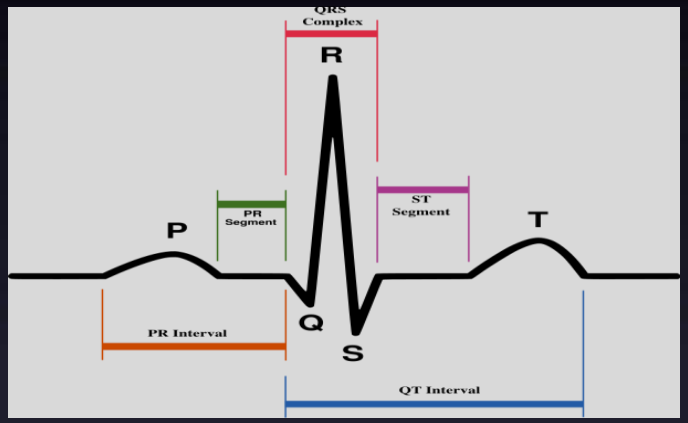
ELECTROCARDIOGRAM (ECG)



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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

DEFINITION

“ECG is a graphical representation of the sum of all the electrical activities of the heart usually recorded from the body surface”.

ECG can help the doctor see if you have heart muscle damage or electrical problems in the heart.

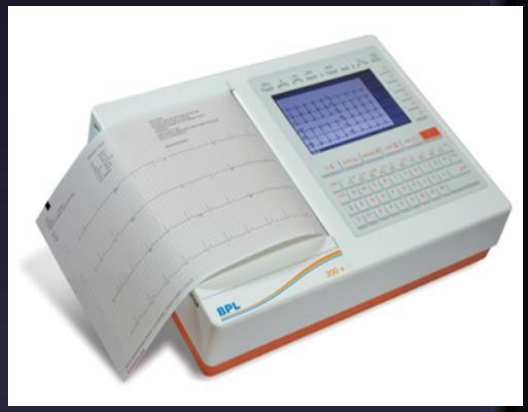
History of ECG

- The invention of the capillary electrometer in the early 1870s by Gabriel Lippmann led to the first recording of a human electrocardiogram by Augustus D. Waller. Without exposing the heart
- Einthoven presented his idea of applying the galvanometer to the recording of the cardiac electrical activity in 1903.
- He also coined the term elektrokardiogramm in German (the dominant language at the time for scientific publications) and labeled the recorded waveforms P, Q, R, S, T, and U to differentiate them from the original—but incomplete—A, B, C, and D described by Waller
- Waller was nominated for the Nobel Prize along with Einthoven but died before it could be presented, so Einthoven alone received it. (Waller AD J Phys 1917)

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 Immersed in Jars of Salt Solution

Modern ECG Machines



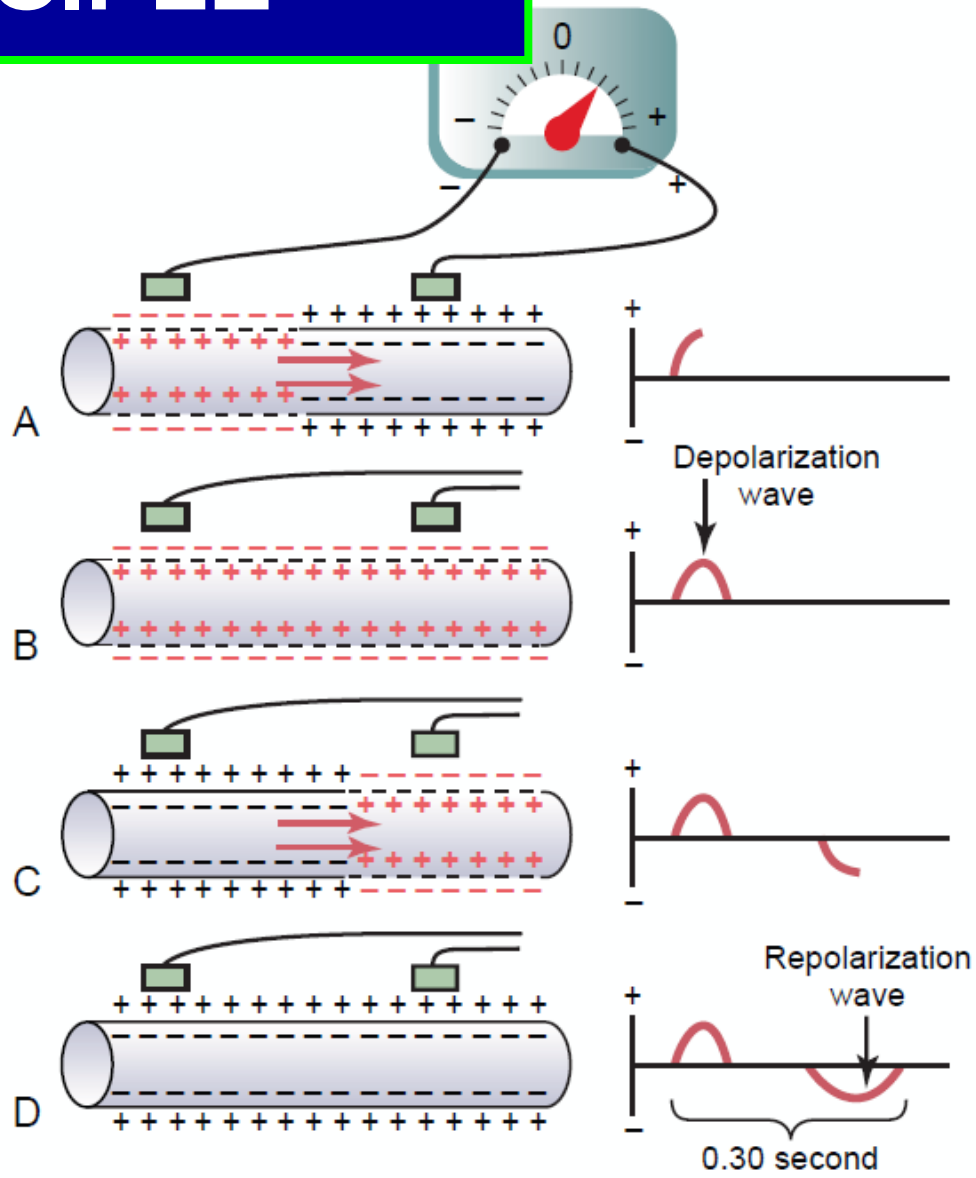
ECG helps in diagnosis of…

- Abnormal rhythms
- Conduction defects
- Electrolyte imbalances
- Abnormal heart rates
- Myocardial damage
- Chamber hypertrophies

What types of information can we obtain from an ECG?

- Heart rate
- Heart Rhythem
- Myopathies
- Helps in diagnosis of chest pain
- Proper use of thrombolysis in treatment of MI depend upon it
- Electrolyte disturbances (i.e. hyperkalemia, hypokalemia)
- Drug toxicity (i.e. digoxin and drugs which prolong the QT interval)

ECG PRINCIPLE



ECG PRINCIPLE

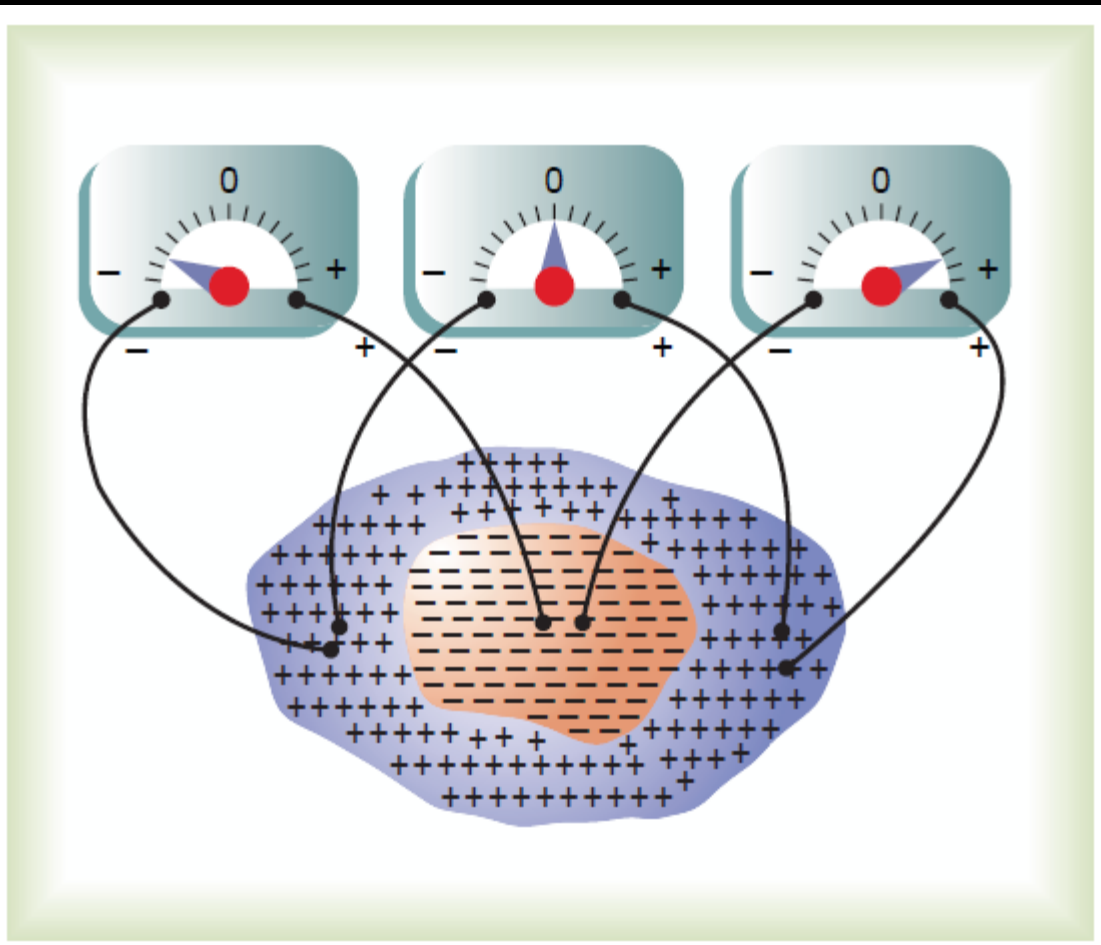


Figure 11–4

Instantaneous potentials develop on the surface of a cardiac muscle mass that has been depolarized in its center.

ECG Waveforms

P wave = atrial depolarisation.

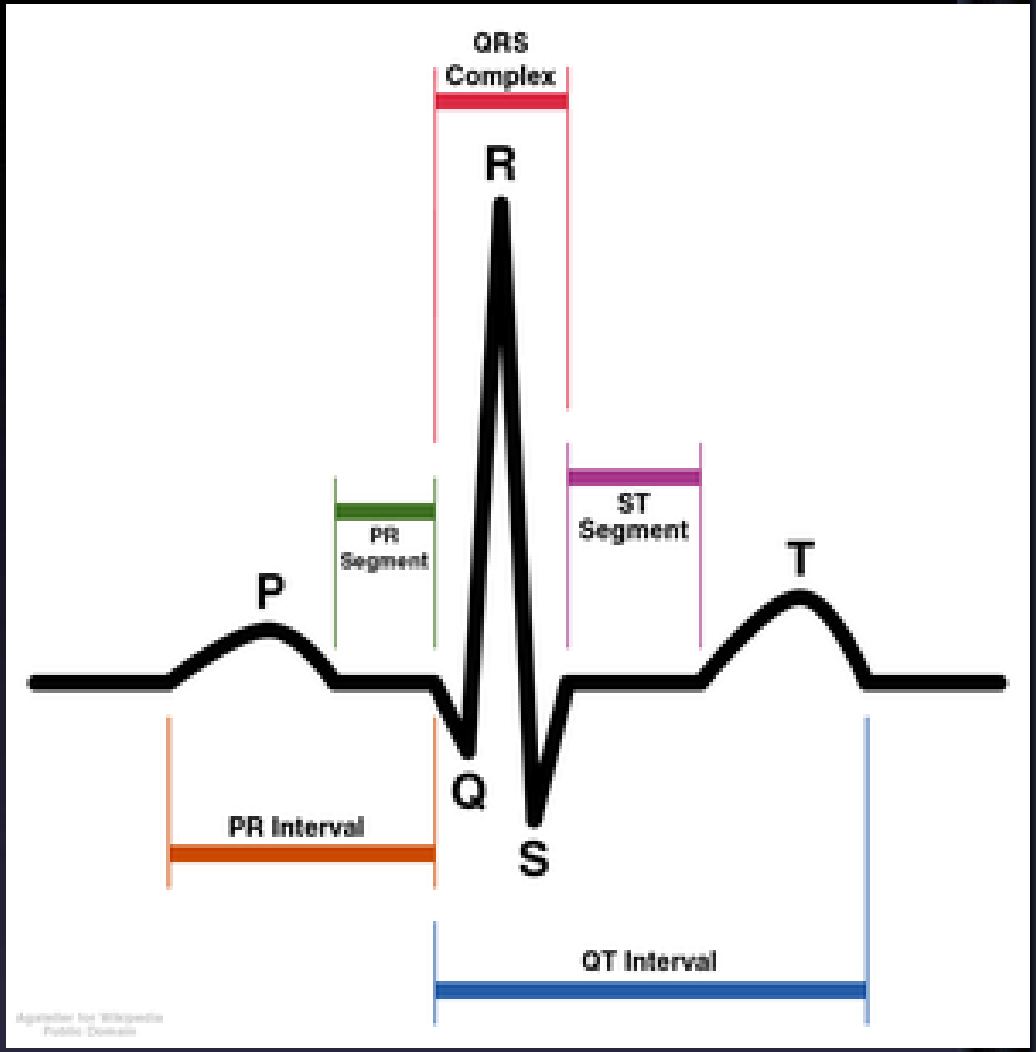
PR Interval = impulse from atria to ventricles.

QRS complex = ventricular depolarisation.

ST segment = isoelectric - part of repolarisation.

T wave = usually same direction as QRS - ventricular repolarisation.

QT Interval = This interval spans the onset of depolarisation to the completion of repolarization of the ventricles.



Causes of ECG Waves

ECG Wave	Cause	Represent
P- wave	**Atrial depolarization**	Time of electrical impulse from SA node to spread through atrial muscle. Duration = 0.08 –0.1 sec Precedes atrial contraction by ≈ 0.01 - 0.02 sec
QRS complex	**Ventricular depolarization**	Measured from beginning of Q wave till end of S wave. Consists of 3 waves: **Q wave: (-ve):** Produced by depolarization of interventricular septum. **R wave: (+ve):** Produced by depolarization of ventricular wall. **S wave: (-ve):** Produced by depolarization ofthe base of the heart. Duration ≤ 0.1 sec. Precedes ventricular contraction by ≈ 0.02 sec. Occurs after P-wave by ≈ 0.12-0.2 sec = PR interval
T- wave	**Ventricular repolarization**	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

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.

