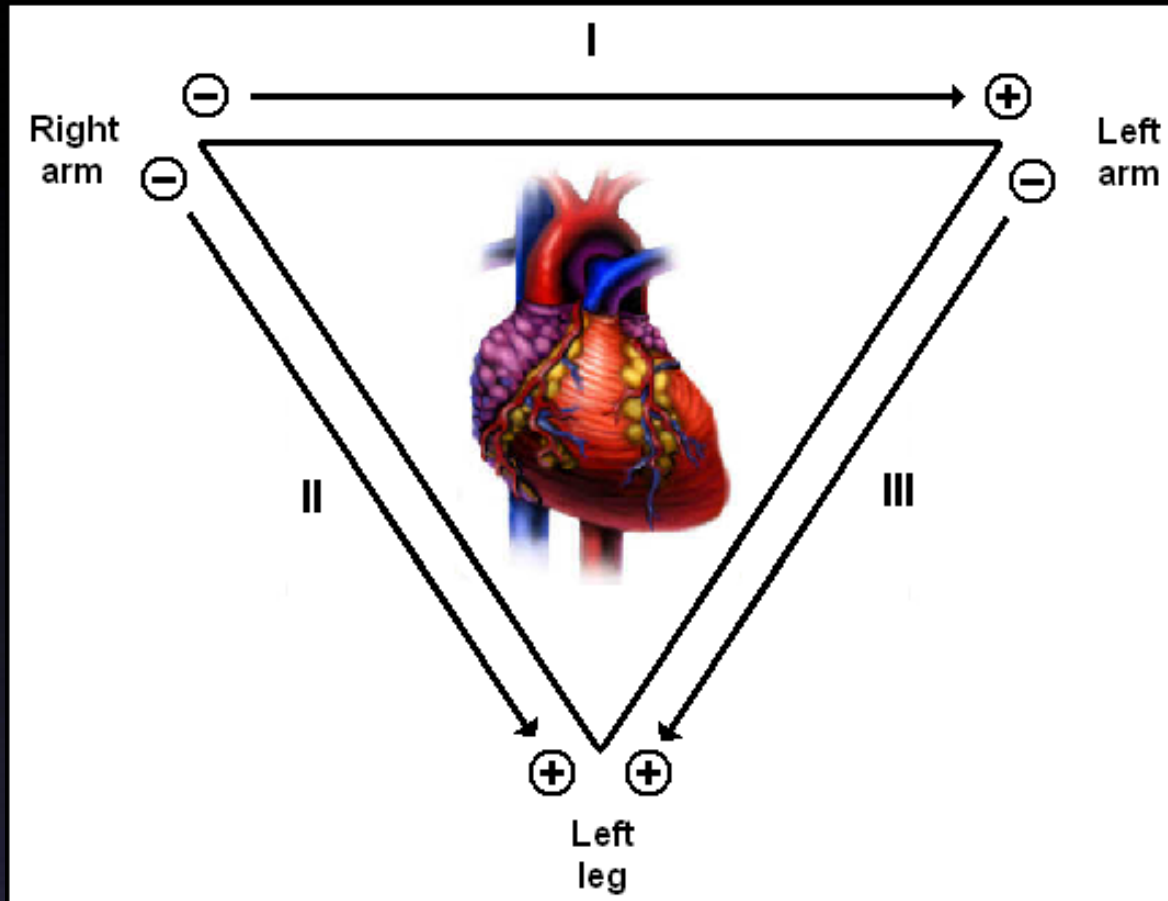


**Figure 11-6**

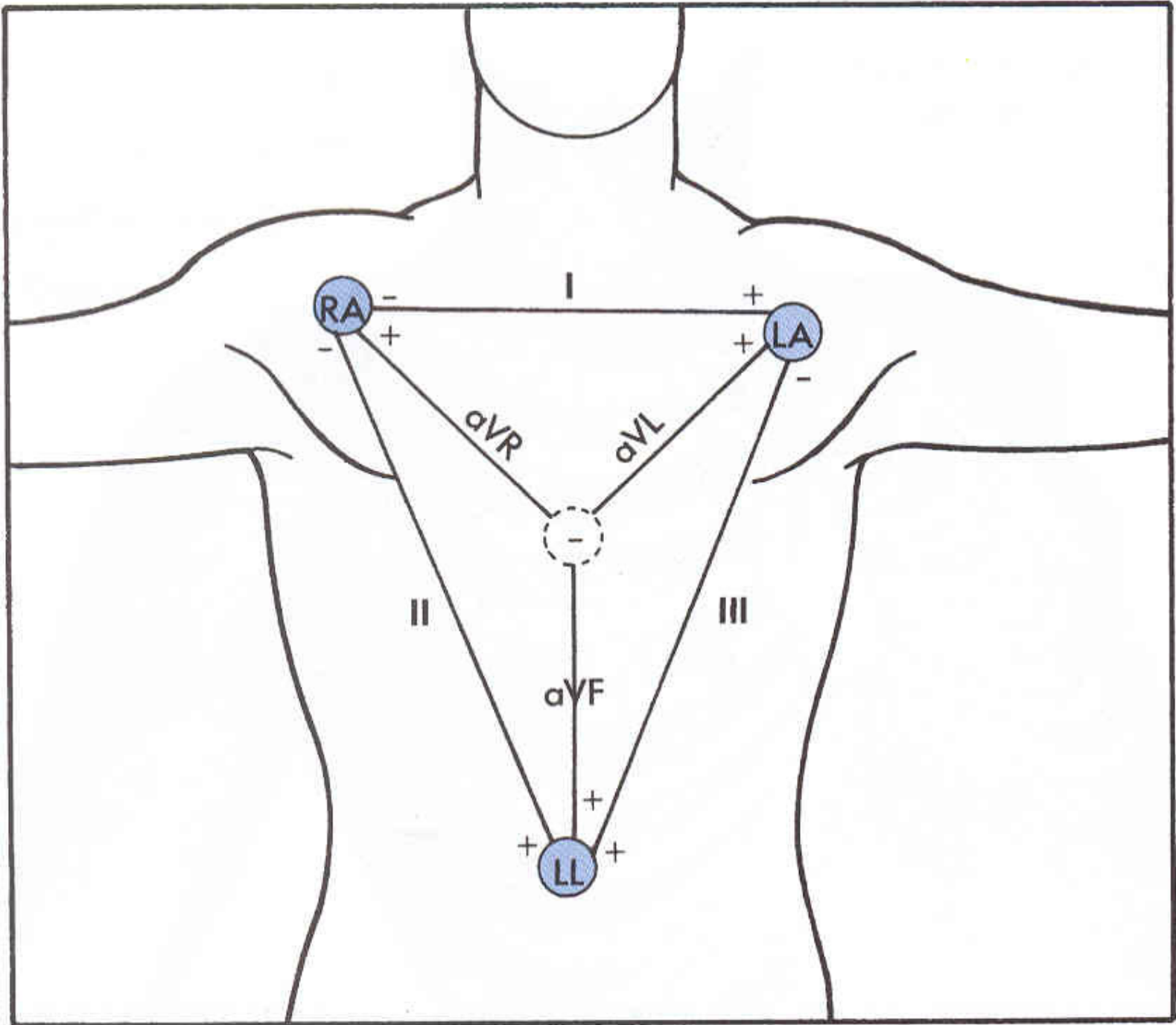
Conventional arrangement of electrodes for recording the standard electrocardiographic leads. Einthoven's triangle is superimposed on the chest.



