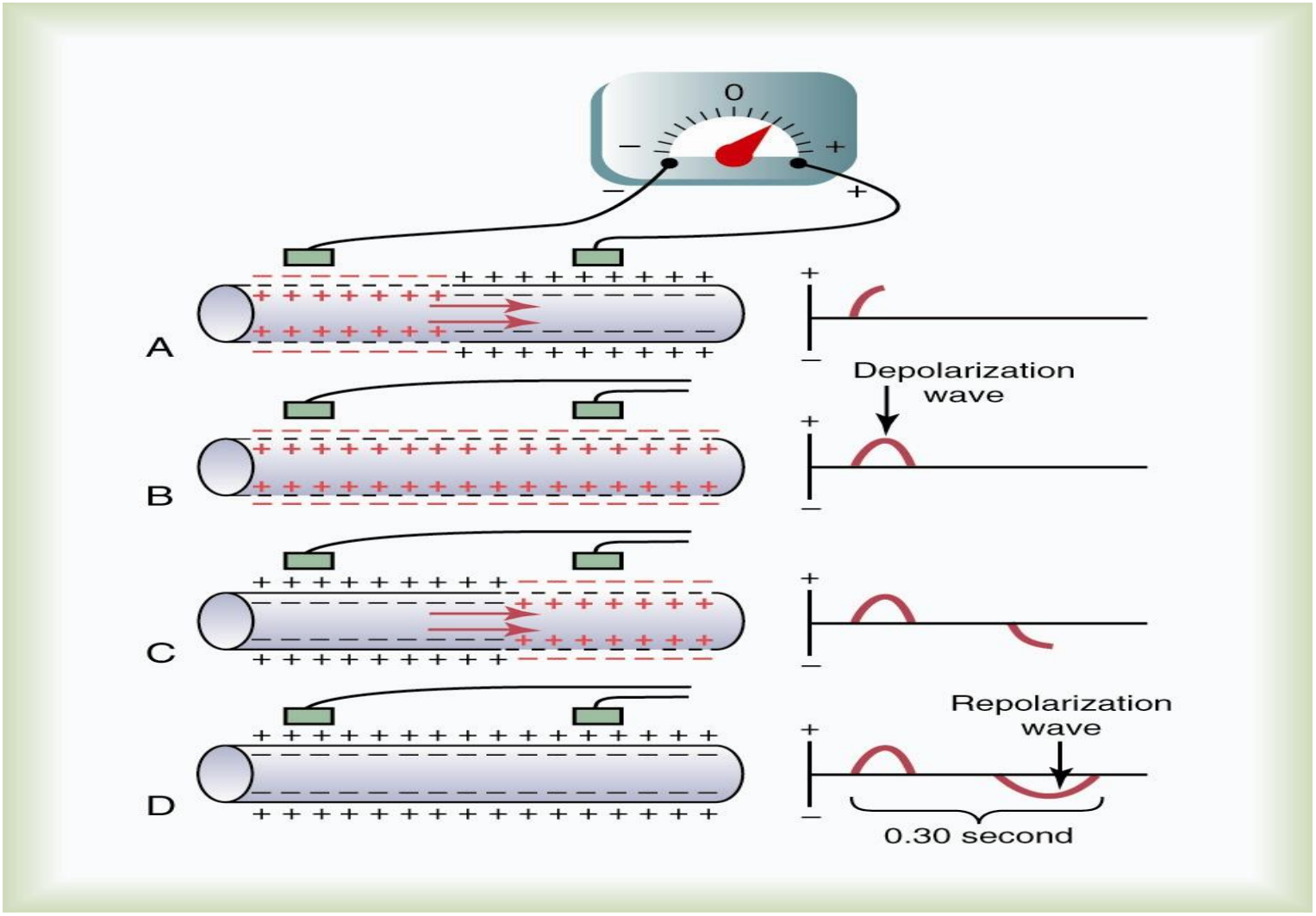
Electrocardiography – Normal 5

Faisal I. Mohammed, MD, PhD

Objectives

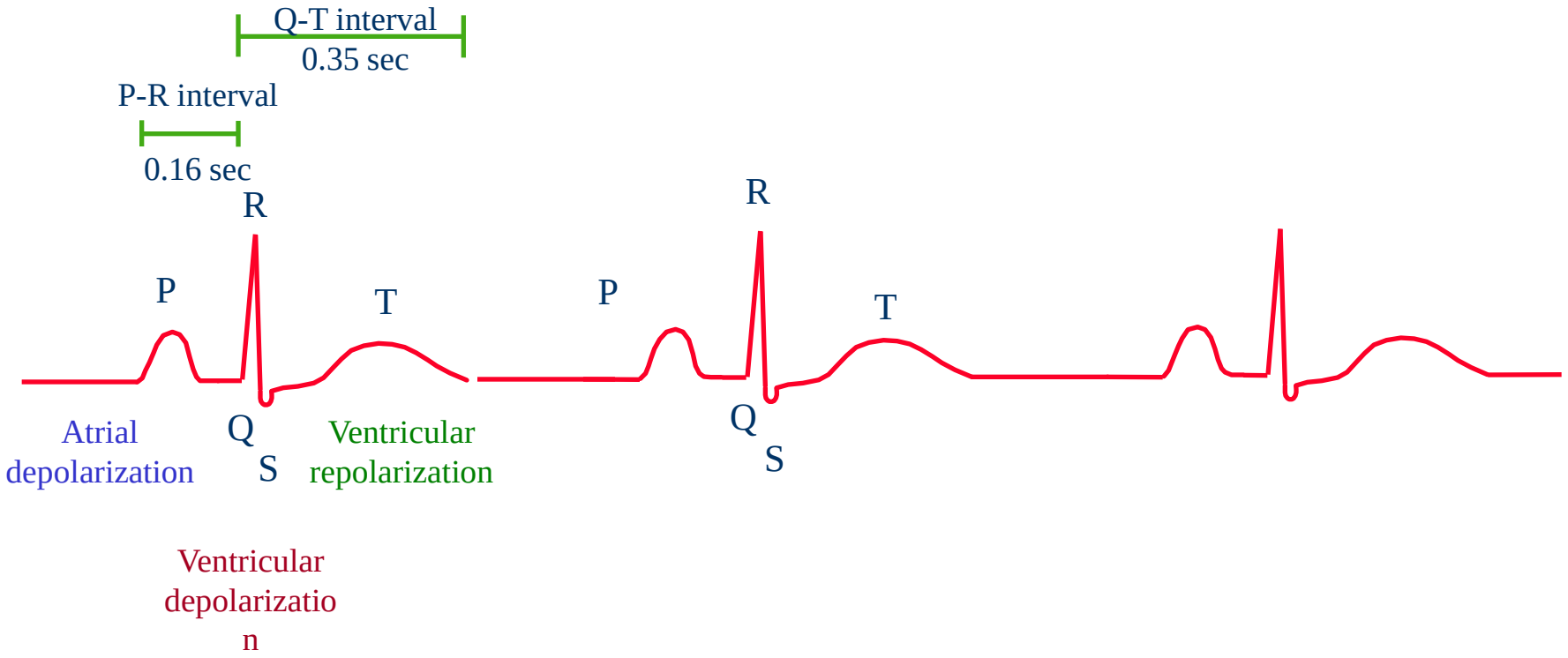
1. Describe the different “waves” in a normal electrocardiogram.
2. Recall the normal P-R and Q-T interval time of the QRS wave.
3. Distinguish the difference in depolarization and repolarization waves.
4. Recognize the voltage and time calibration of an electrocardiogram chart.
5. Point out the arrangement of electrodes in the bipolar limb leads, chest leads, and unipolar leads.
6. Describe Einthoven’s law.