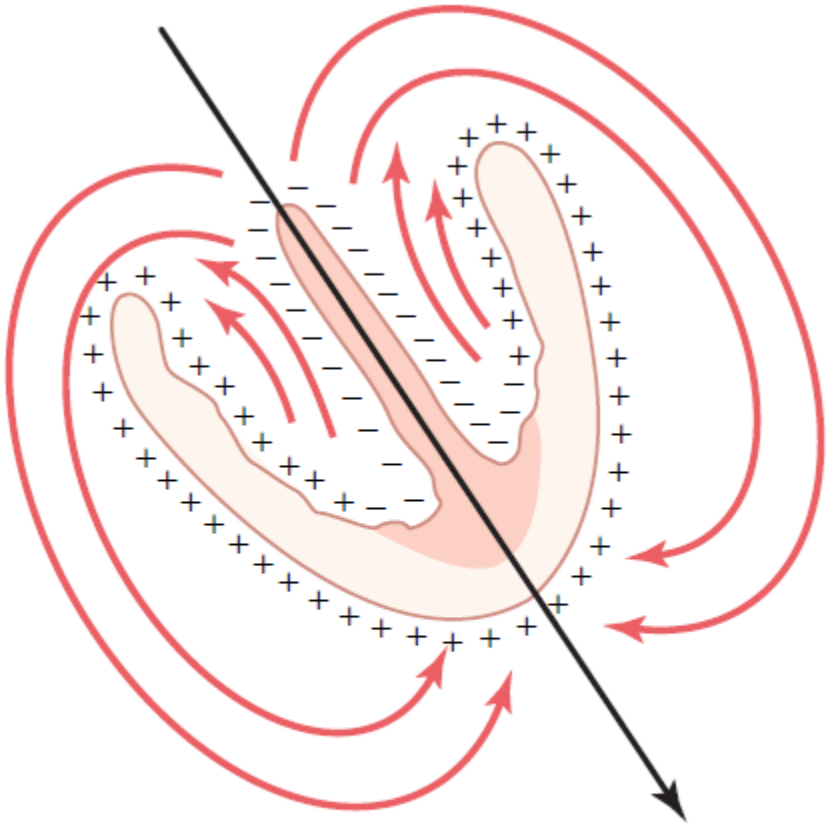


Figure 12–1

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

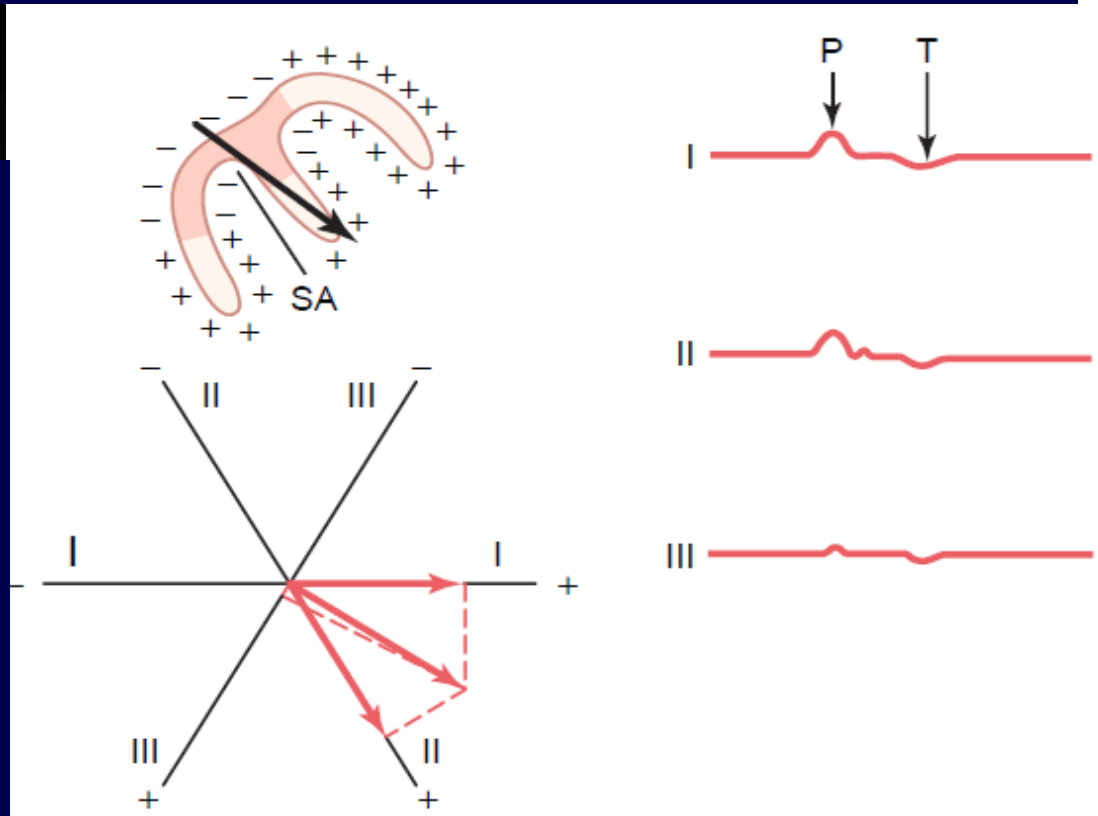


Figure 12–9

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

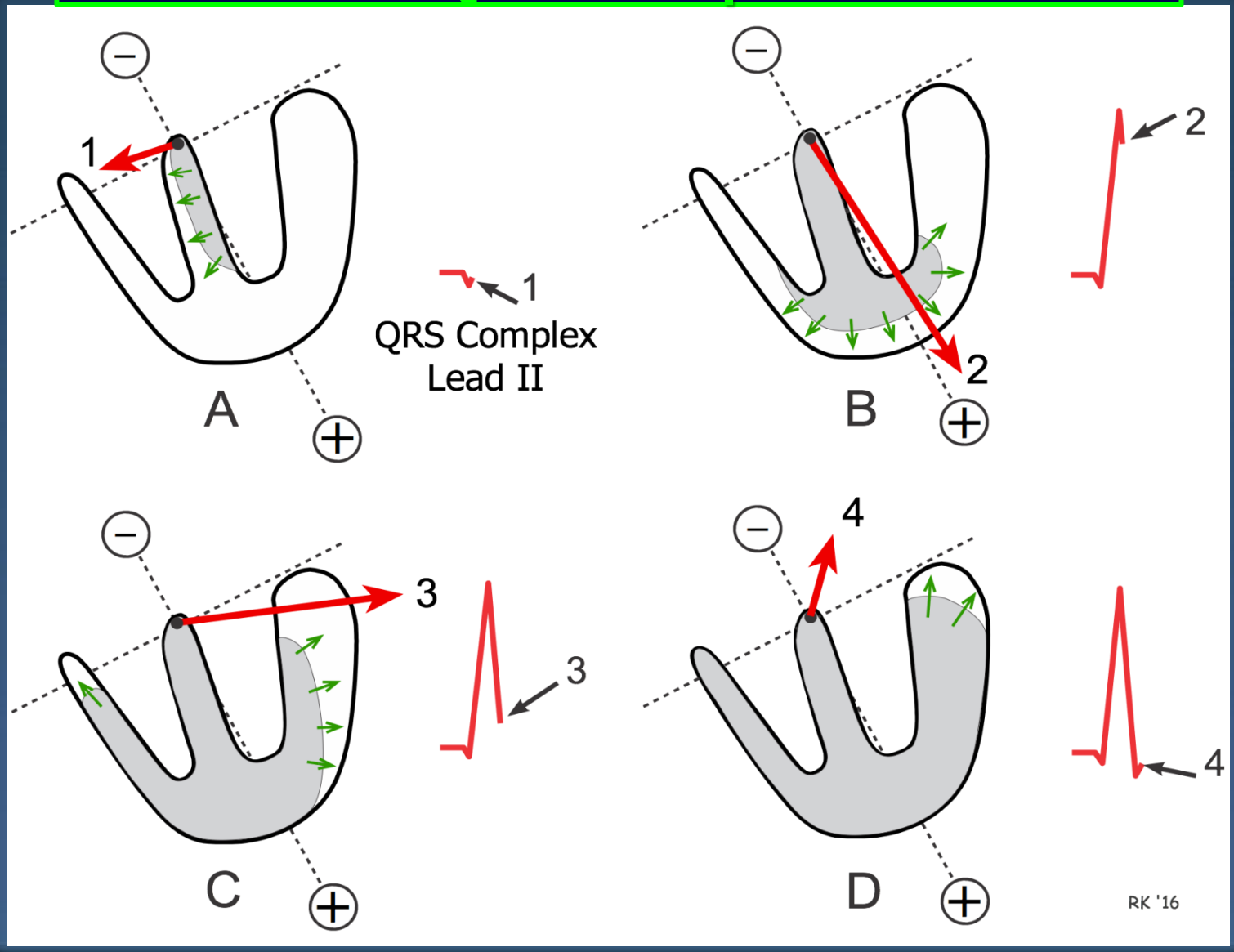
- When the cardiac impulse enters the ventricles through the atrioventricular bundle, the first part of the ventricles to become depolarized is the left endocardial surface of the septum.
- It spreads through the ventricular muscle to the outside of the heart
- Q wave is caused by initial depolarization 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 REPOLARIZATION—THE T WAVE

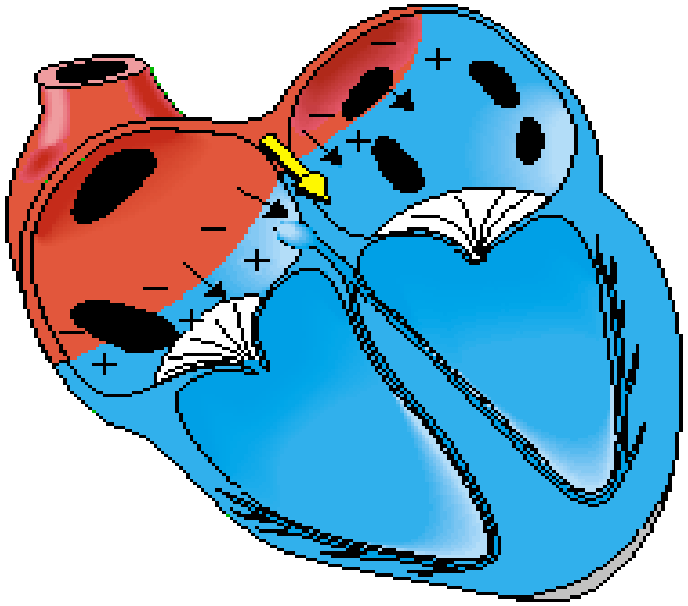
- The greatest portion of ventricular muscle mass to repolarize first is the entire outer surface of the ventricles, especially near the apex of the heart because the septum and other endocardial areas have a longer period of contraction than do most of the external surfaces of the heart so endocardial 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.

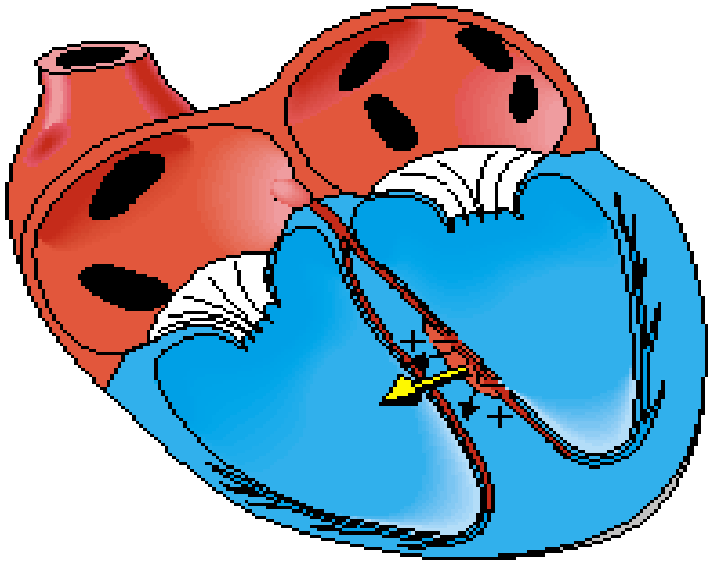
Pattern of Excitation of Ventricles to Produce QRS Complex in ECG



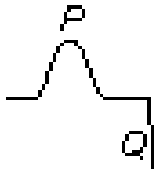
ATRIAL
DEPOLARIZATION
80 ms



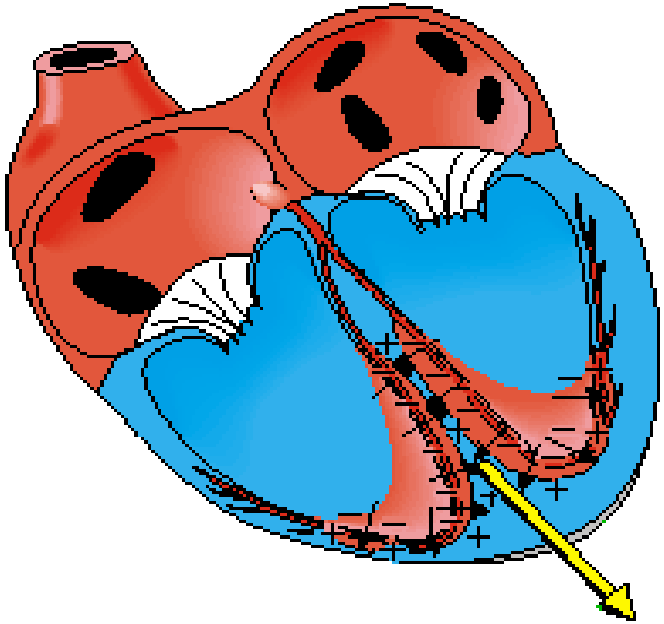
SEPTAL
DEPOLARIZATION
220 ms

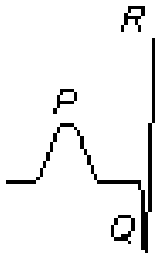


Pattern of Excitation of Heart & ECG

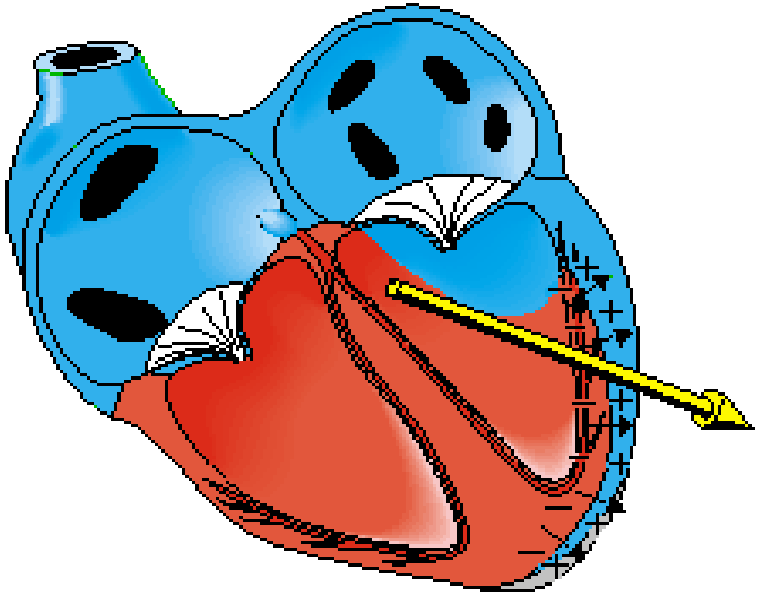


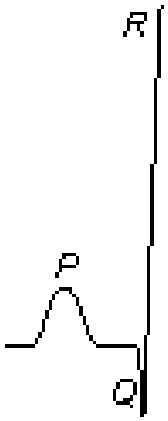
APICAL
DEPOLARIZATION
230 ms





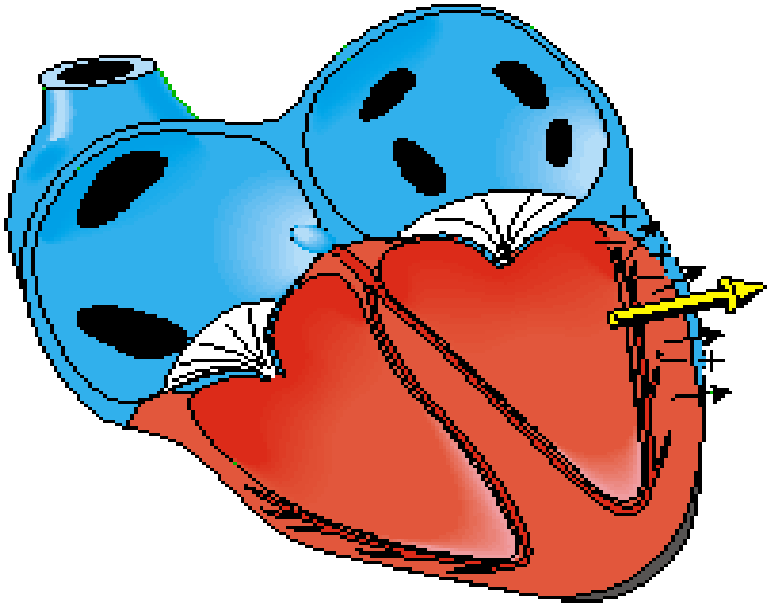
LEFT VENTRICULAR
DEPOLARIZATION
240 ms

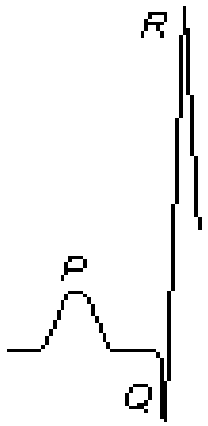




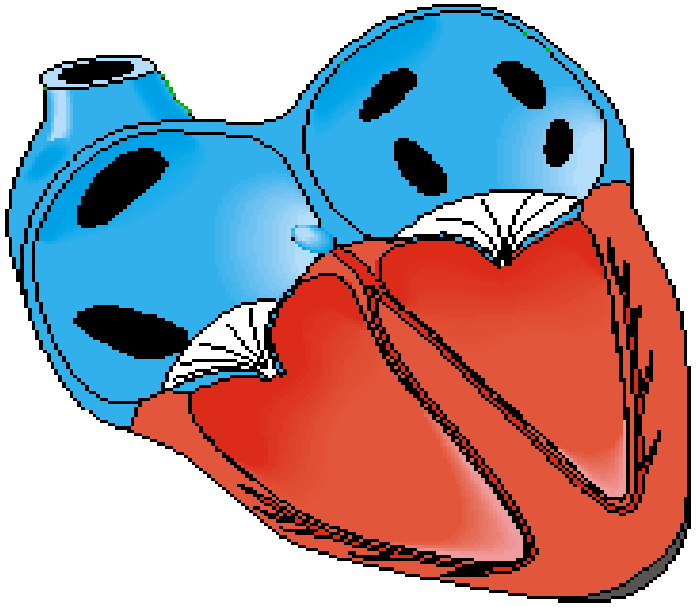
Pattern of Excitation of Heart & ECG waves

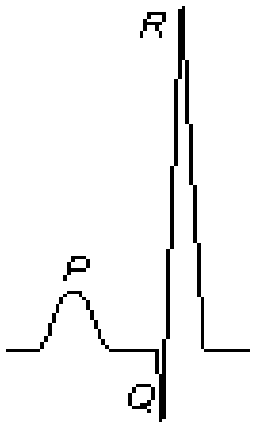
LATE LEFT VENTRICULAR
DEPOLARIZATION
250 ms