# Standard Bipolar Limb Leads



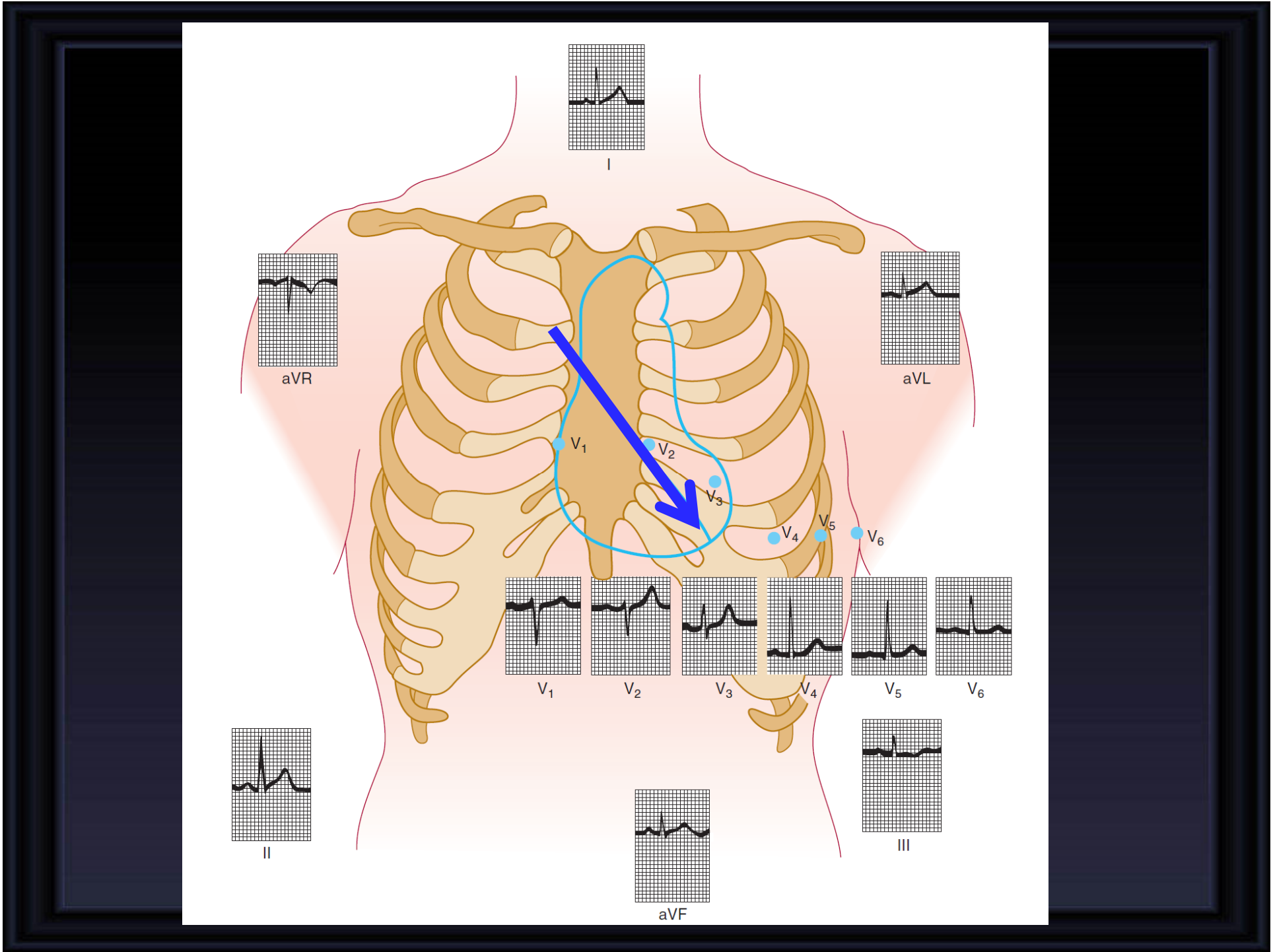
**Einthoven's Law.** Einthoven's law states that if the ECGs are recorded simultaneously with the three limb leads, the sum of the potentials recorded in leads I and III will equal the potential in lead II.