Depolarization and Repolarization Waves

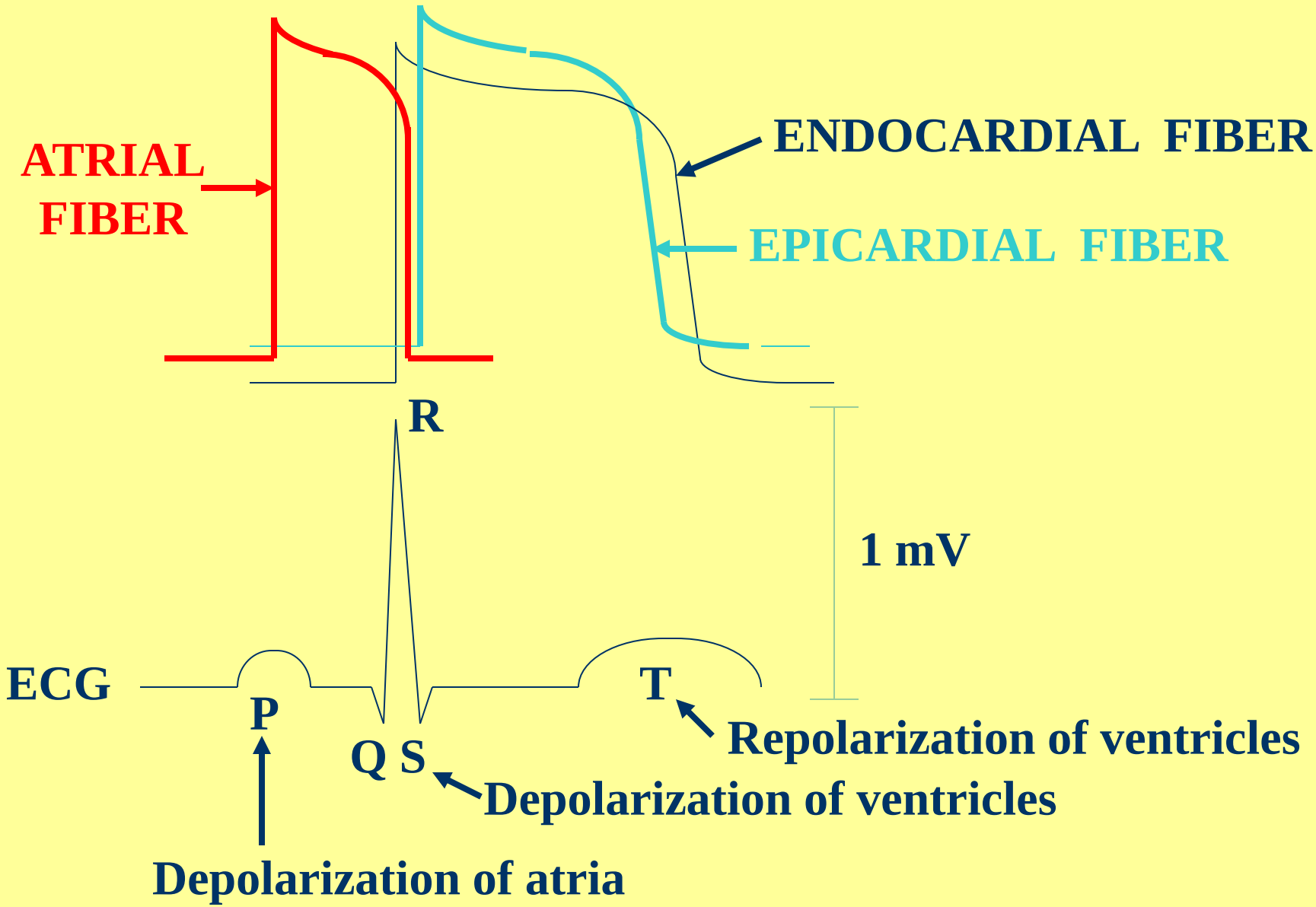


- Note that no potential is recorded when the ventricular muscle is either completely depolarized or repolarized.

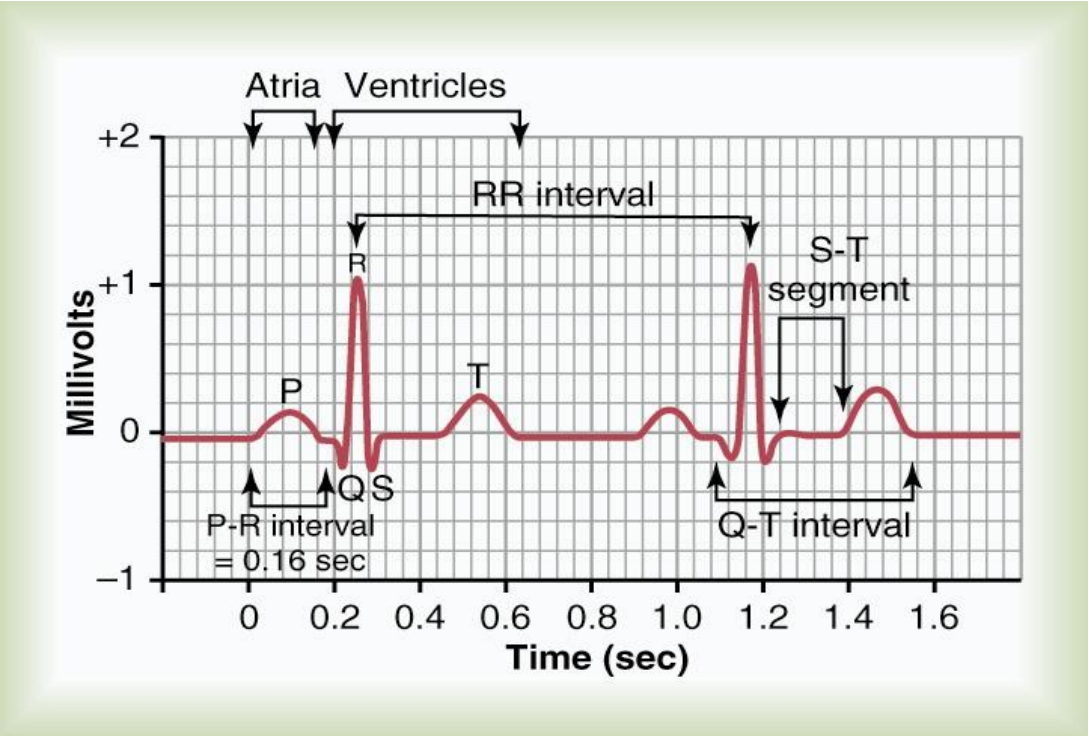
Normal EKG


Q-T interval
0.35 sec
P-R interval
0.16 sec
R
P
T
P
R
T
Atrial
depolarization
Q
S
Ventricular
repolarization
Q
S
Ventricular
depolarizatio
n