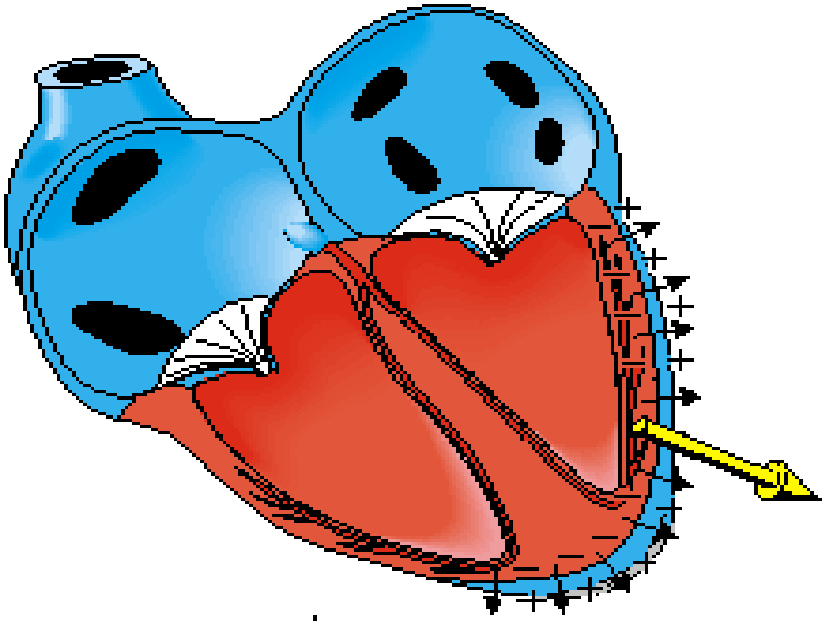
VENTRICLES
DEPOLARIZED
350 ms



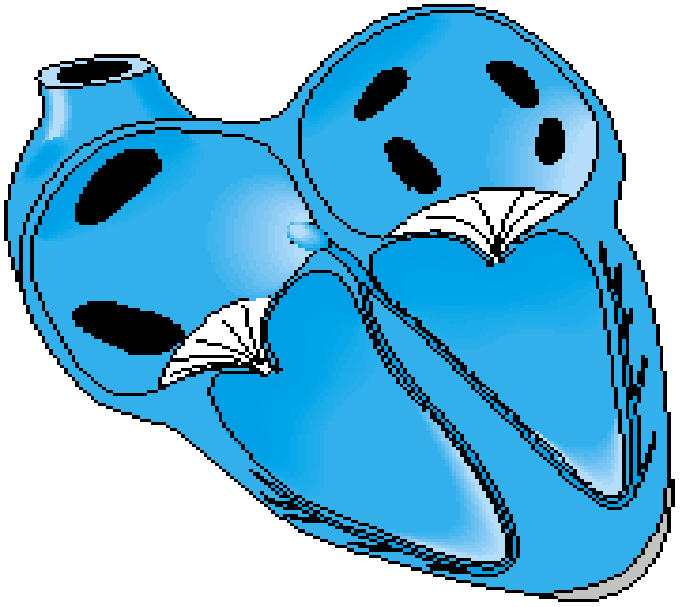


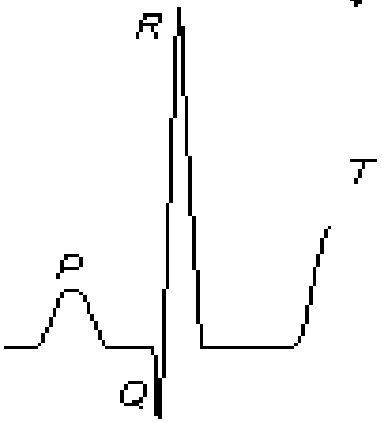
Pattern of Excitation of Heart & ECG waves

VENTRICULAR
REPOLARIZATION
450 ms



VENTRICLES
REPOLARIZED
600 ms





Pattern of Excitation of Heart & ECG waves

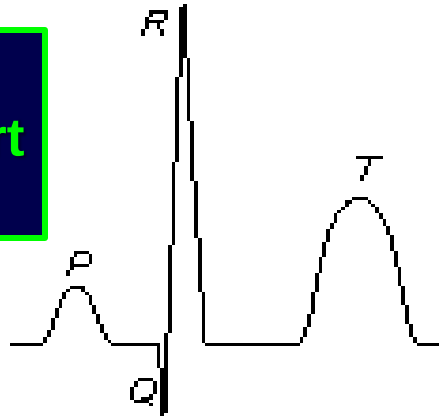


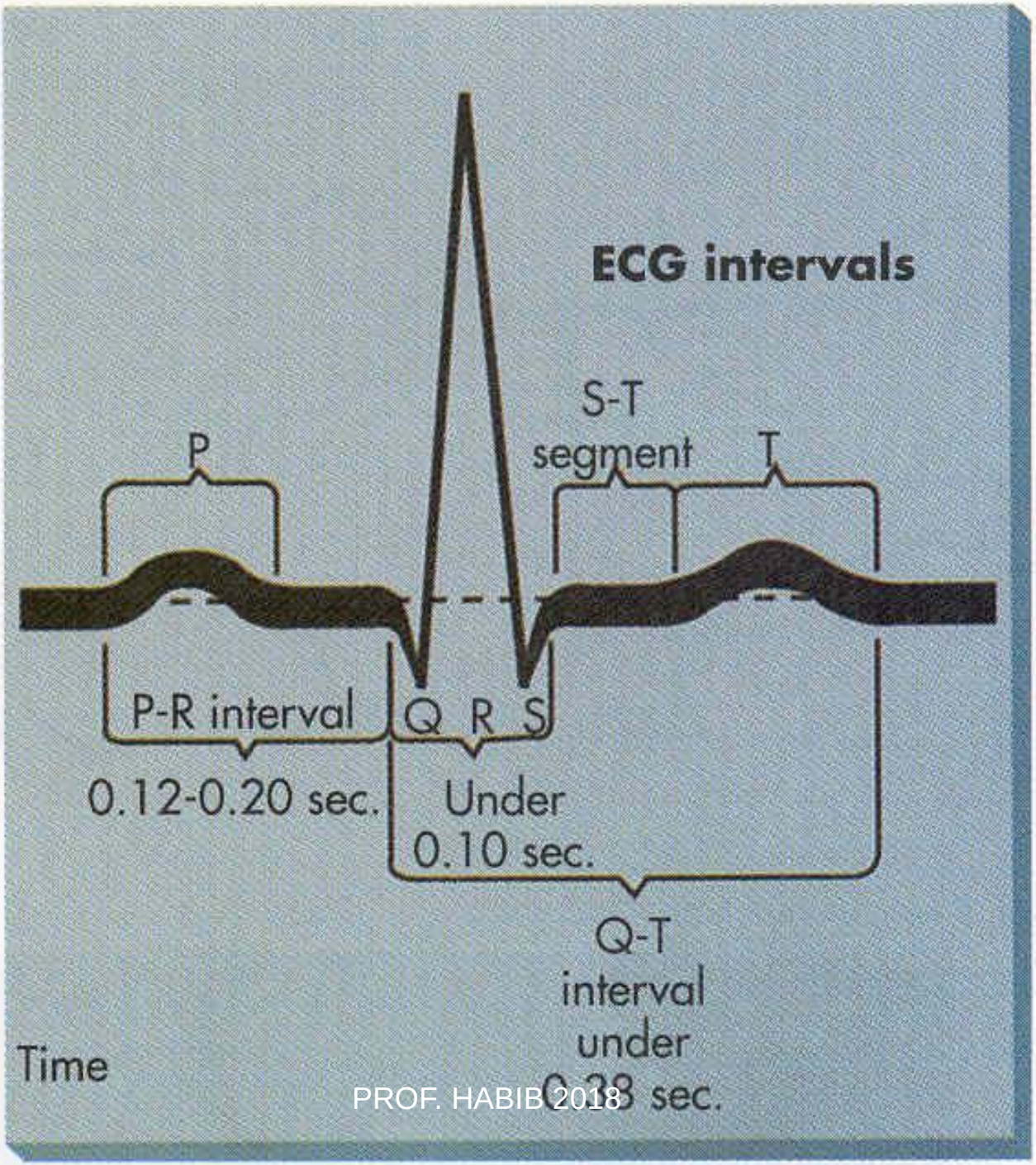
TABLE 29–2 ECG intervals.

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

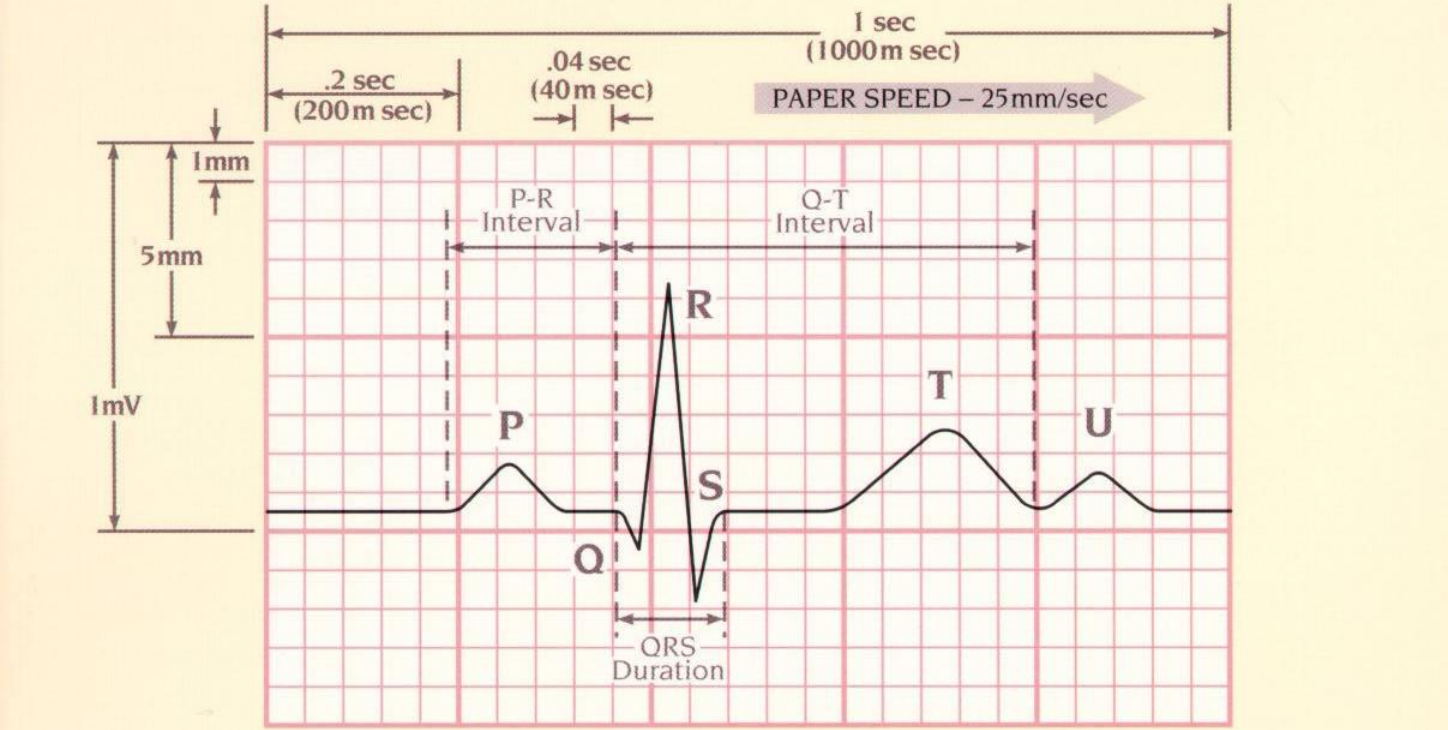
[a]Measured from the beginning of the P wave to the beginning of the QRS complex.

[b]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.

[c]Can be lower (0.35) depending on the heart rate



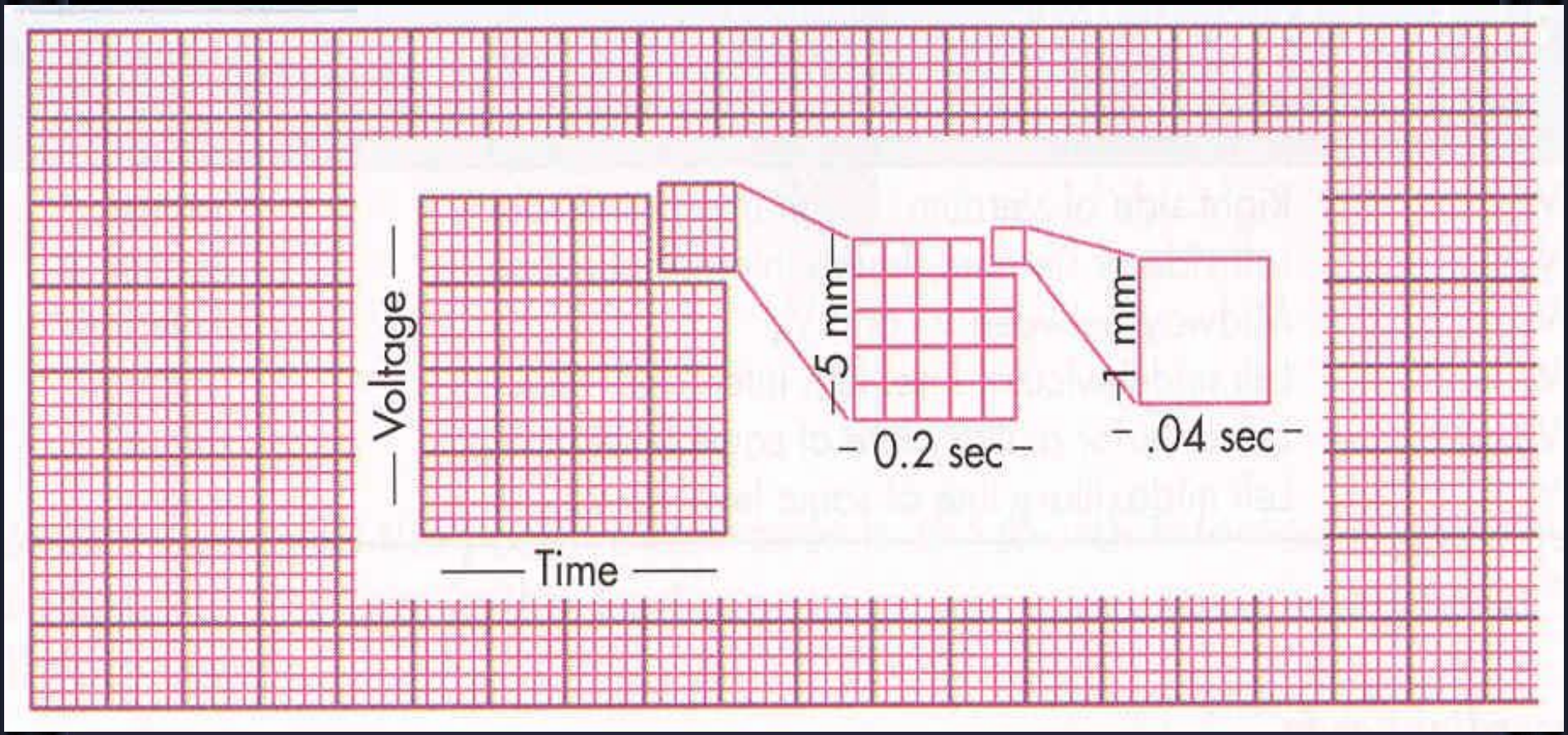
The ECG Paper



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

HORIZONTAL AXIS	
	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



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
Bipolar	I, II, III (standard limb leads)	-
Unipolar (V leads)	aVR, aVL, aVF (augmented limb leads)	V_1-V_6

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.