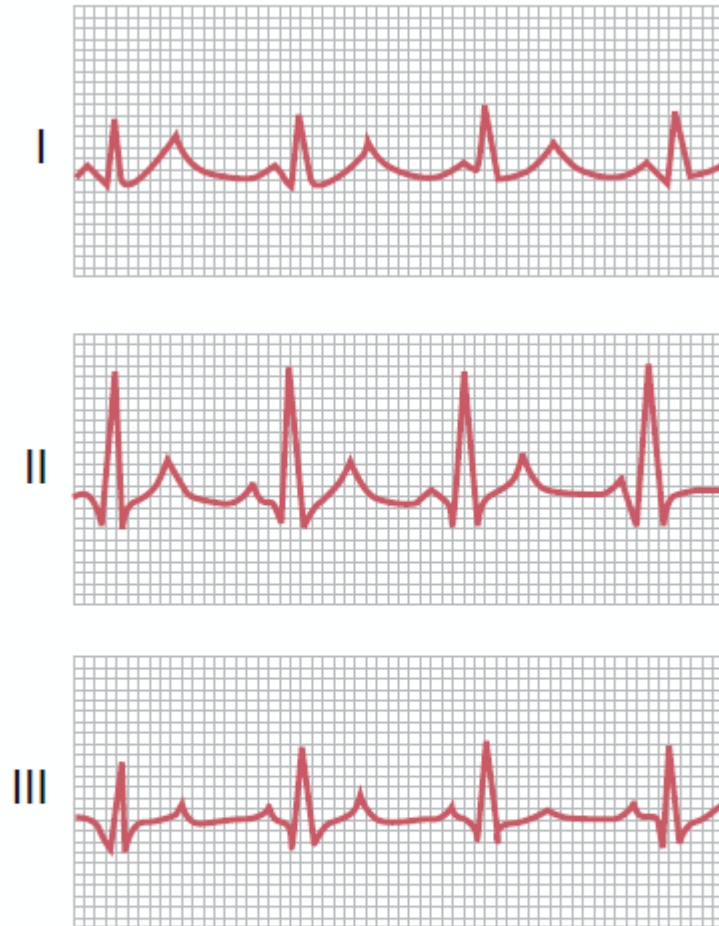


Two leads of the same anatomic group are "Anatomically Contiguous"

I Lateral	aVR	VI Septal	V4 Anterior
II Inferior	aVL Lateral	V2 Septal	V5 Lateral
III Inferior	aVF Inferior	V3 Anterior	V6 Lateral

The criteria for a ST elevation myocardial infarction (STEMI) is ST segment elevation in two or more contiguous Leads