SINGLE VENTRICULAR ACTION POTENTIAL



Standardized EKG's

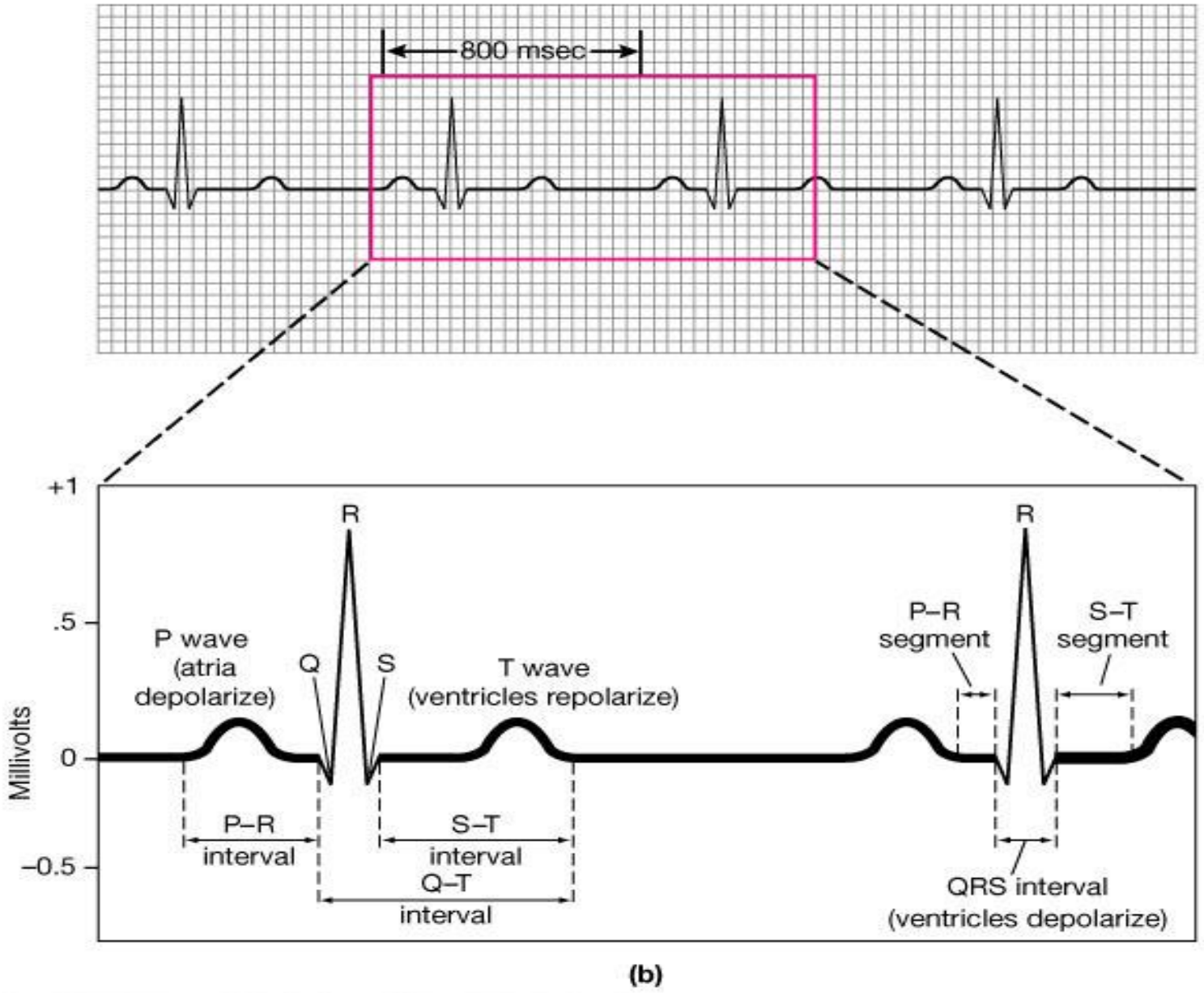


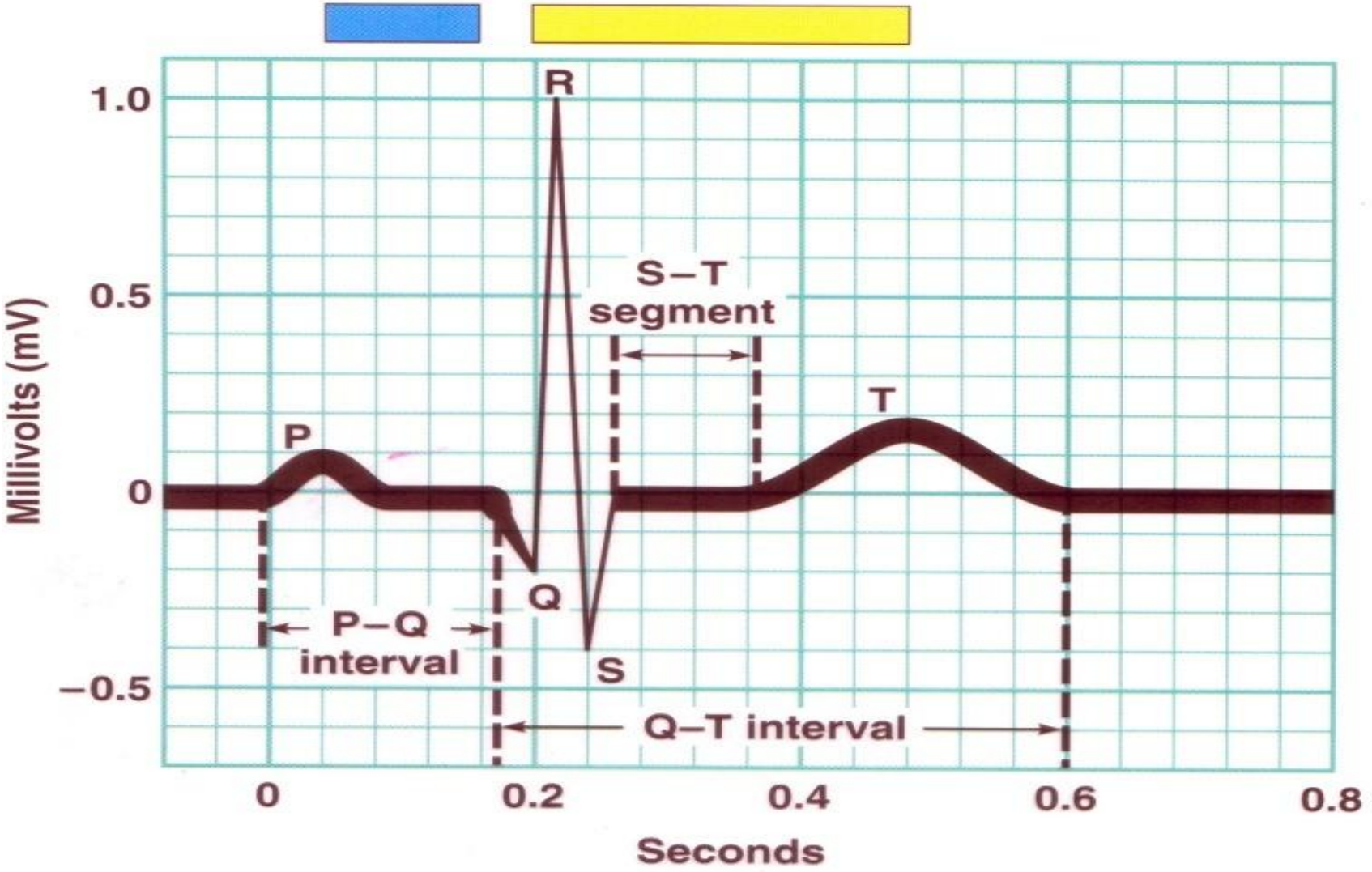
- Time and voltage calibrations are standardized

Electrocardiogram

- Record of electrical events in the myocardium that can be correlated with mechanical events
- **P wave**: depolarization of atrial myocardium.
  - Signals onset of atrial contraction
- **QRS complex**: ventricular depolarization
  - Signals onset of ventricular contraction..
- **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)
- **Q-T interval**: time required for ventricles to undergo a single cycle of depolarization and repolarization
  - Can be lengthened by electrolyte disturbances, conduction problems, coronary ischemia, myocardial damage

Electrocardiogram



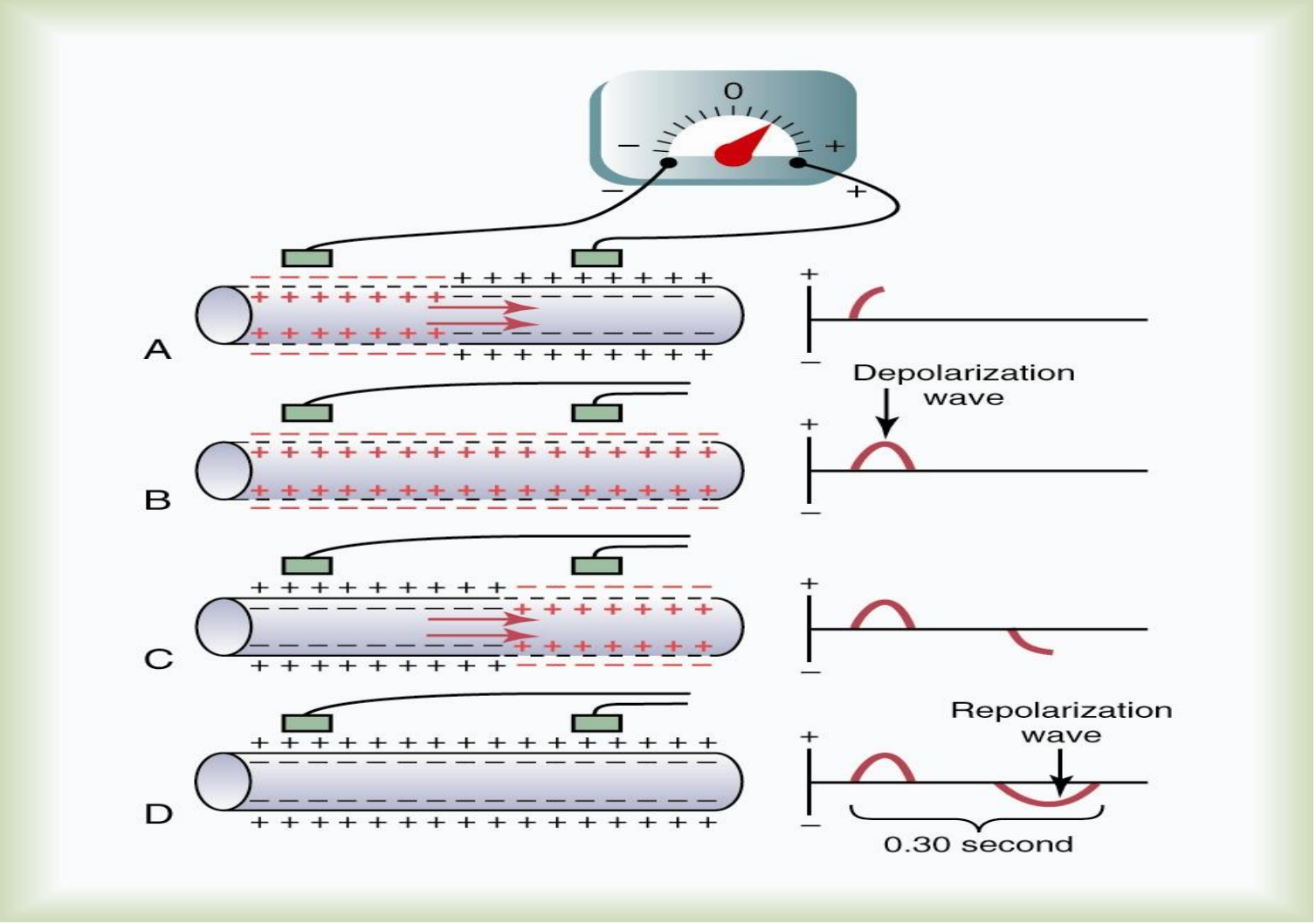


Key:

Atrial contraction

Ventricular contraction

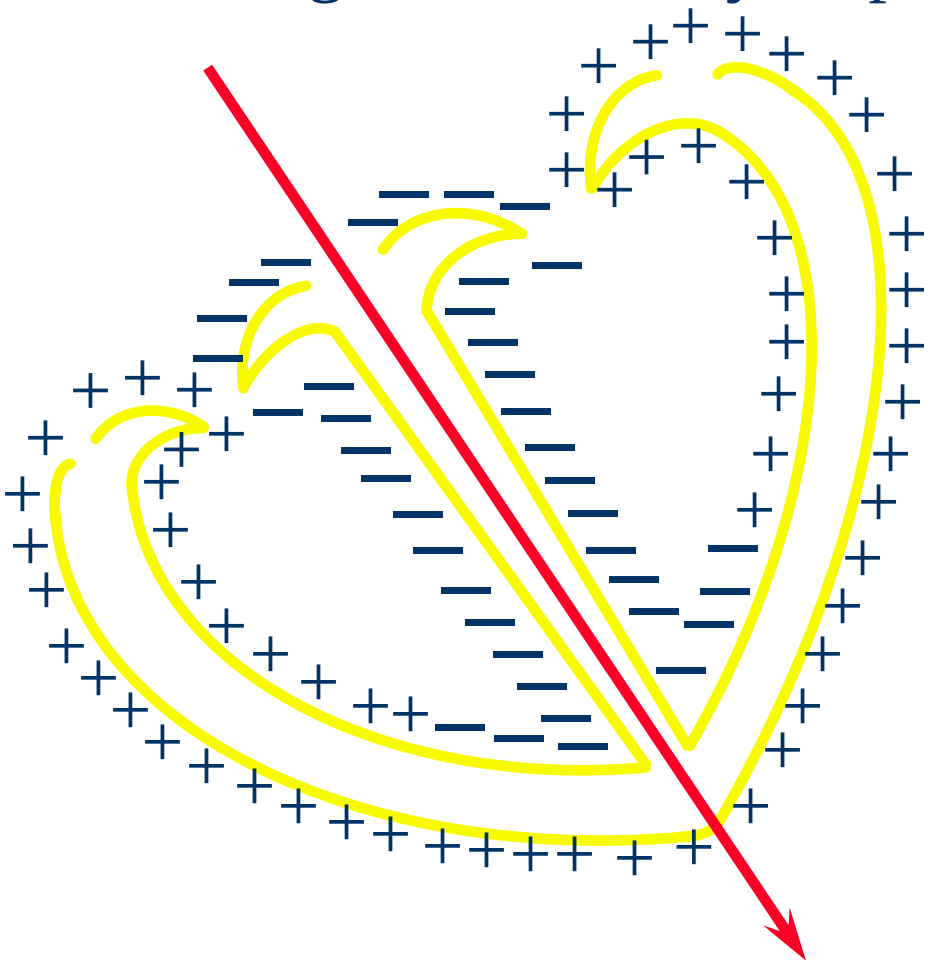
Depolarization and Repolarization Waves



- Note that no potential 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



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.
- 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).