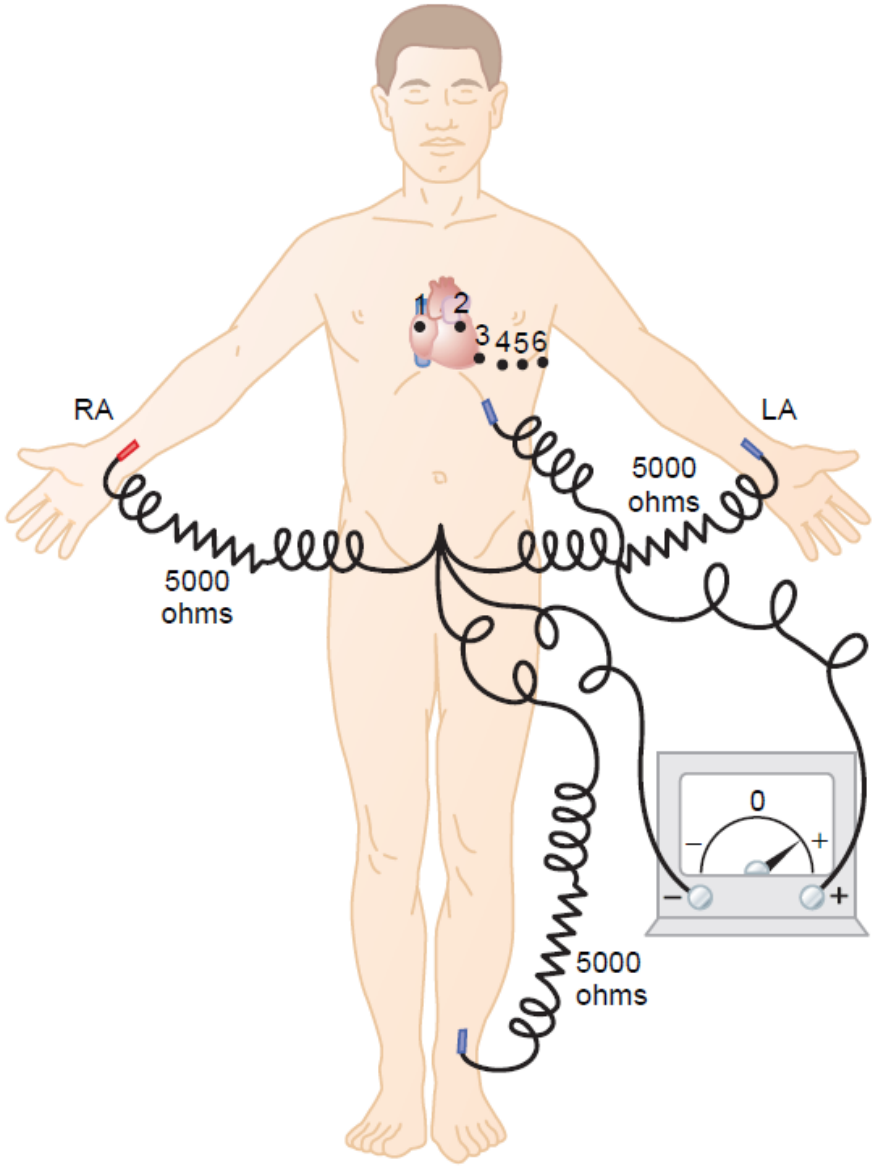


Figure 11–8

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

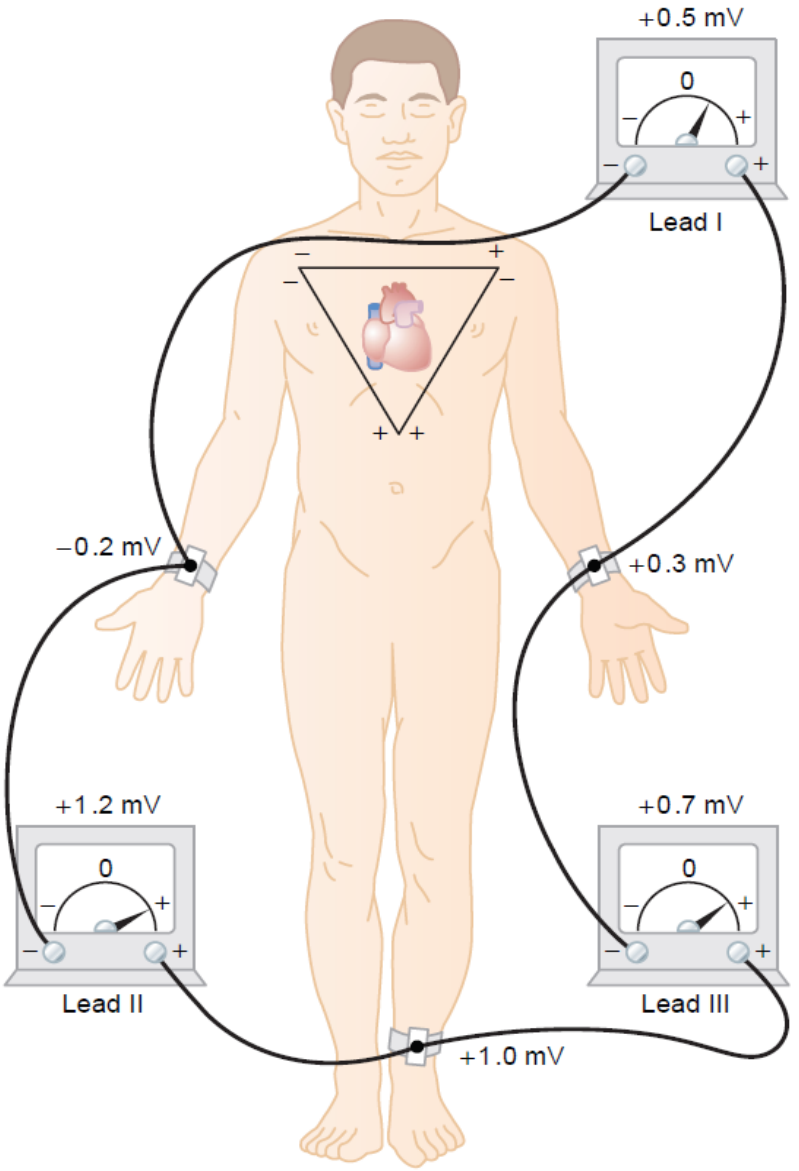
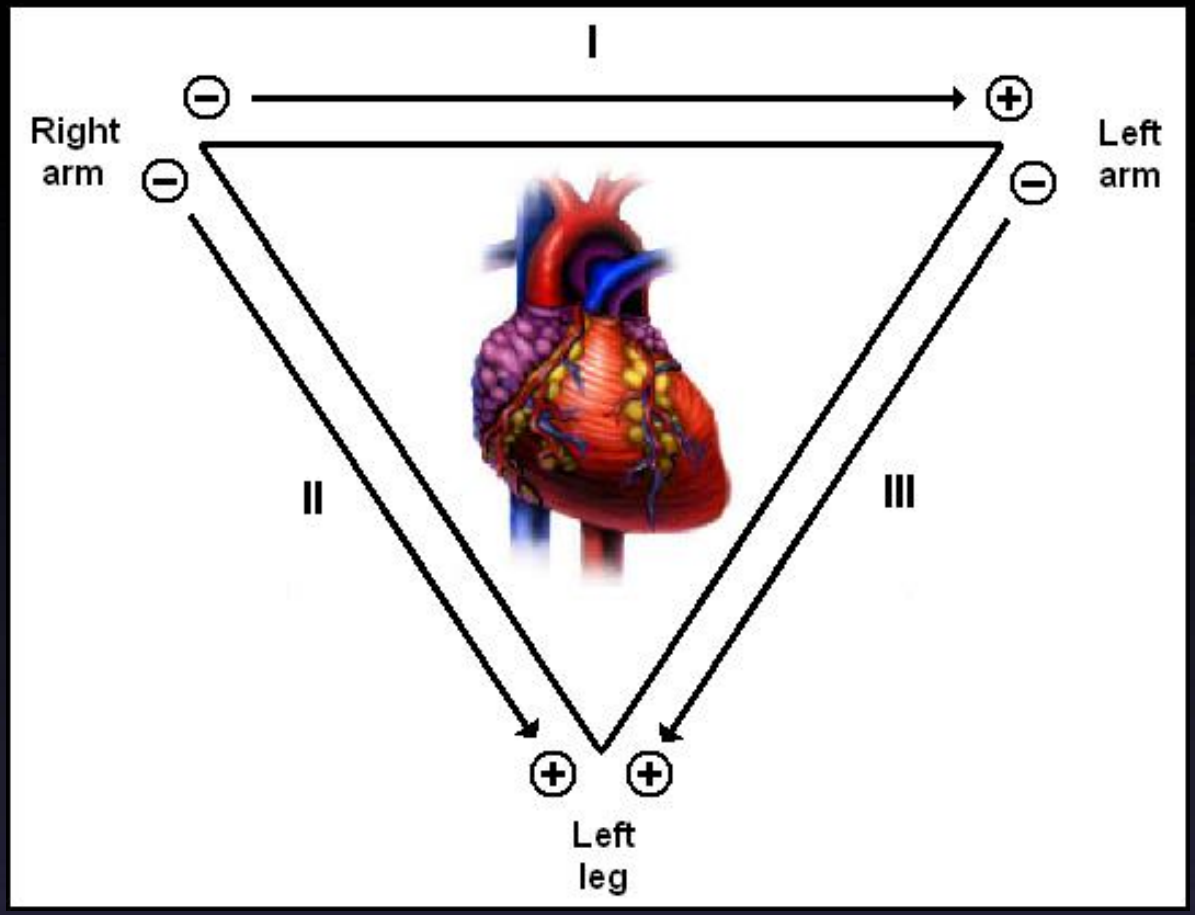


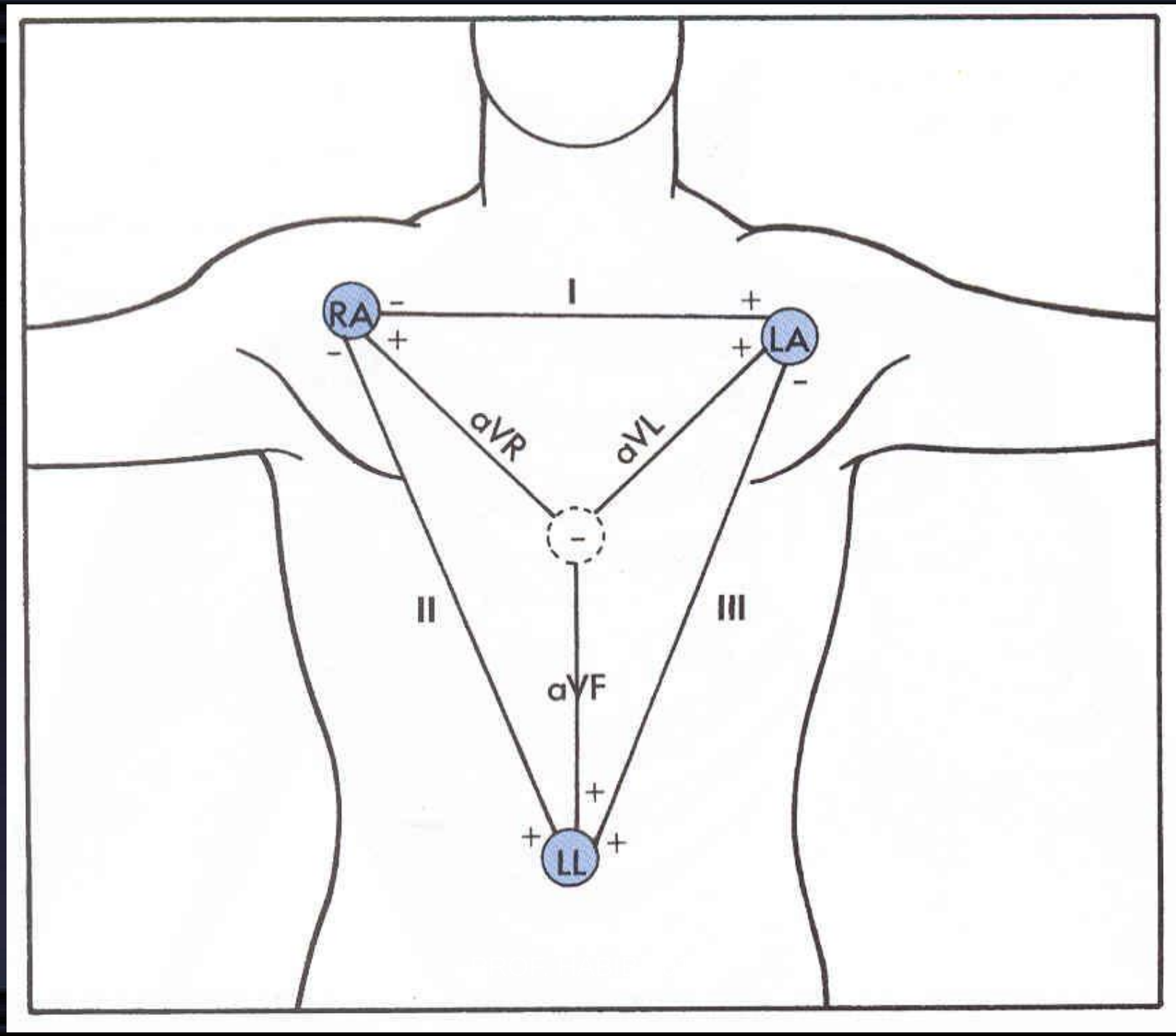
Figure 11–6

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.


RA
LA
LL
I
II
III
aVR
aVL
aVF
–
+

Lead Placement

V1 = 4th ICS right sternum

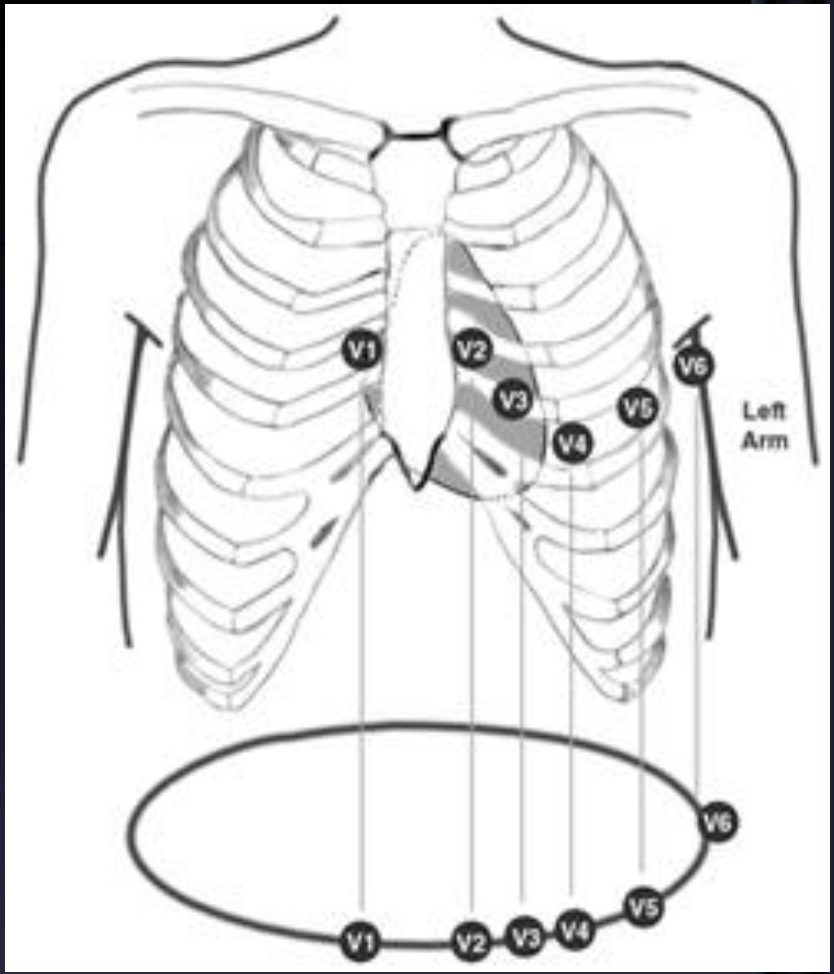
V2 = 4th ICS left sternum

V3 = midway between V2 and V4

V4 = 5th ICS midclavicular

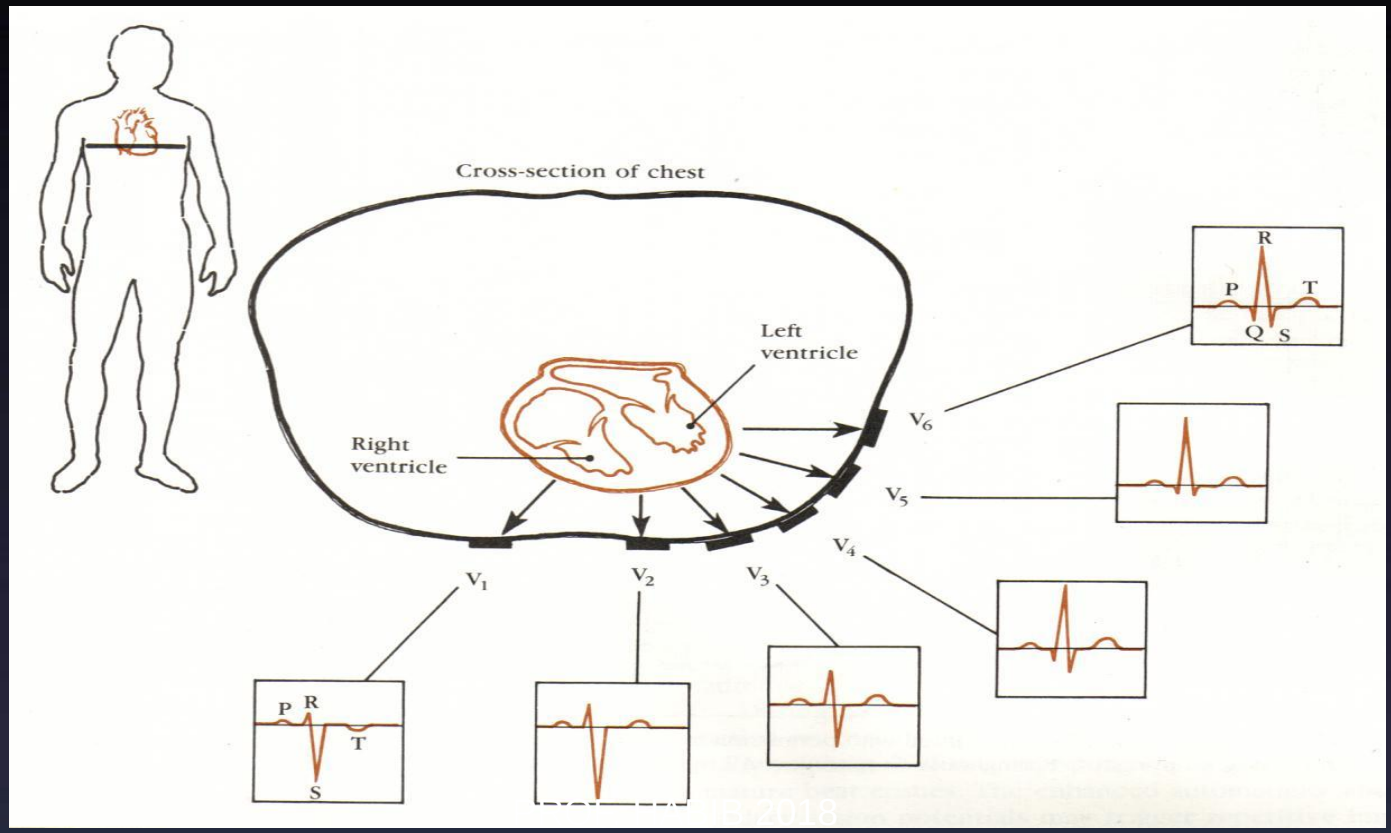
V5 = between V4 and V6 anterior auxiliary line