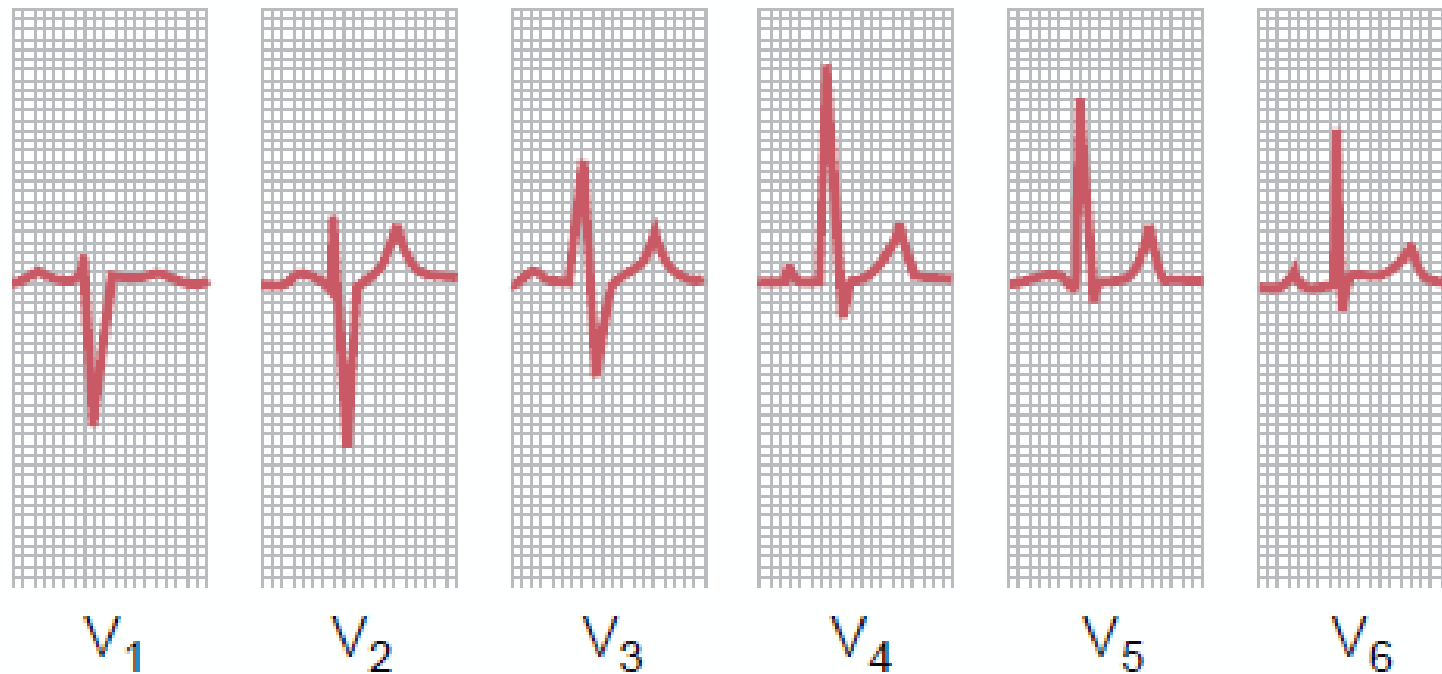
**Figure 11-7**

Normal electrocardiograms recorded from the three *standard* electrocardiographic leads.



**Figure 11-10**

Normal electrocardiograms recorded from the three *augmented unipolar limb leads*.



**Figure 11-9**

Normal electrocardiograms recorded from the six standard chest 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. 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 hypokalemia, but may be present in hypercalcemia, thyrotoxicosis, or exposure to digitalis, epinephrine, and Class 1A and 3 antiarrhythmics, as well as in congenital long QT syndrome, and in the setting of intracranial hemorrhage.

An inverted U wave may represent myocardial ischemia or left ventricular volume overload