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)

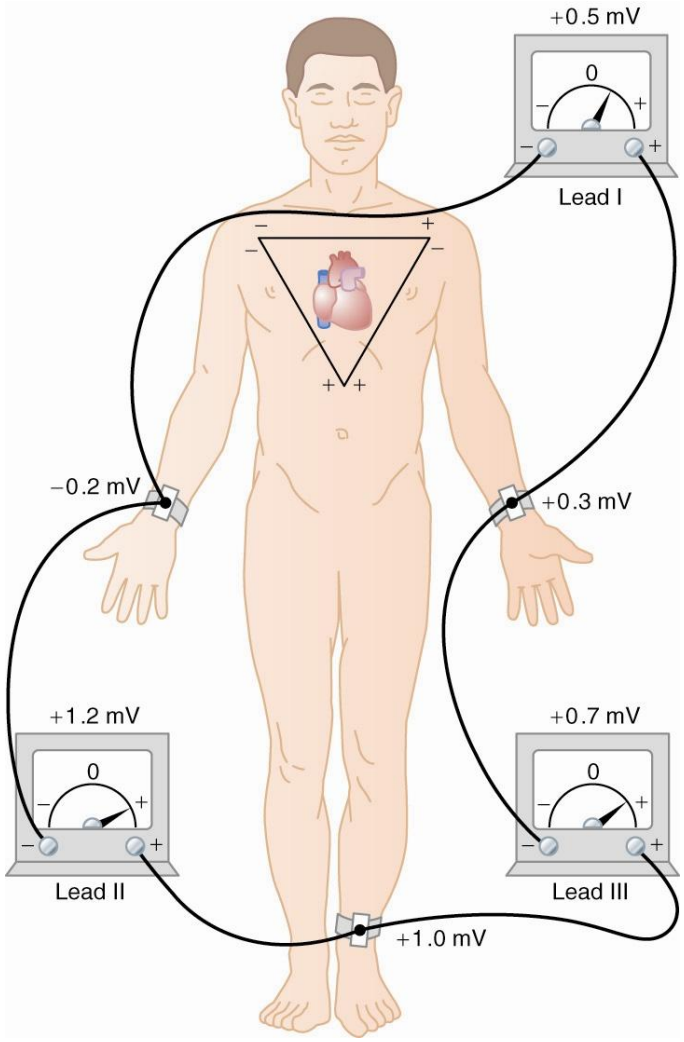
- The P-Q or P-R interval on the electrocardiogram has a normal value of 0.16 seconds and is the duration of time between the beginning of the P wave and the beginning of the QRS wave; this represents the time between the beginning of atrial contraction and the beginning of ventricular contraction.

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.
- The heart rate can be determined with the reciprocal of the time interval between each heartbeat.

Bipolar Limb Leads

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



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.

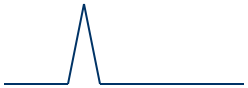
Bipolar Limb Leads (cont'd)

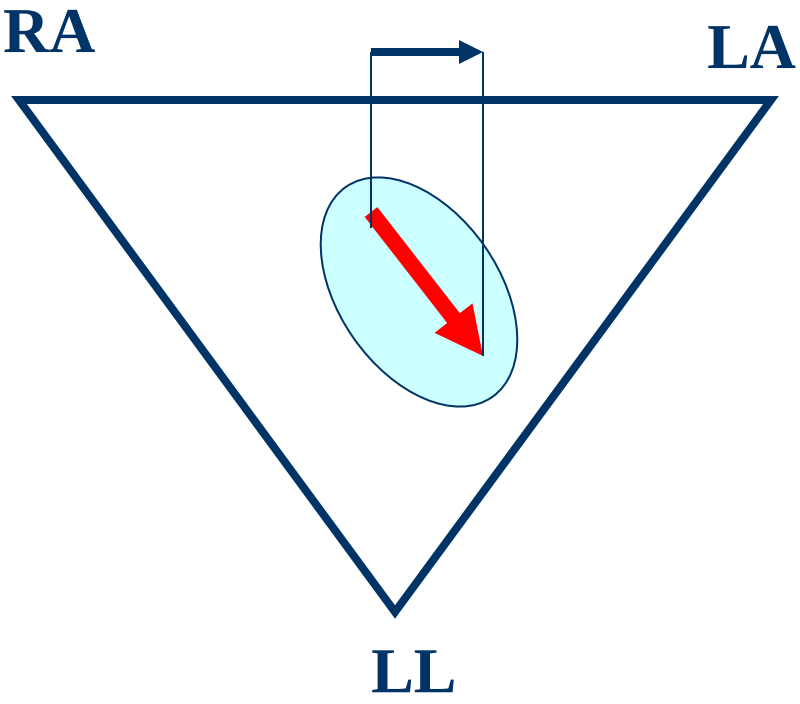
- Lead III - The negative terminal of the electrocardiogram is connected to the left arm, and the positive terminal is connected to the left leg.
- Einthoven's Law states that the electrical potential of any limb equals the sum of the other two (+ and - signs of leads must be observed). L II= L I + L 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

ECG Recordings (QRS Vector pointing leftward, inferiorly & anteriorly)

3 Bipolar Limb Leads:

I = RA vs. LA (+)



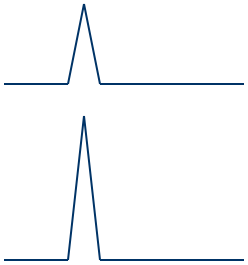


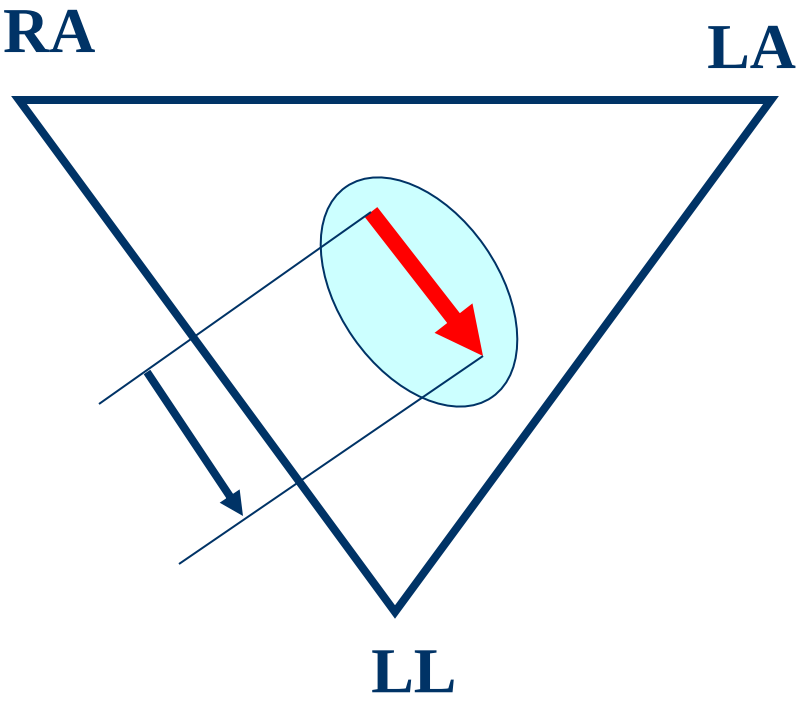
ECG Recordings (QRS Vector pointing leftward, inferiorly & anteriorly)

3 Bipolar Limb Leads:

I = RA vs. LA (+)

II = RA vs. LL (+)





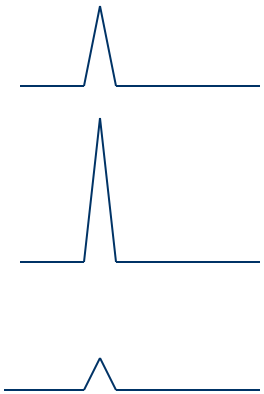
ECG Recordings (QRS Vector pointing leftward, inferiorly & anteriorly)

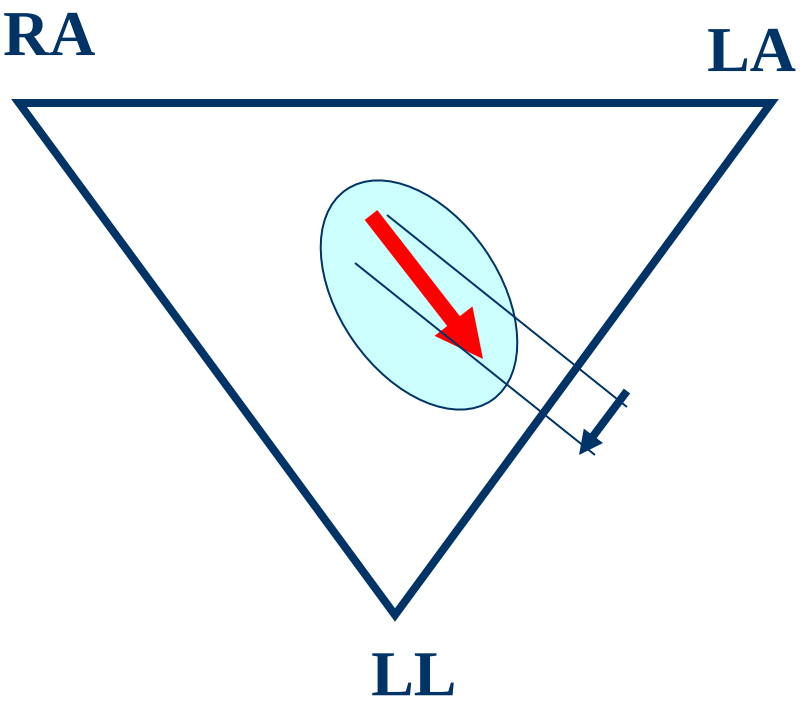
3 Bipolar Limb Leads:

I = RA vs. LA (+)

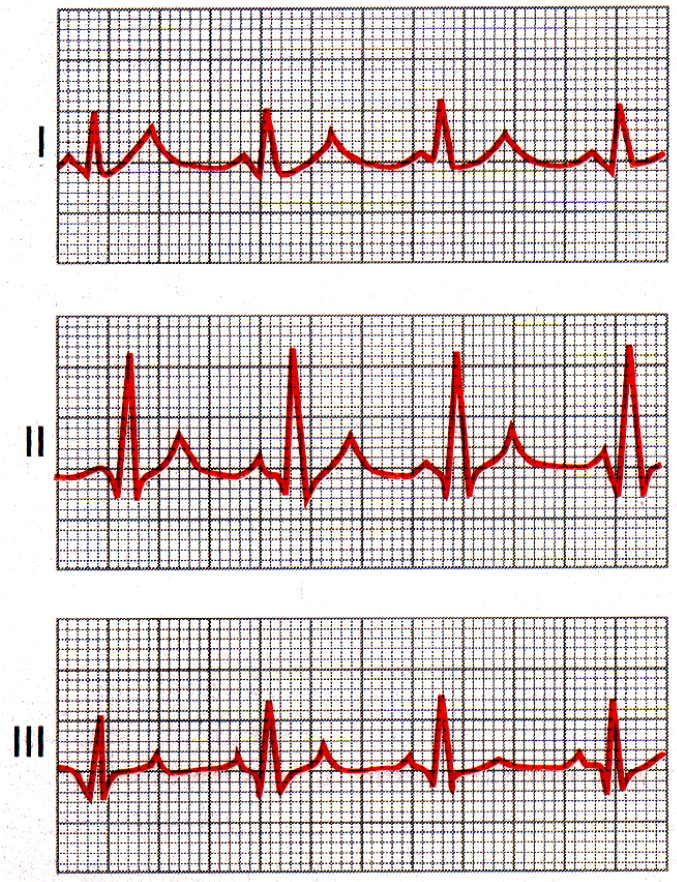
II = RA vs. LL (+)

III = LA vs. LL (+)





Bipolar Limb Leads (cont'd)

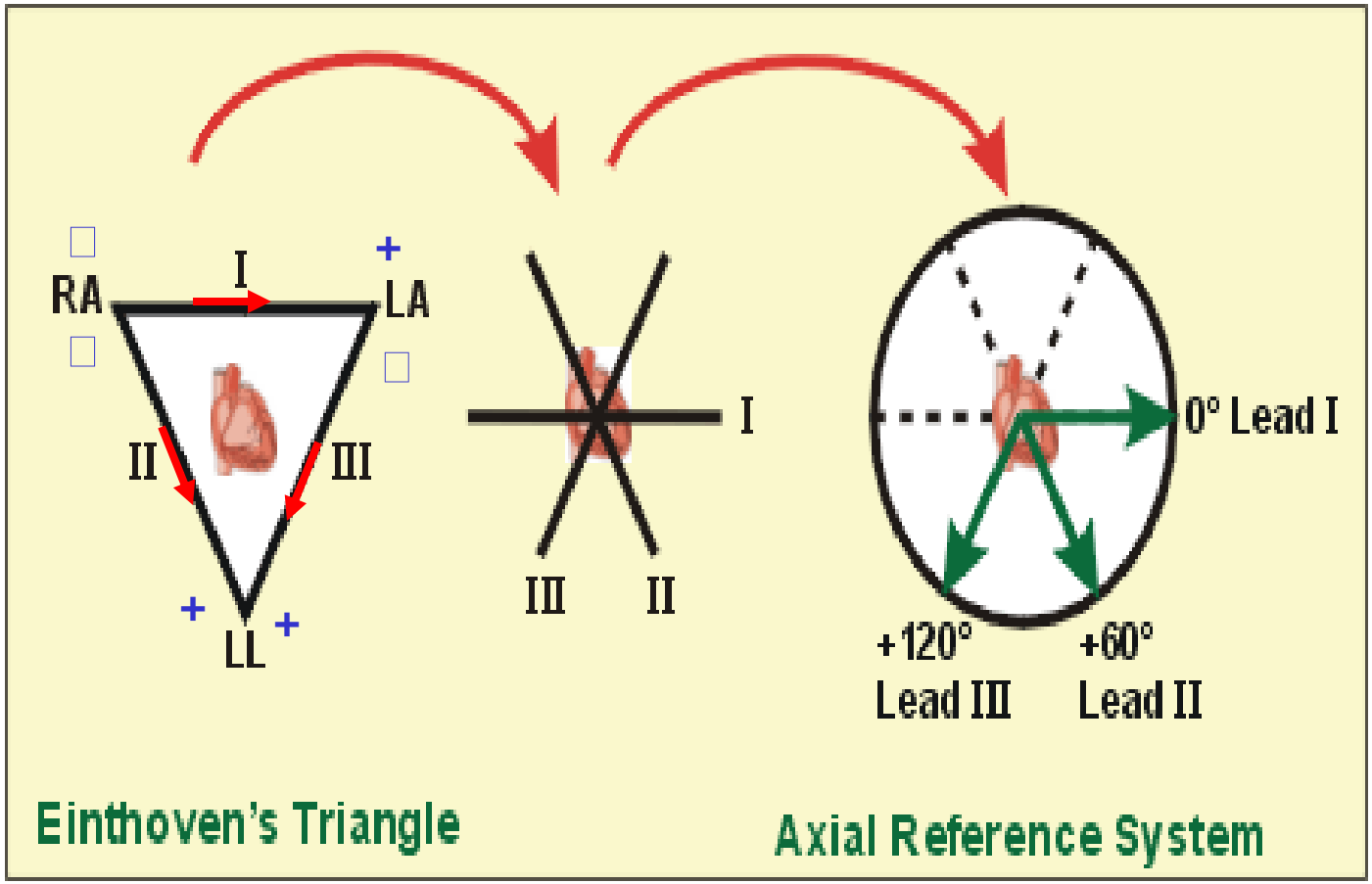


0.5 mV

1.2 mV

0.7 mV

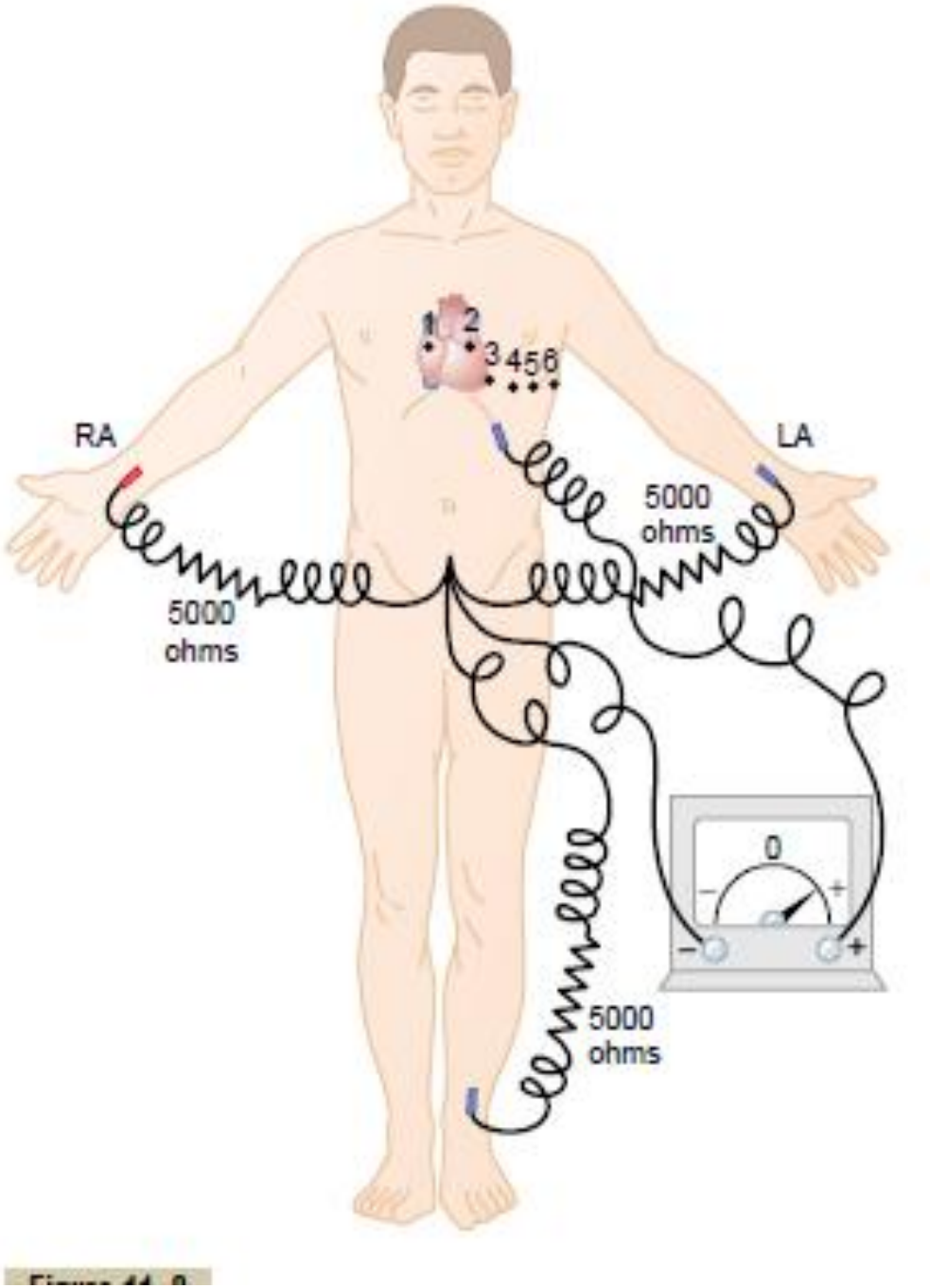
Einthoven's triangle and law



Other EKG Leads (cont'd)