V6 = midauxillary line lateral to V4 and V5

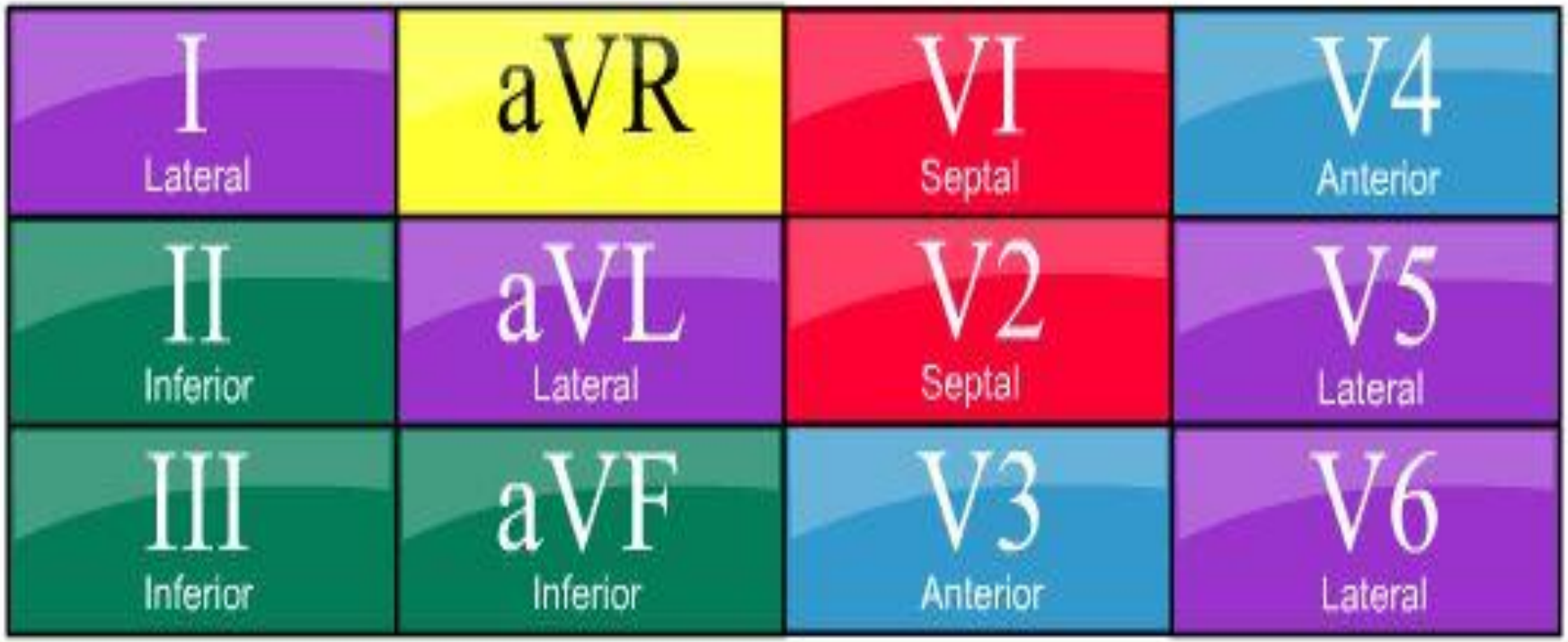


Lead Placement

- Electrical activity towards a recording electrode = ↑ potential
- Electrical activity away from a recording electrode = ↓ potential



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



The criteria for a STEMI is ST segment elevation in two or more contiguous Leads

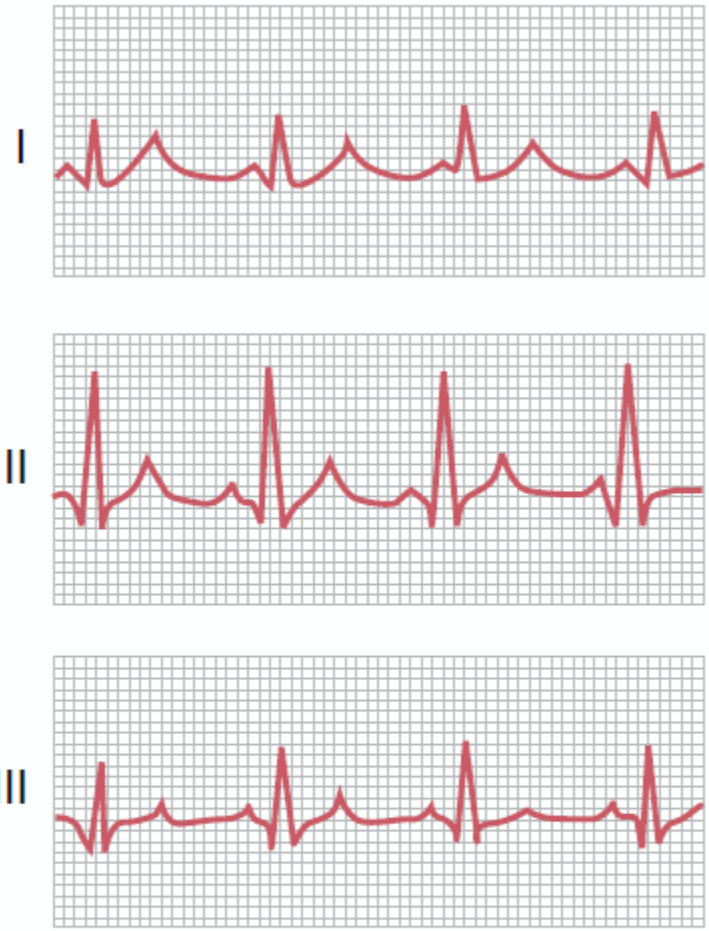


Figure 11–7

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

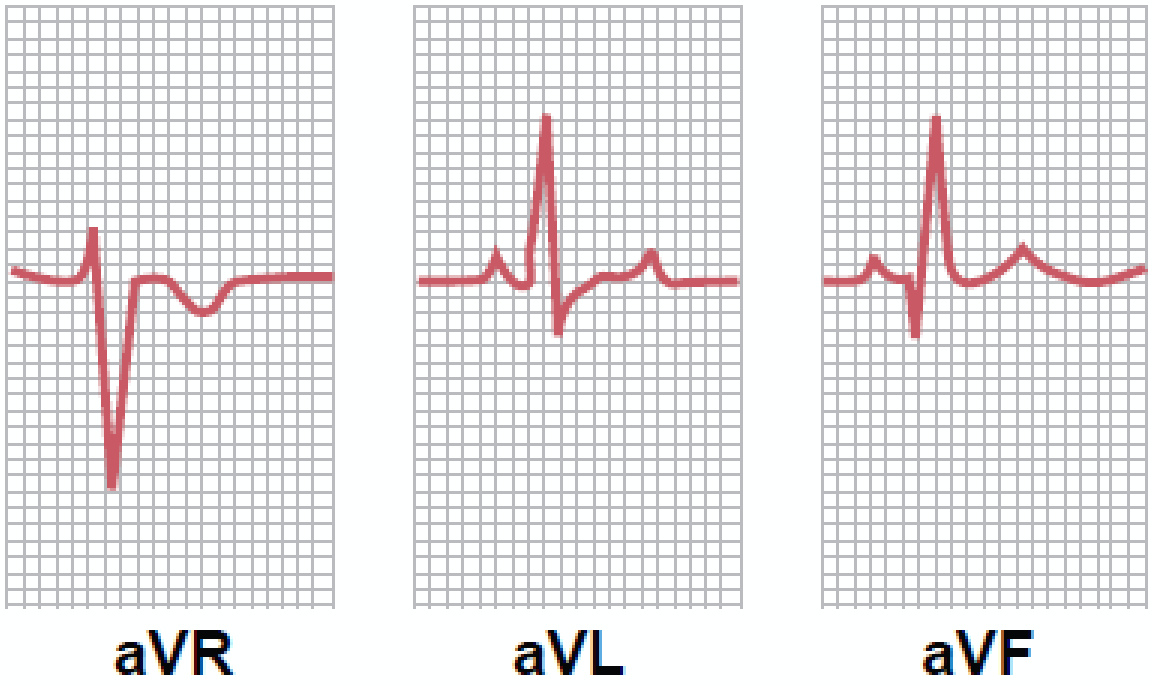


Figure 11–10

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

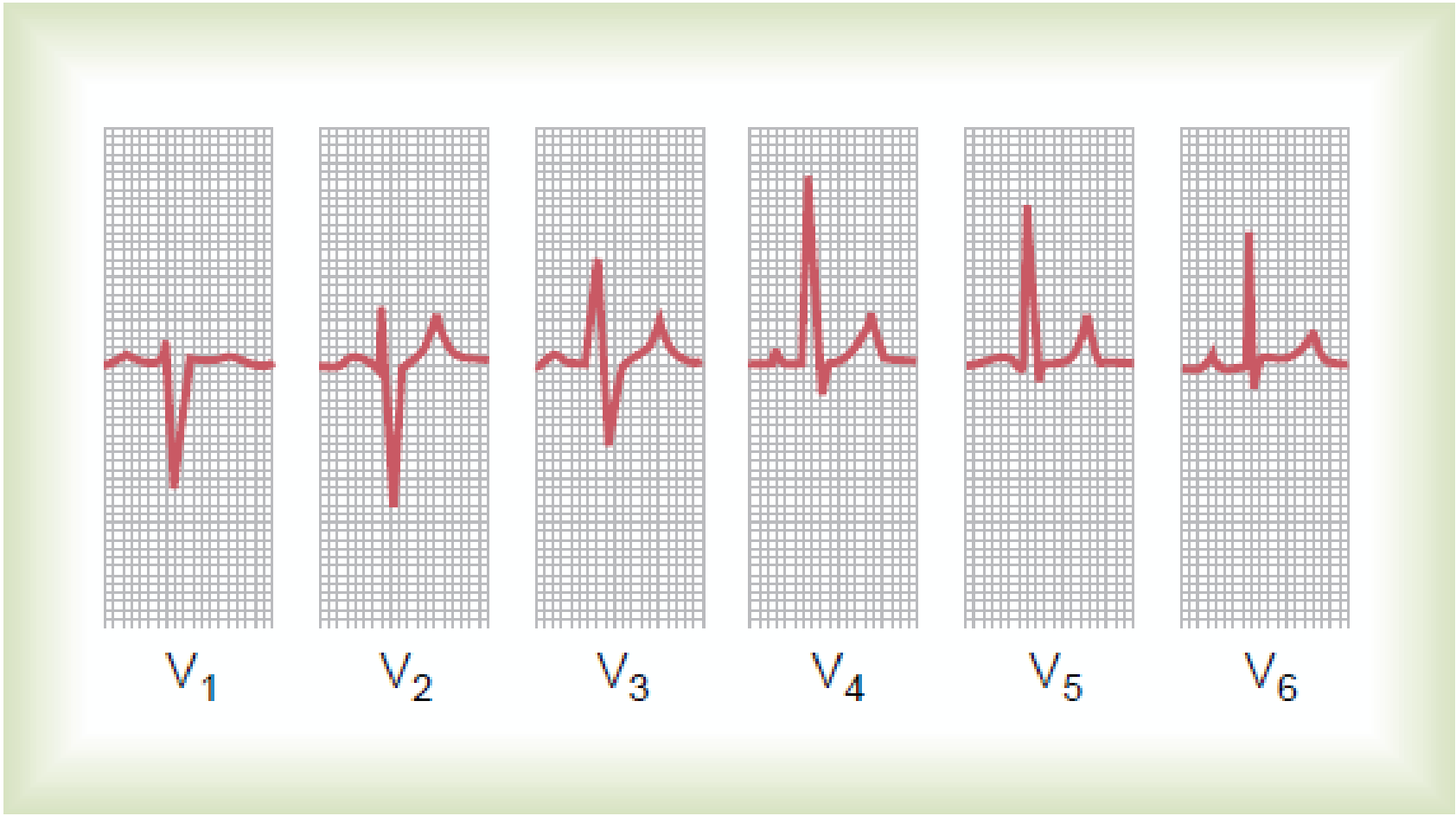


Figure 11–9

Normal electrocardiograms recorded from the six standard chest leads.


THANKS
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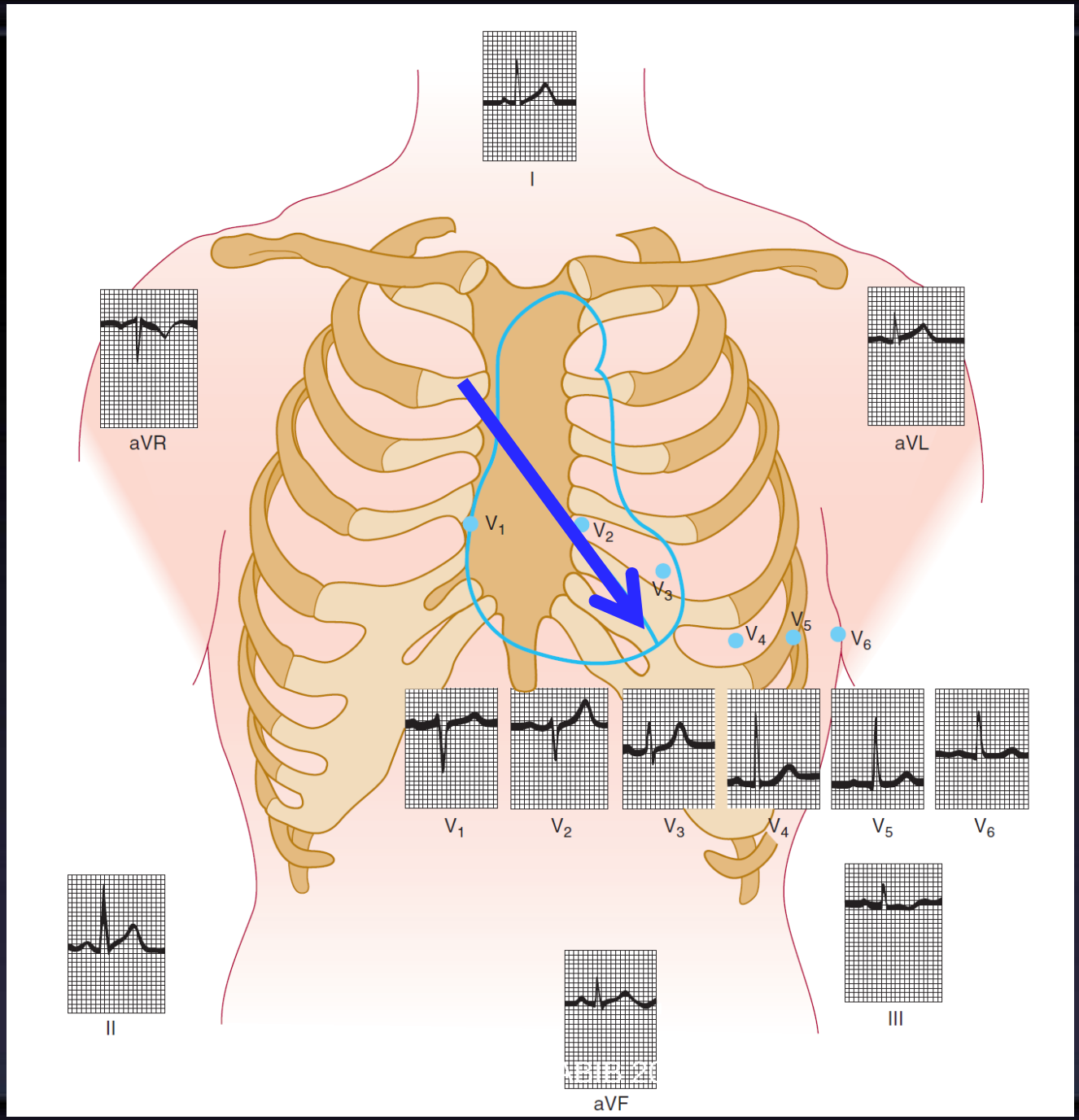