# HEXA AXIAL REFERENCE SYSTEM DIAGRAM

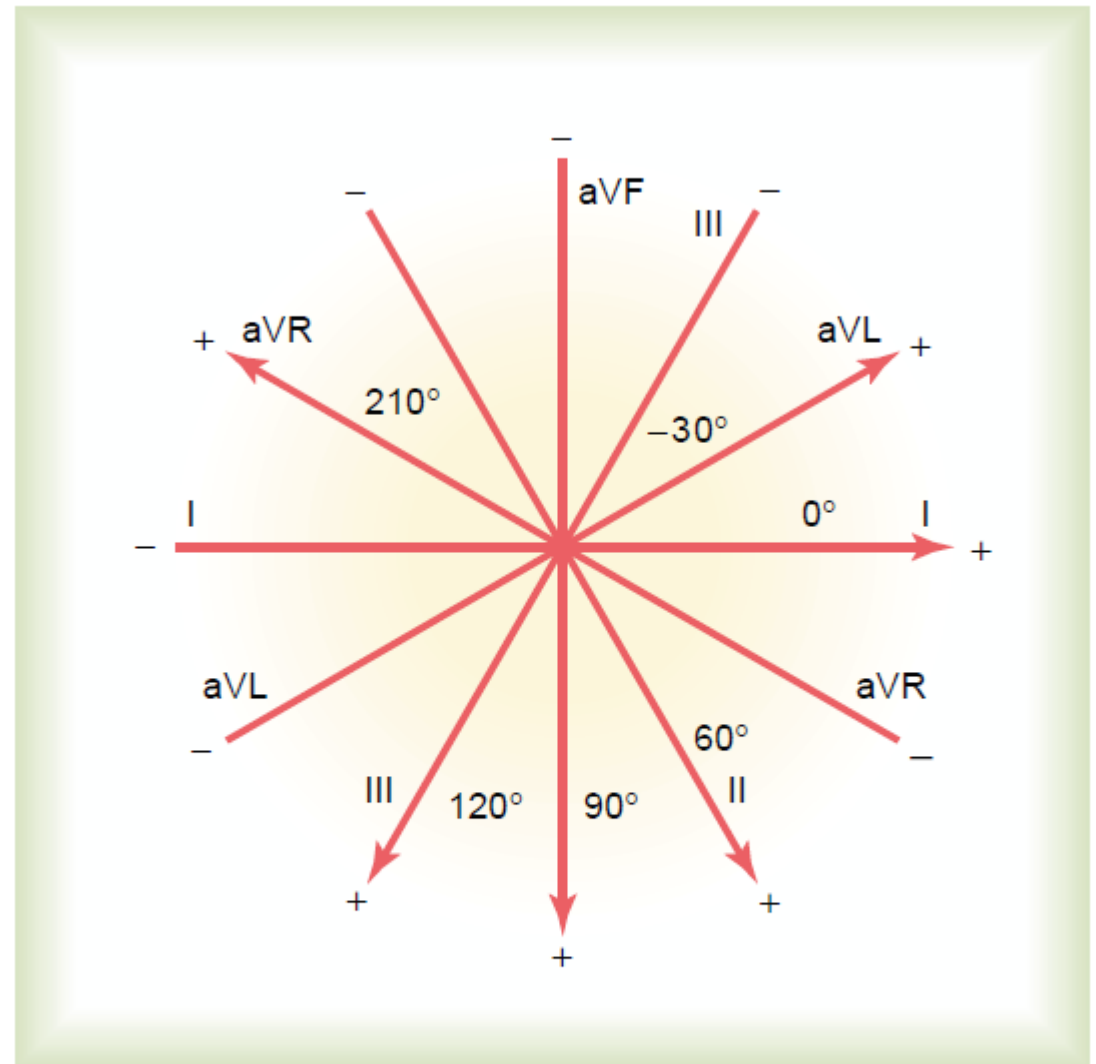
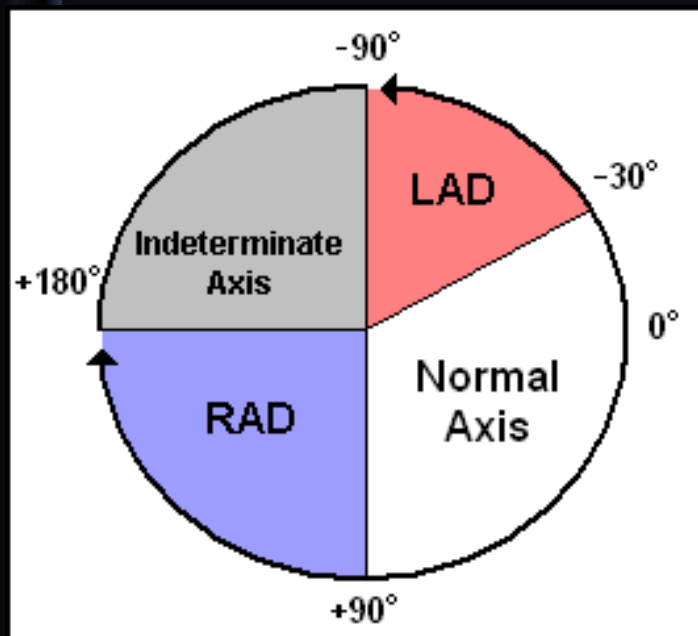


Figure 12-3

Axes of the three bipolar and three unipolar leads.