- Augmented Unipolar Limb Leads aVR, aVL, and aVF are also in use. For aVR the + electrode is the right arm, and the - electrode is the left arm + left leg; aVL + electrode is left arm; aVF + electrode is left foot and the negative electrode is the other two limbs

Unipolar Limb Leads



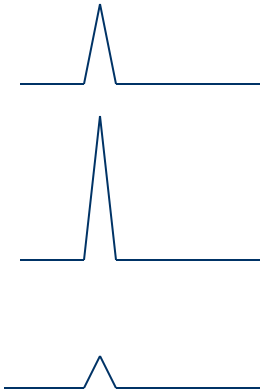
ECG Recordings (QRS Vector pointing leftward, inferiorly & anteriorly)

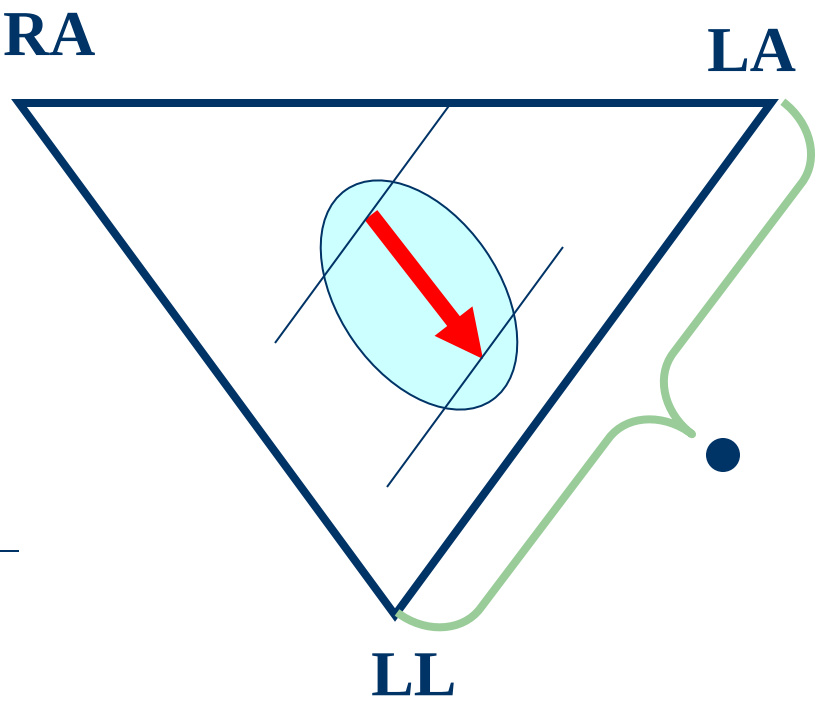
3 Bipolar Limb Leads:

I = RA vs. LA (+)

II = RA vs. LL (+)

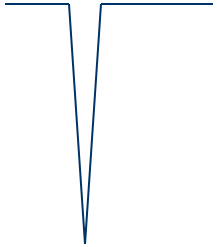
III = LA vs. LL (+)





3 Augmented Limb Leads:

aVR = (LA-LL) vs. RA(+)



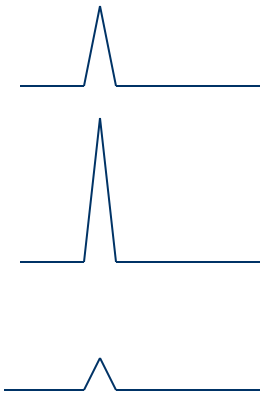
ECG Recordings (QRS Vector pointing leftward, inferiorly & anteriorly)

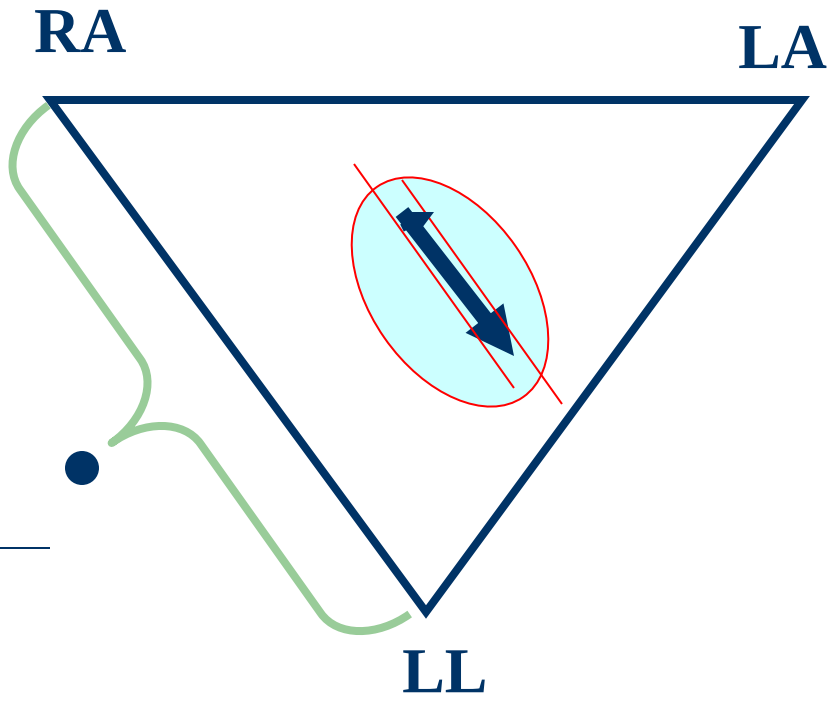
3 Bipolar Limb Leads:

I = RA vs. LA (+)

II = RA vs. LL (+)

III = LA vs. LL (+)

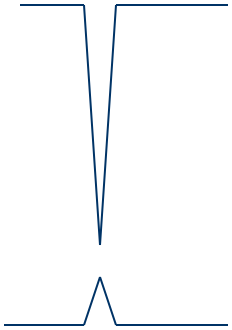




3 Augmented Limb Leads:

aVR = (LA-LL) vs. RA(+)

aVL = (RA-LL) vs. LA(+)



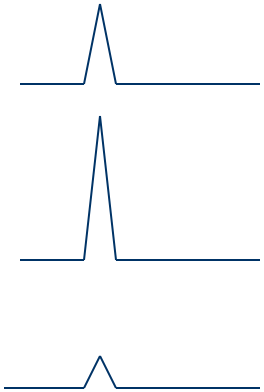
ECG Recordings (QRS Vector pointing leftward, inferiorly & anteriorly)

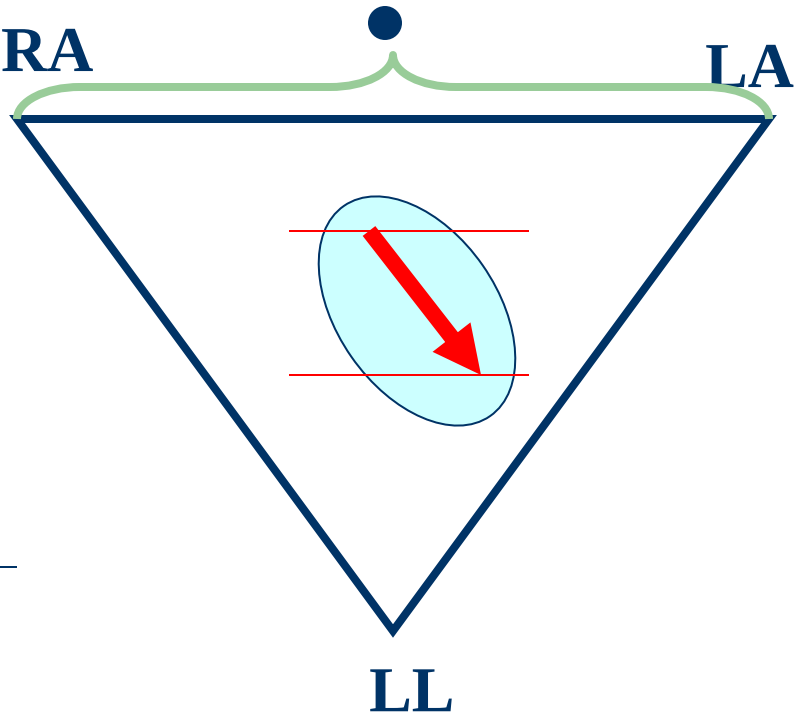
3 Bipolar Limb Leads:

I = RA vs. LA (+)

II = RA vs. LL (+)

III = LA vs. LL (+)