I
aVR
aVL
V1
V2
V3
V4
V5
V6
V1
V2
V3
V4
V5
V6
II
aVF
III

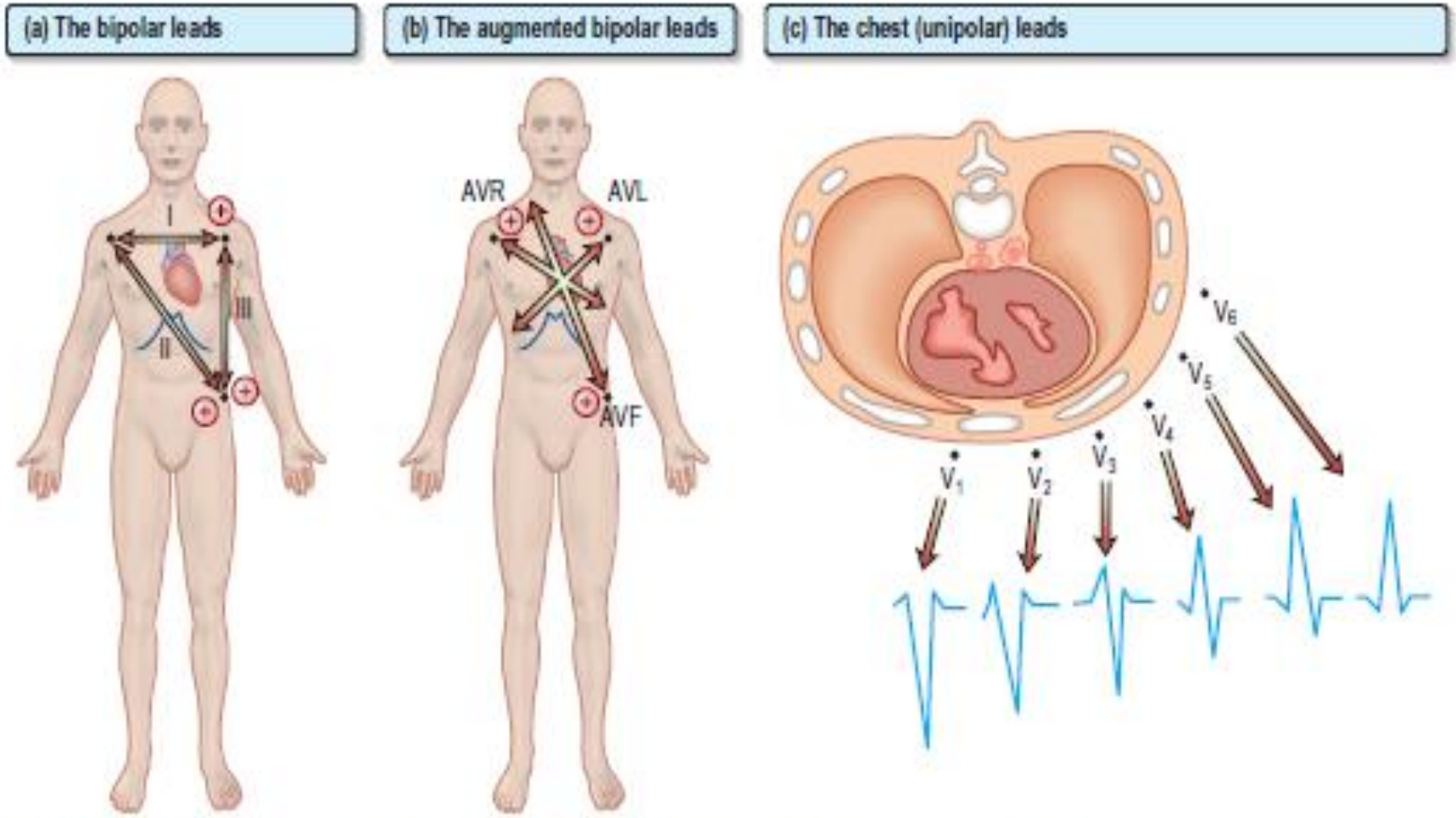
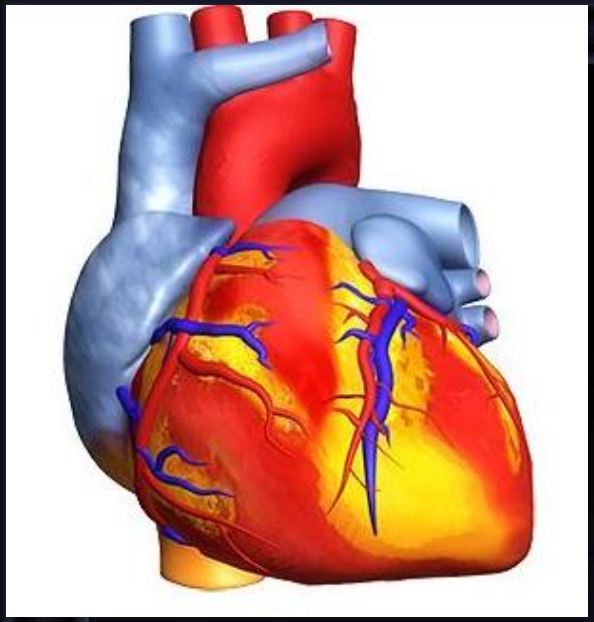
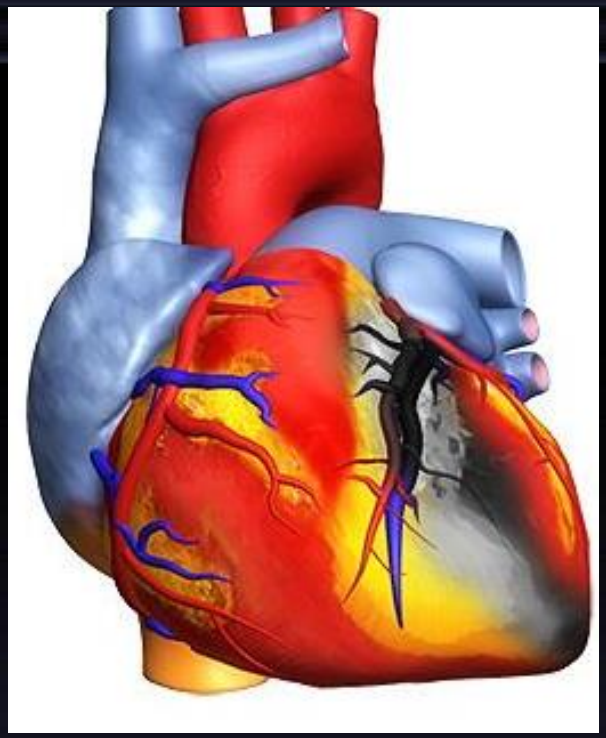
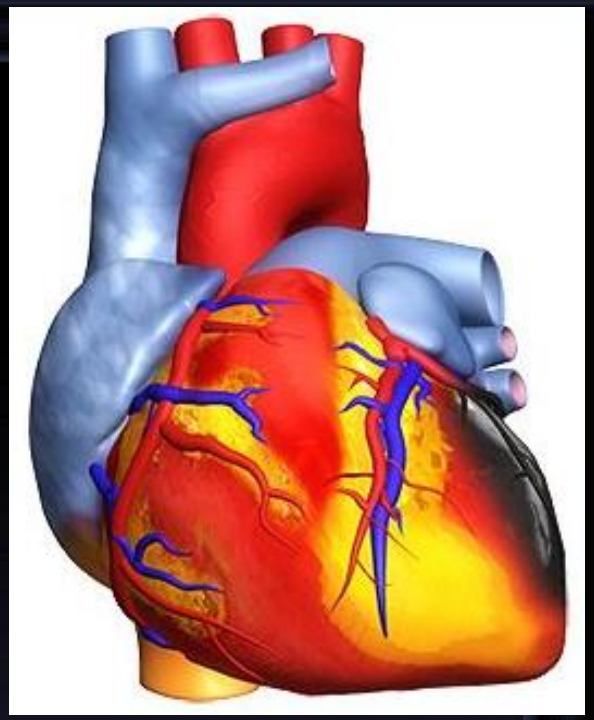
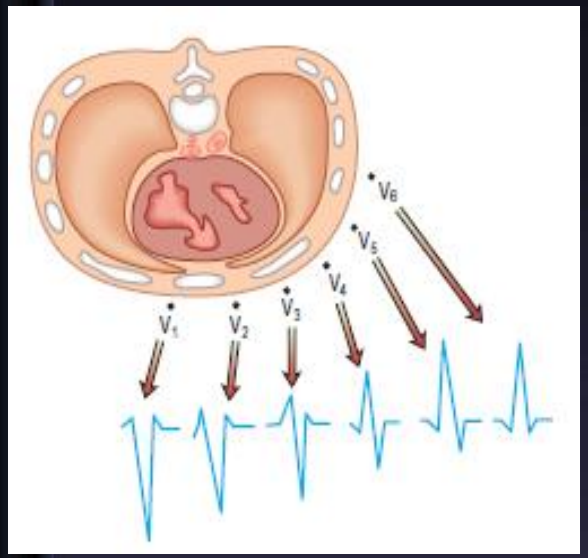


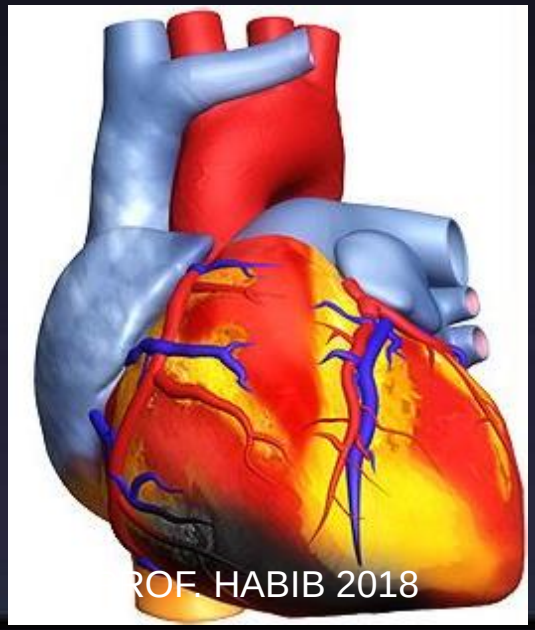
Fig. 13.17 **The connections or directions that comprise the 12-lead electrocardiogram.**

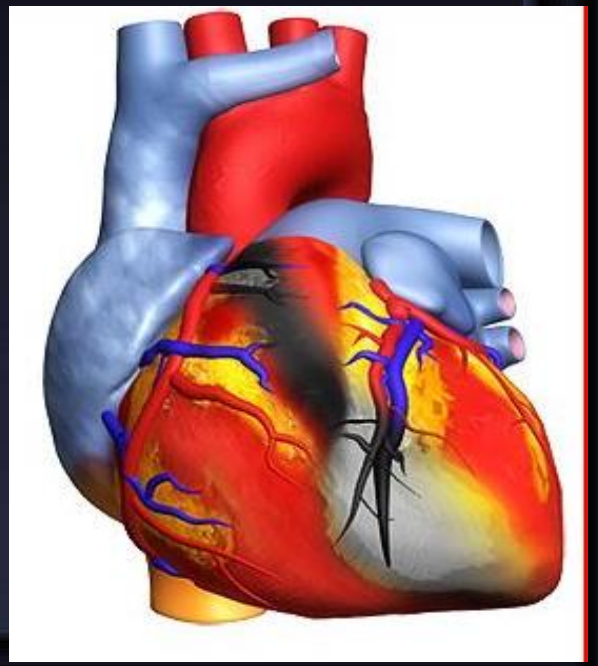







V1
V2
V3
V4
V5
V6





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.

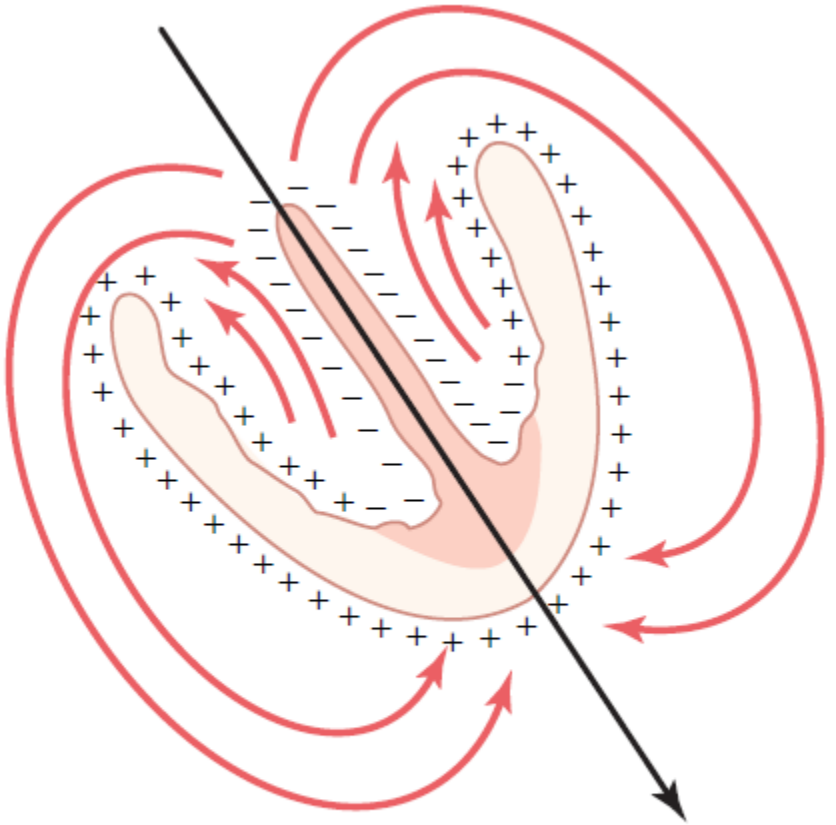


Figure 12–1

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

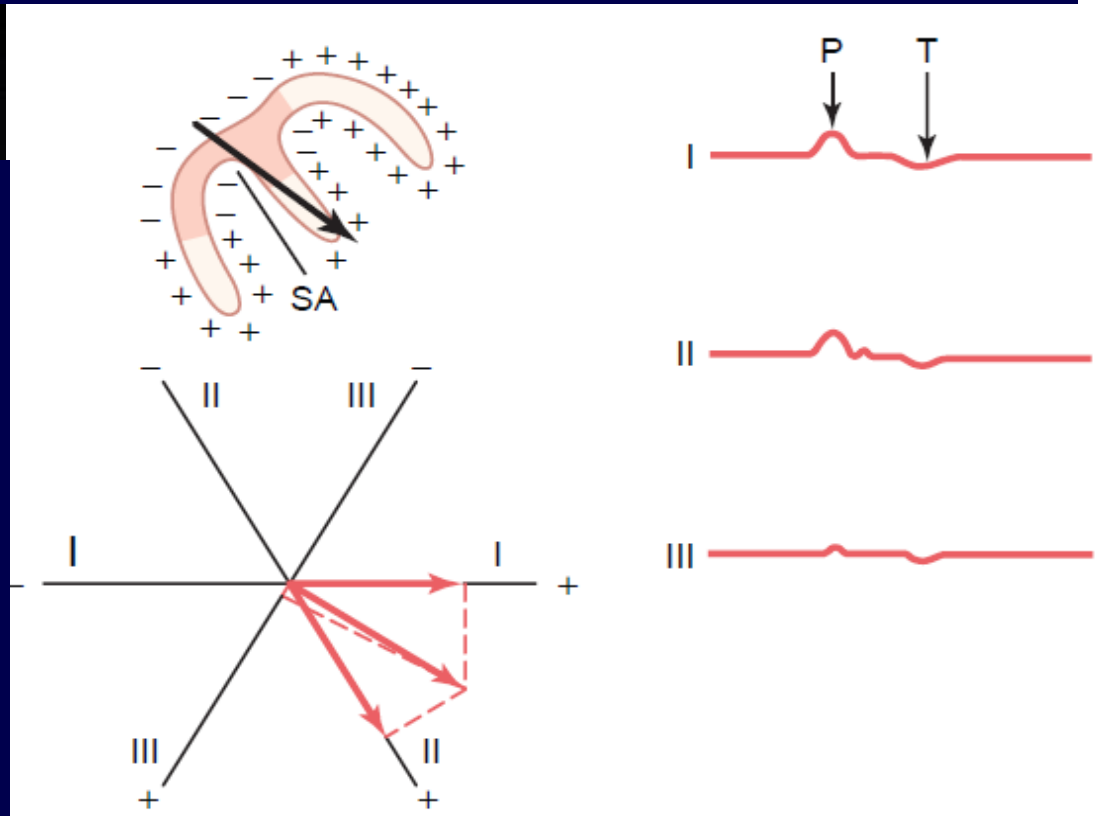


Figure 12–9

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.

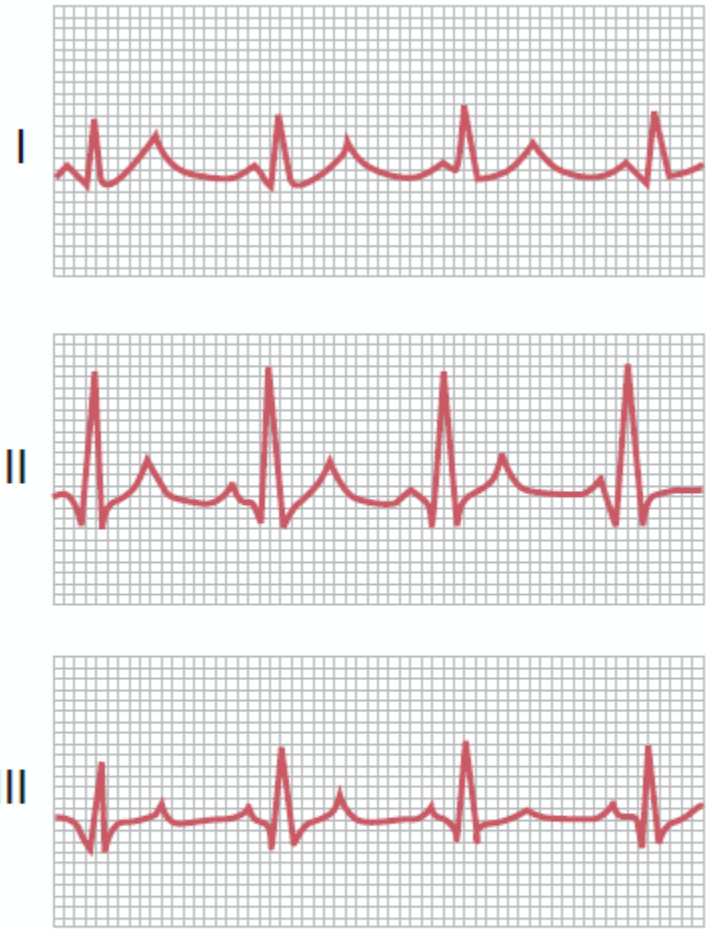


Figure 11–7

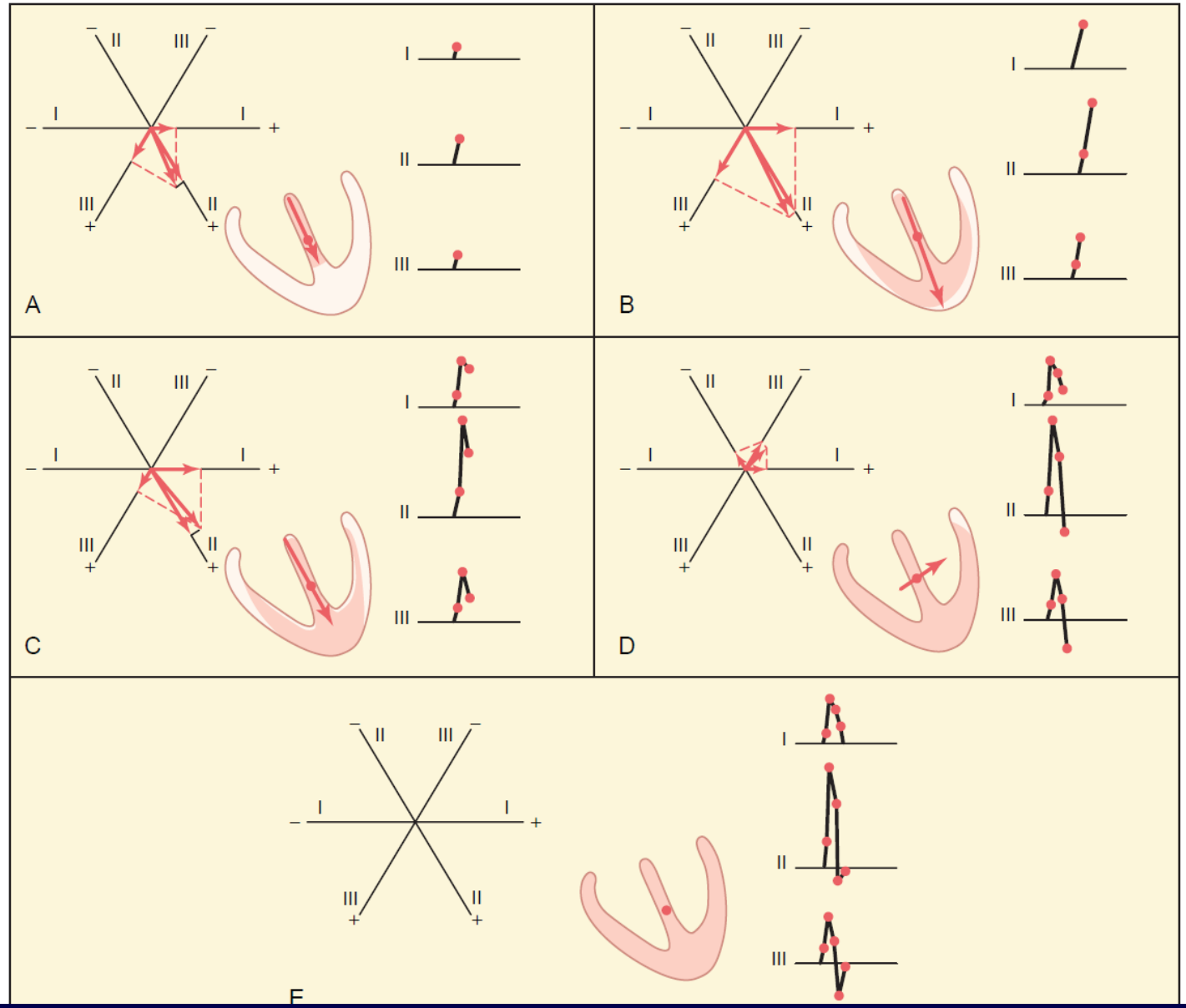
Normal electrocardiograms recorded from the three *standard* electrocardiographic leads.

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

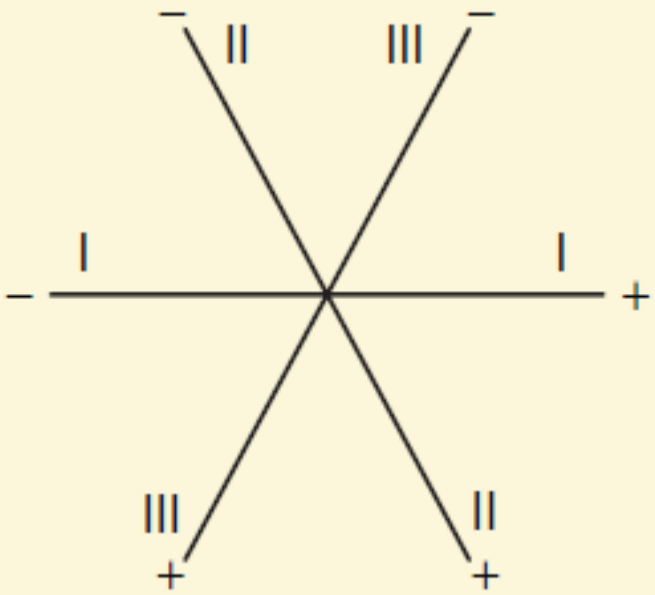
- When the cardiac impulse enters the ventricles through the atrioventricular bundle, the first part of the ventricles to become depolarized is the left endocardial surface of the septum.

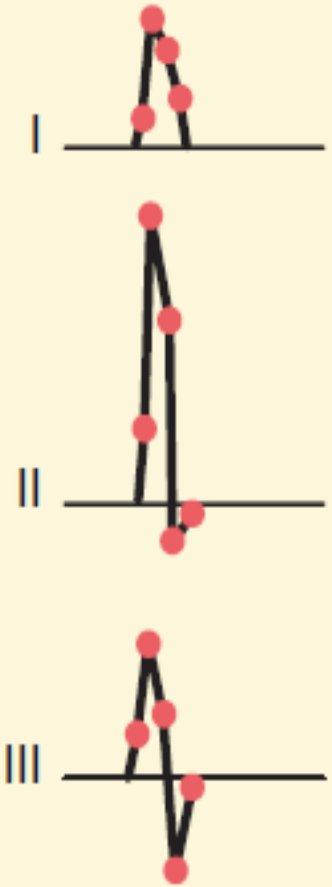
- It spreads through the ventricular muscle to the outside of the heart

- 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.



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 s (B); 0.035 s (C); 0.05 s (D); and after depolarization of the ventricles is complete, 0.06 second after onset (E).





E

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 s (B); 0.035 s (C); 0.05 s (D); and after depolarization of the ventricles is complete, 0.06 second after onset (E).

ELECTROCARDIOGRAM DURING REPOLARIZATION—THE T WAVE

- 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.

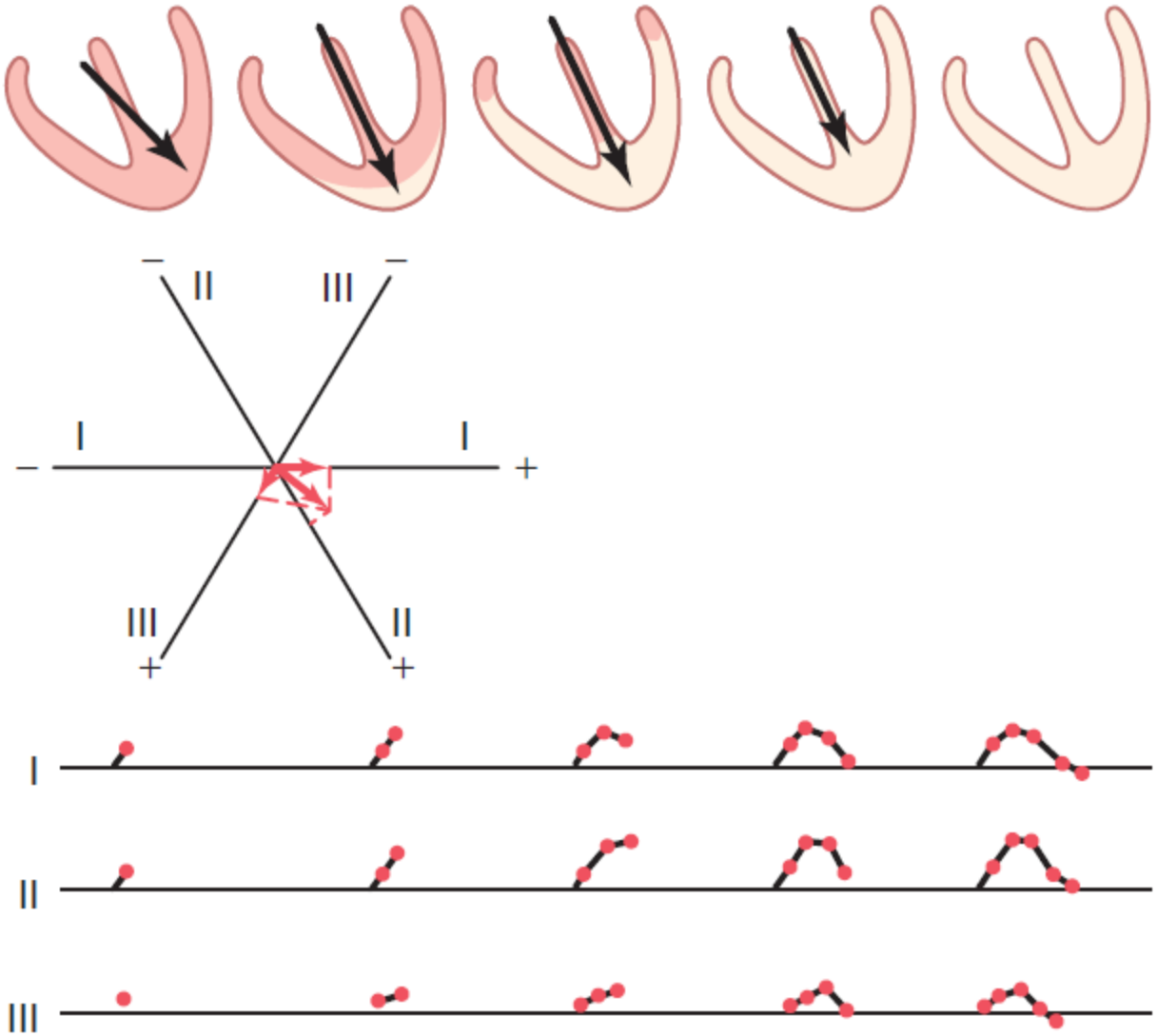


Figure 12-8. Generation of the T wave during repolarization of the ventricles, showing also vectorial analysis of the first stage of repolarization. The total time from the beginning of the T wave to its end is approximately 0.15 second.

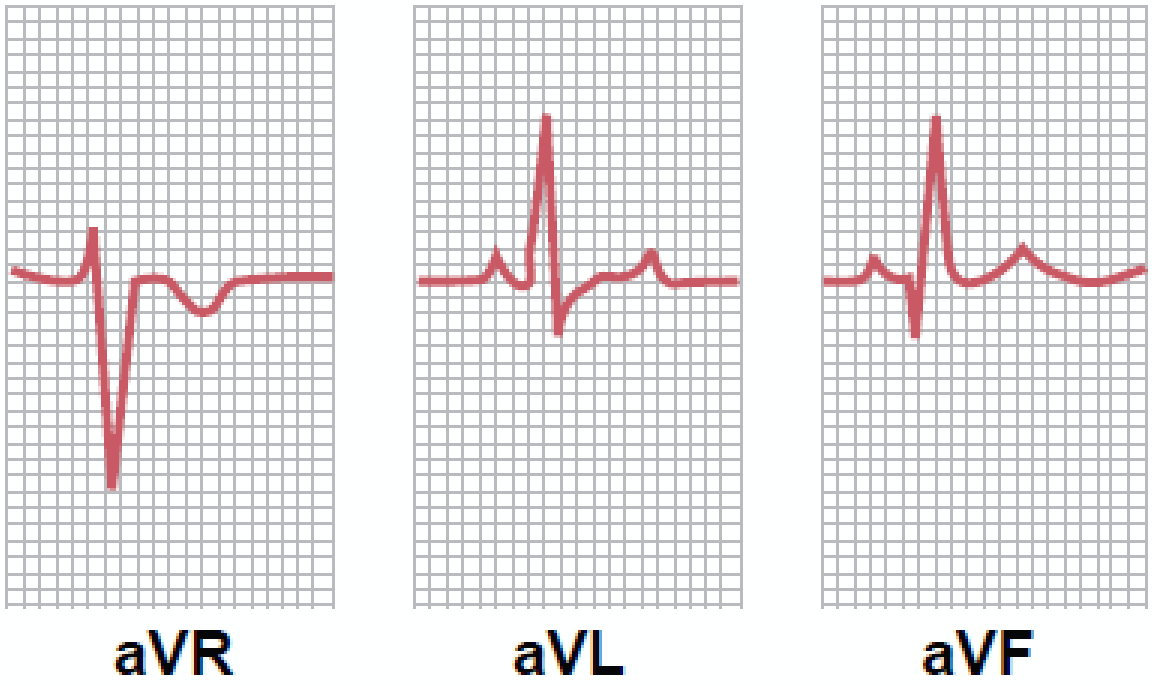


Figure 11–10

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

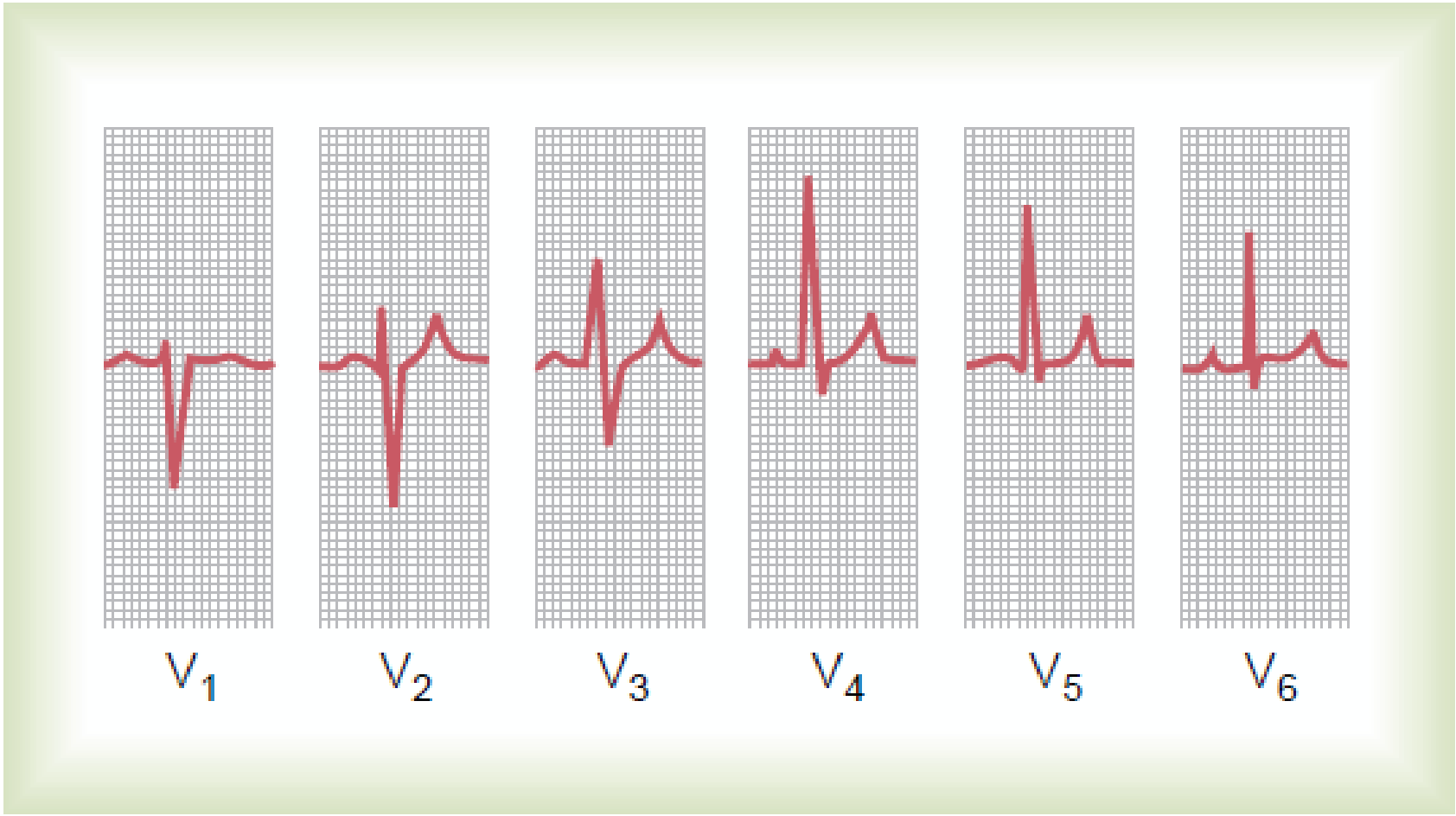
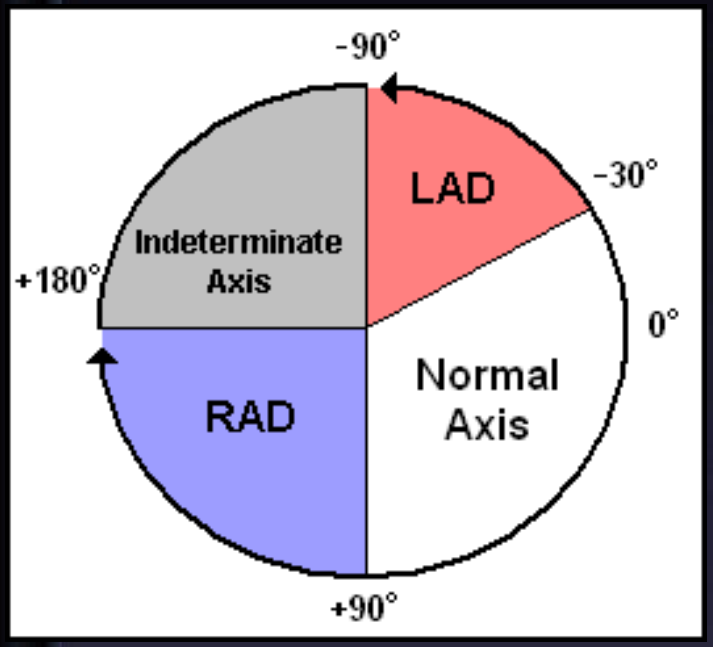


Figure 11–9

Normal electrocardiograms recorded from the six standard chest leads.