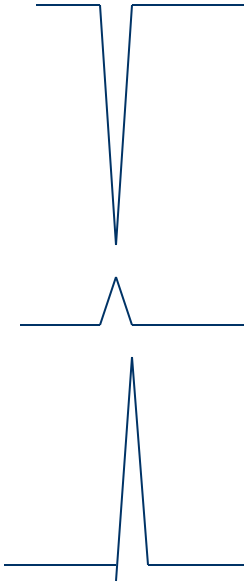


3 Augmented Limb Leads:

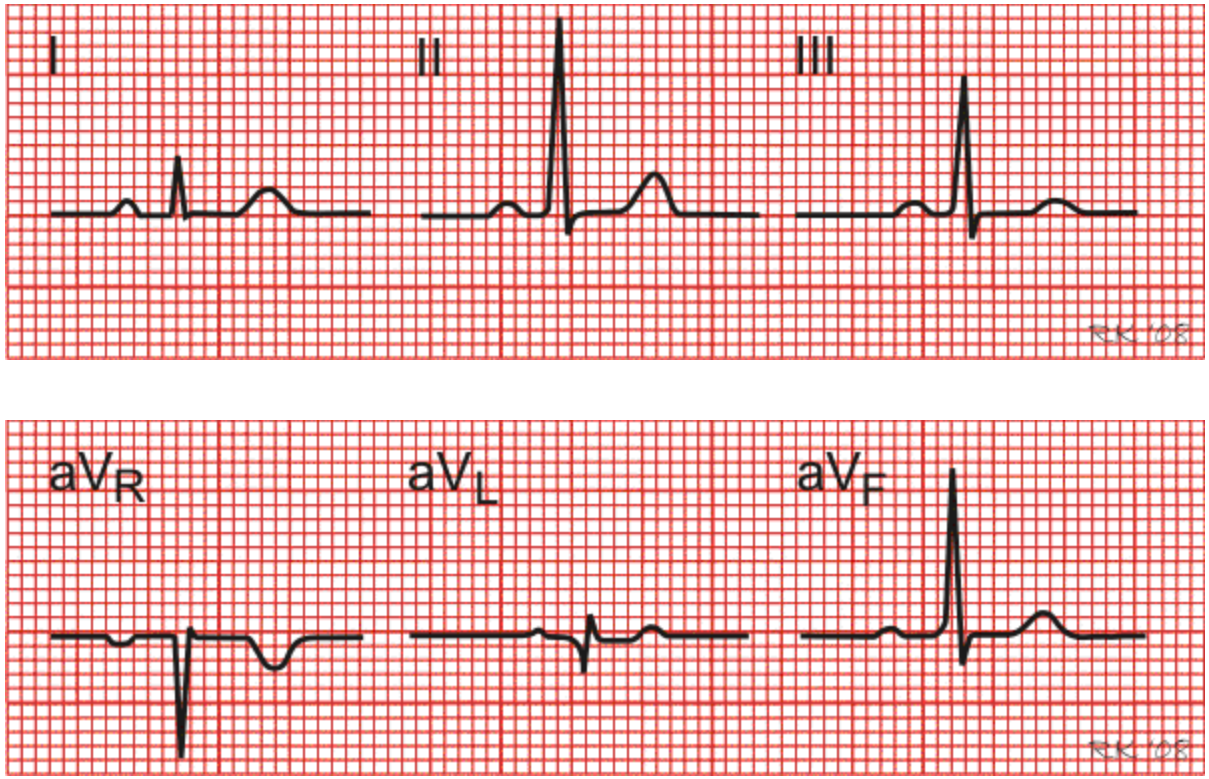
aVR = (LA-LL) vs. RA(+)

aVL = (RA-LL) vs. LA(+)

aVF = (RA-LA) vs. LL(+)

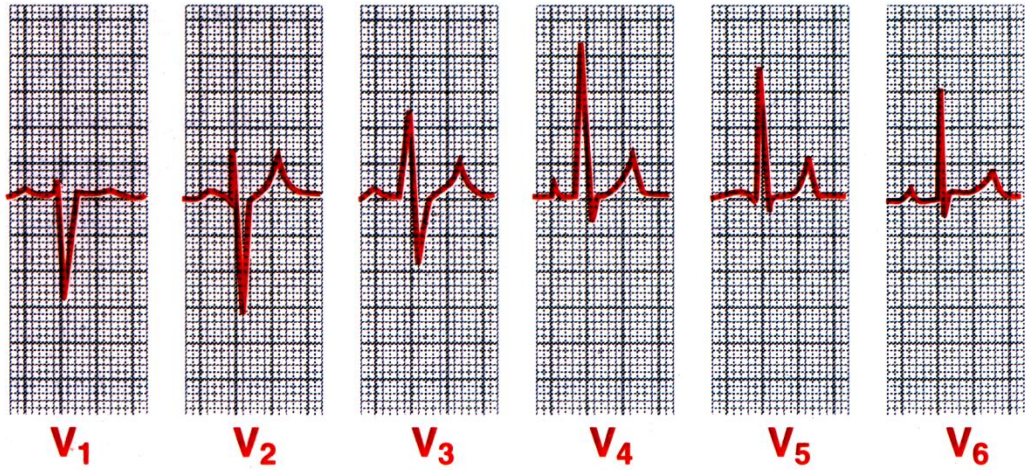


Bipolar and Uniploar Limb Leads

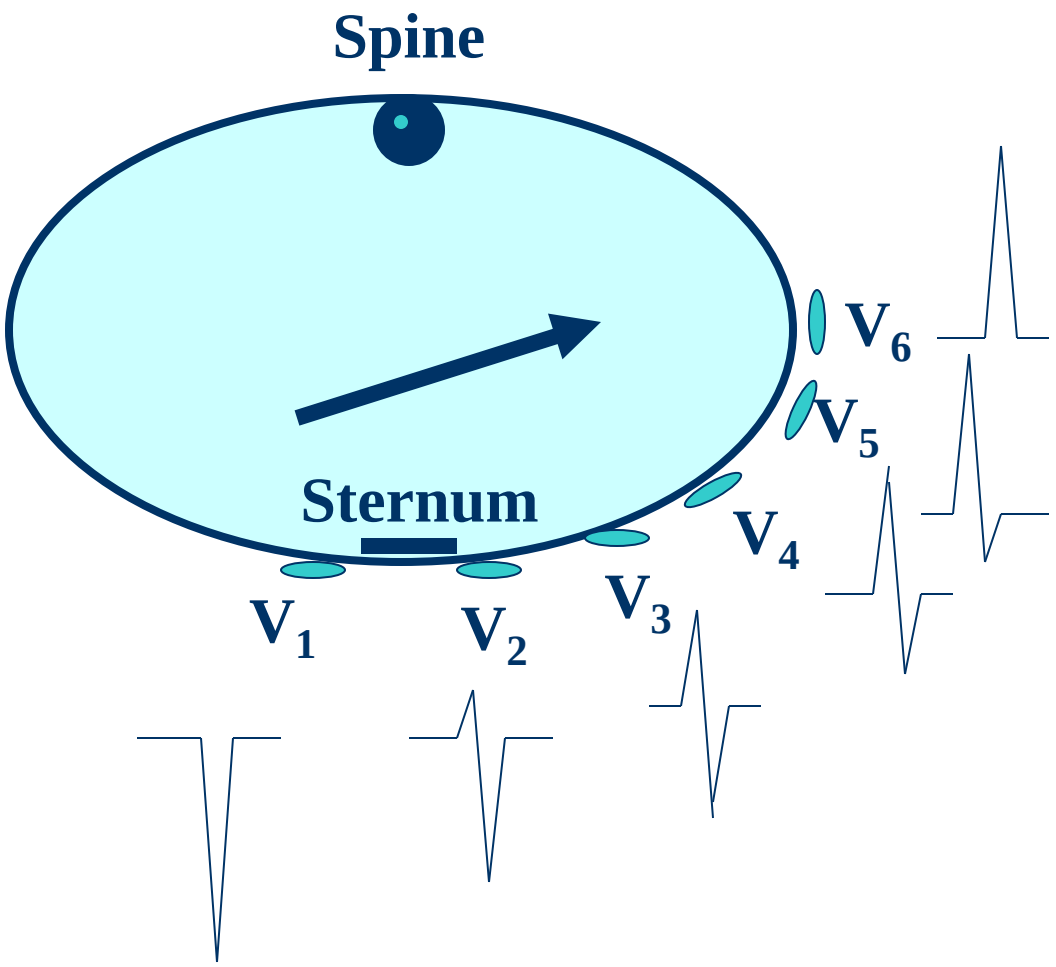


Other EKG Leads

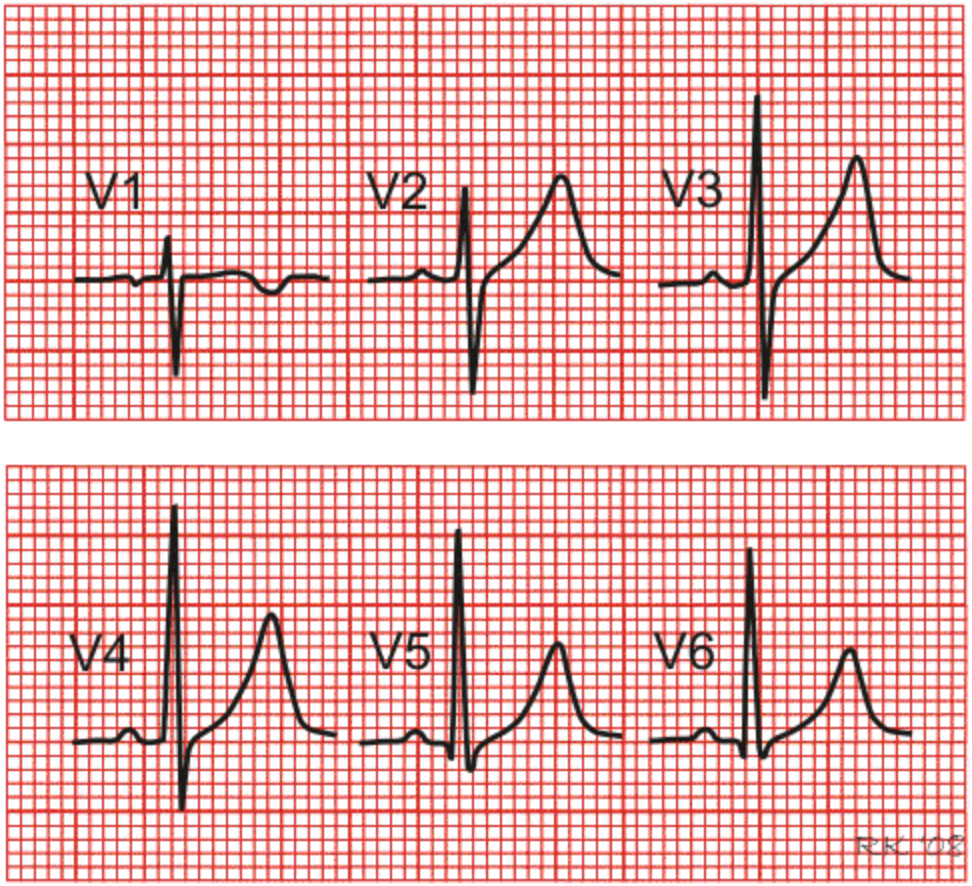
- Chest Leads (Precordial Leads) known as V_1-V_6 are very sensitive to electrical potential changes underneath the electrode.