HEXA AXIAL REFERENCE SYSTEM

DIAGRAM



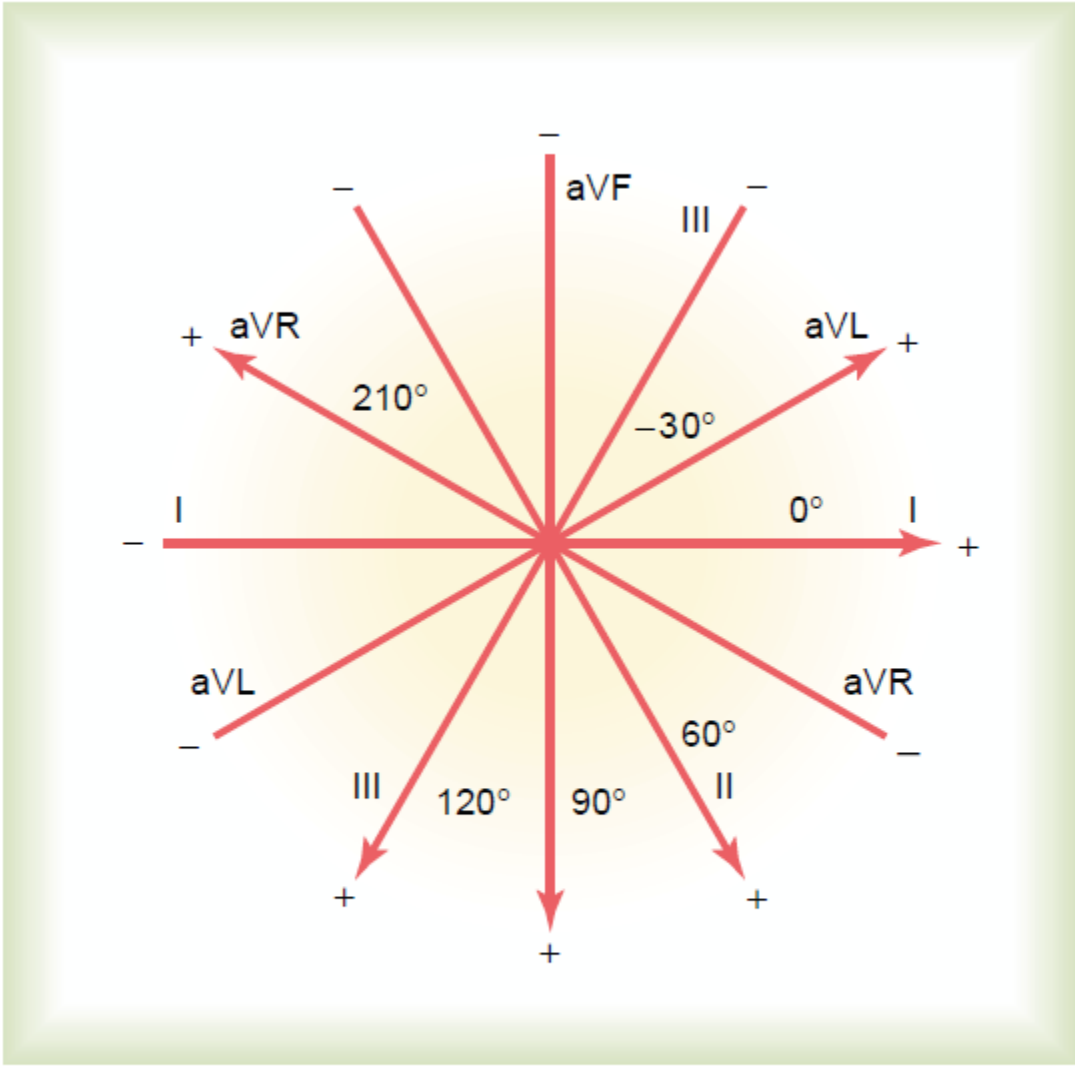
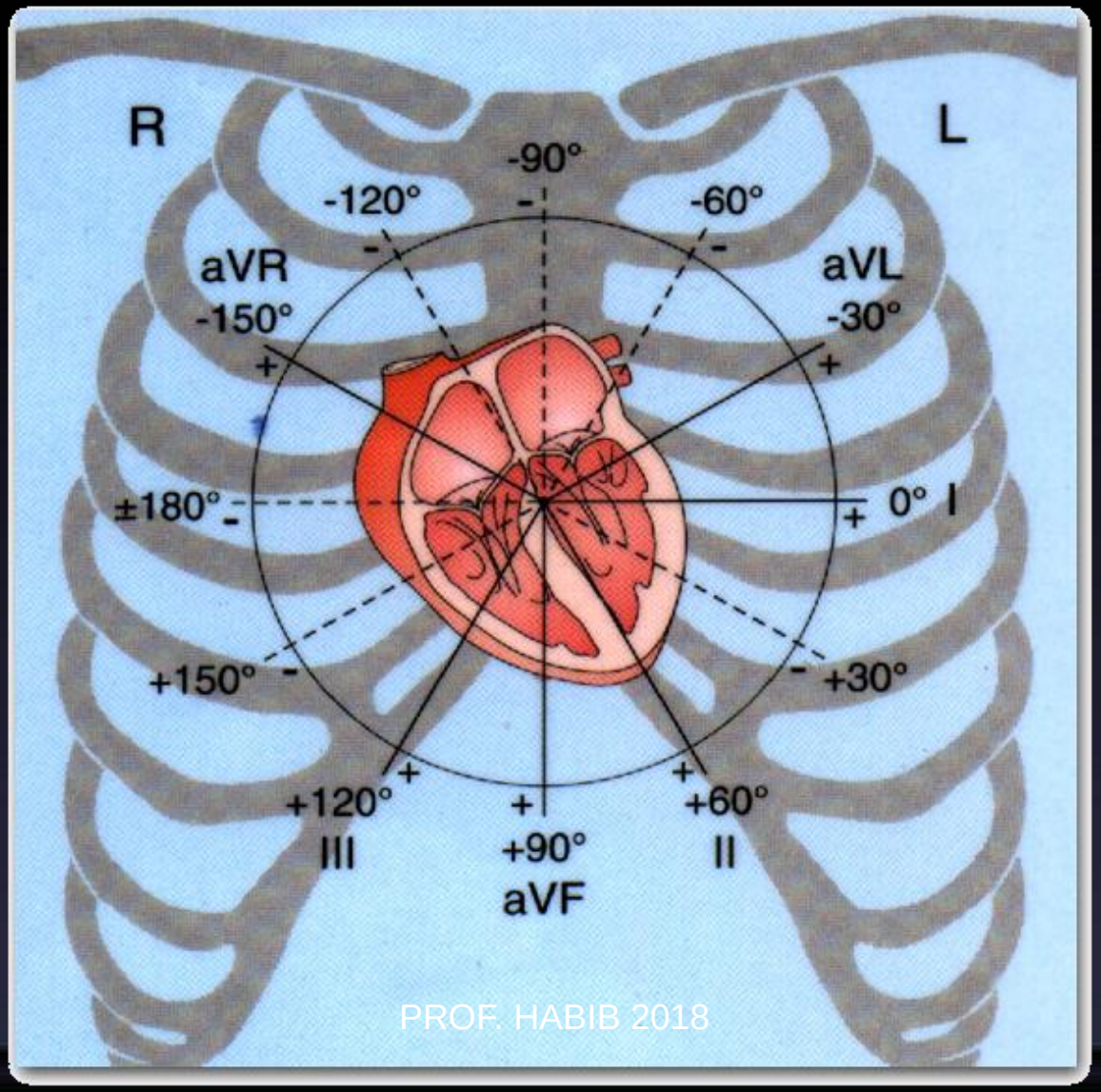


Figure 12–3

Axes of the three bipolar and three unipolar leads.

Lead Placement



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.

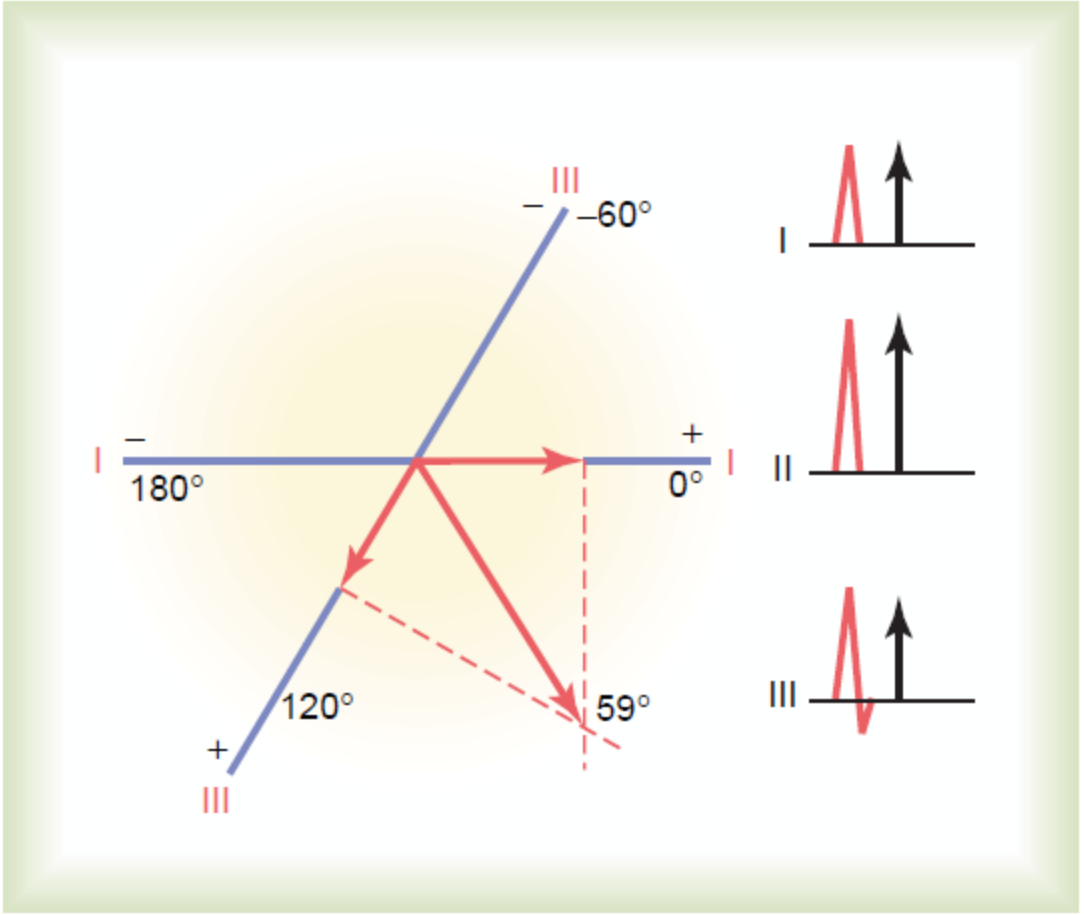


Figure 12–11

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

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.

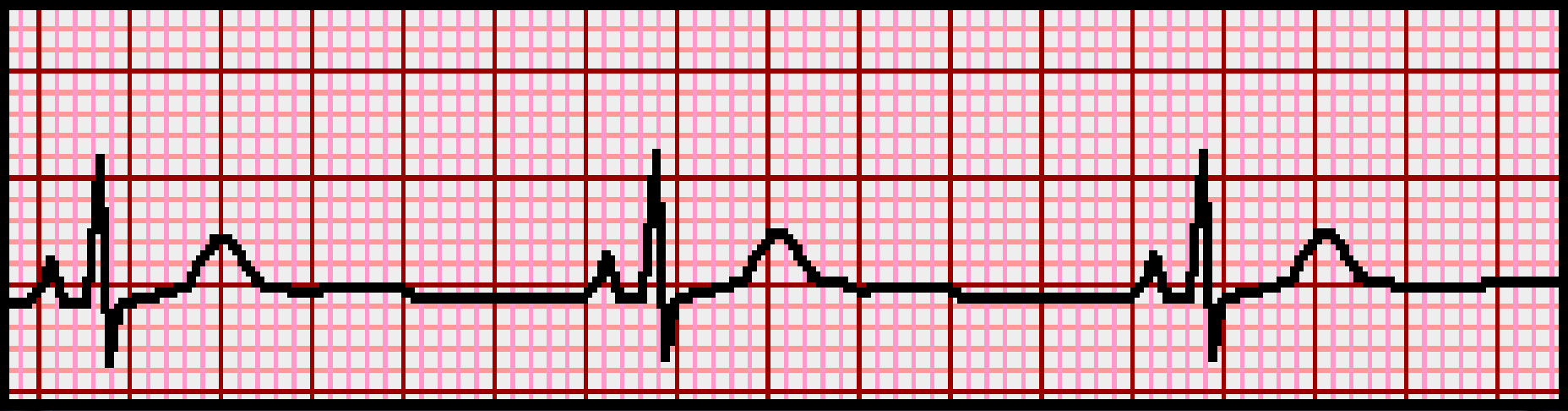
Prominent U waves are most often seen in hypokalemia, but may be present in hypercalcemia, thyrotoxicosis, or exposure to digitalis,epinephrine, and Class 1A and 3 antiarrhythmics, as well as in congenital long QT syndrome, and in the setting of intracranial hemorrhage.

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

Determining the Heart Rate

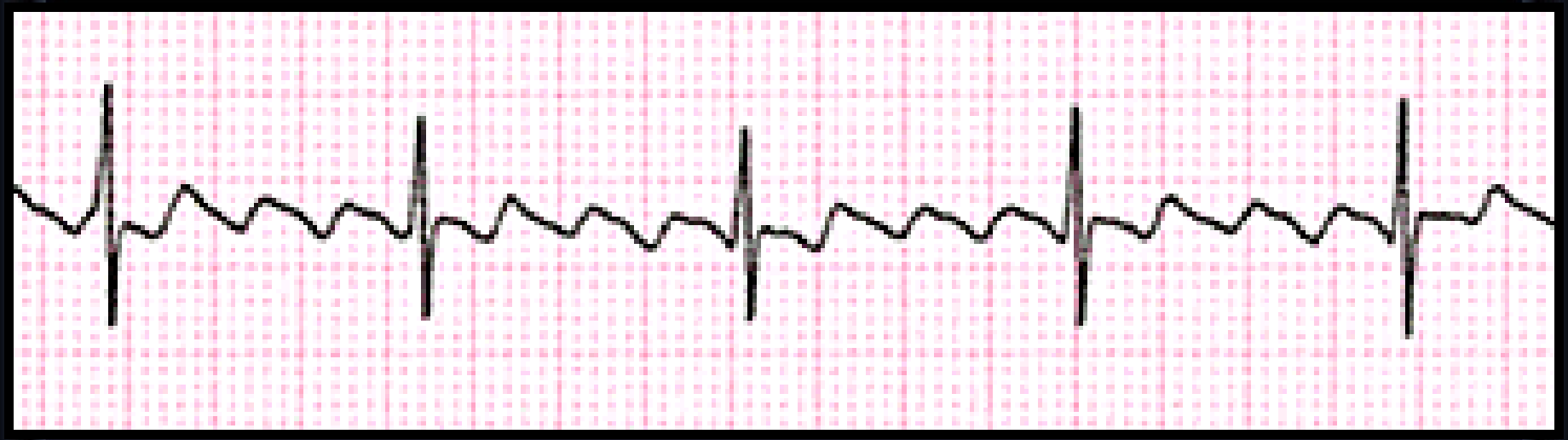
Take the number of “smallest boxes moved by the machine per minute” i.e. (1500) , and divide by the number of boxes between adjacent “R”-”R” waves.

H.R. = 1500 / # of squares b/w 2 “R - R” waves



(1500 / 30) = 50 bpm

What is the heart rate?



(1500 / ~19) = ~ 79 bpm

What is the heart rate?

(1500 / 8) = 187 bpm


THANKS
PROF. HABIB 2018