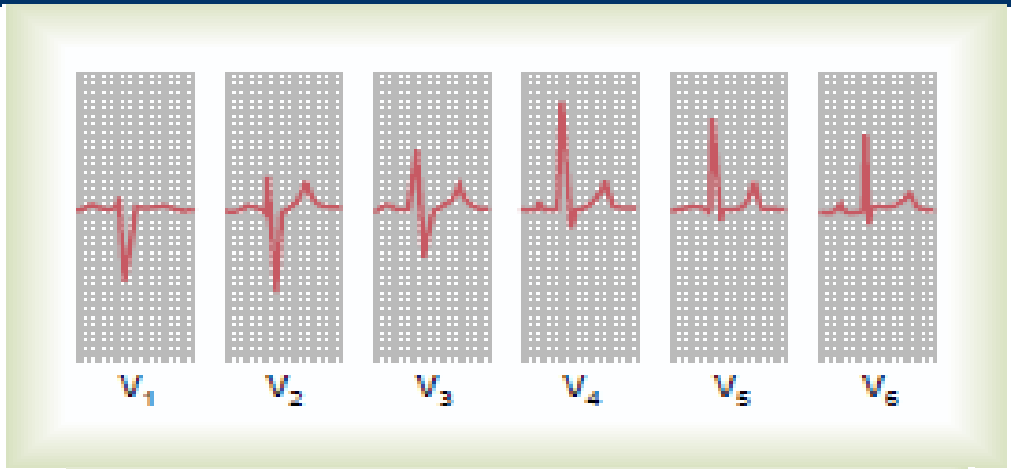
6 PRECORDIAL (CHEST) LEADS

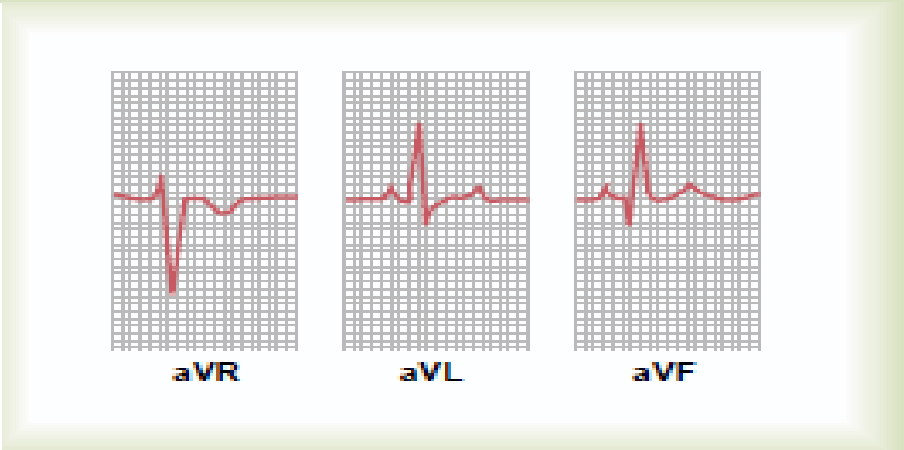


Chest leads (Unipolar)



Uniplolar Leads






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

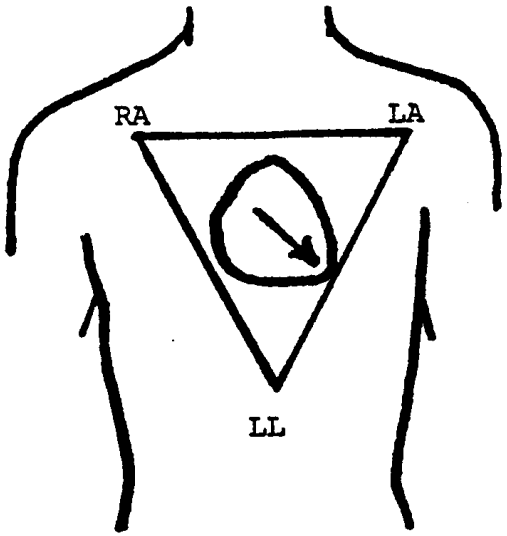
ECG Recordings: (QRS vector---leftward, inferiorly and anteriorly

3 Bipolar Limb Leads

I = RA vs. LA(+)

II = RA vs. LL(+)

III = LA vs. LL(+)

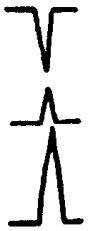


3 Augmented Limb Leads

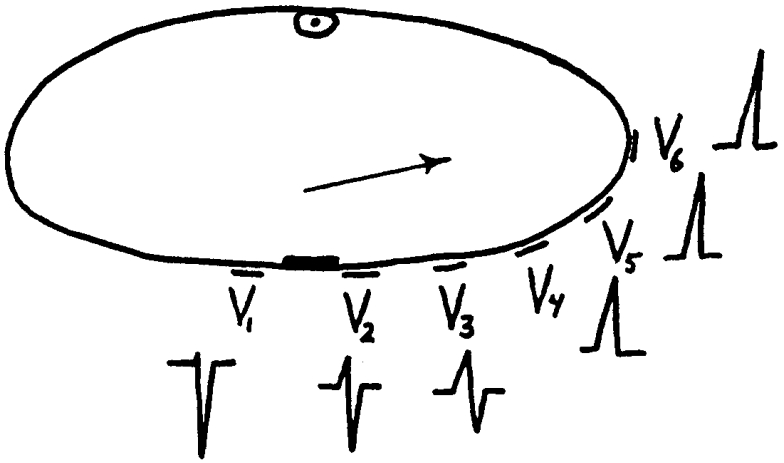
aVR = (LA-LL) vs. RA(+)

aVL = (RA-LL) vs. LA(+)

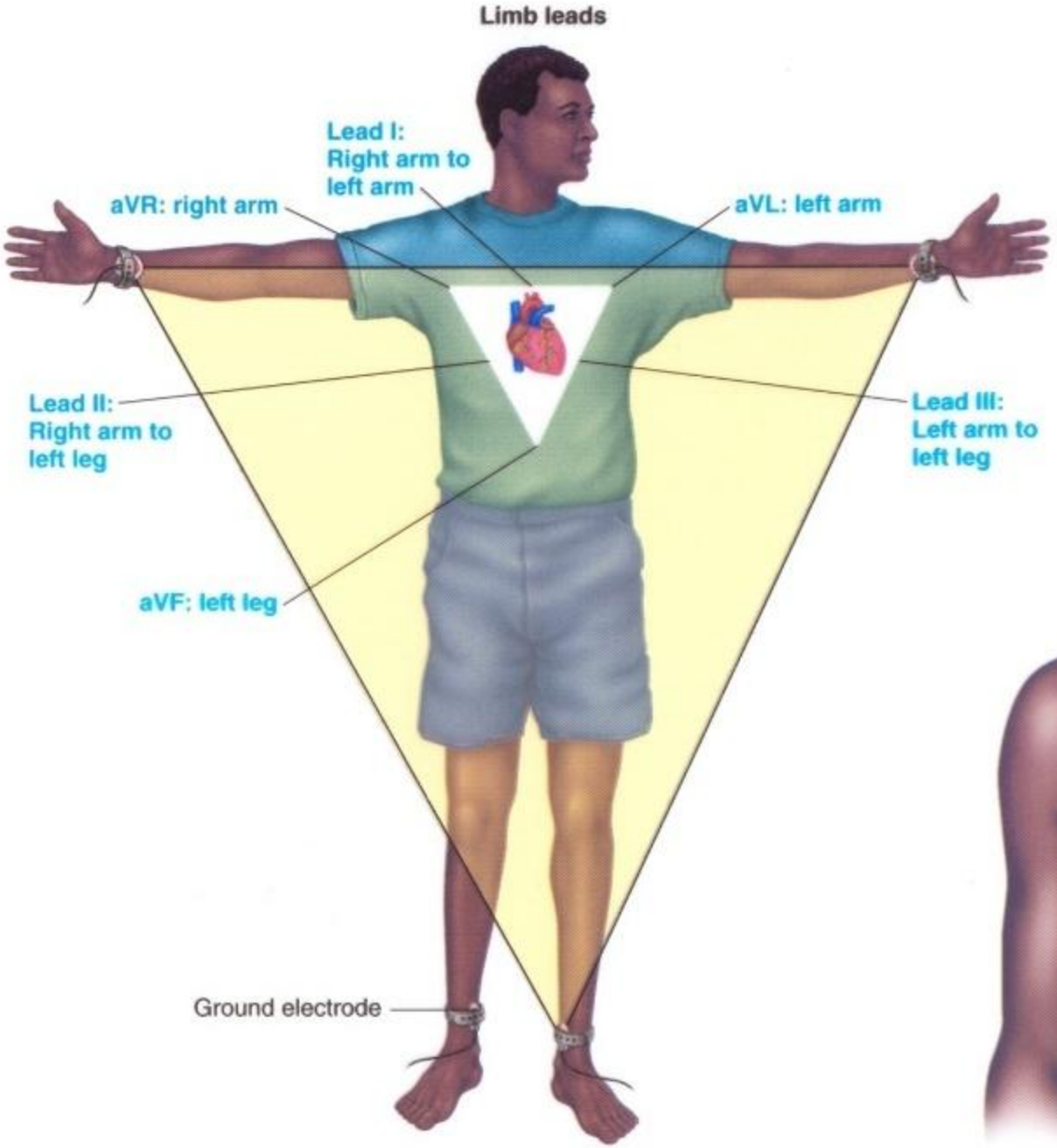
aVF = (RA-LA) vs. LL(+)



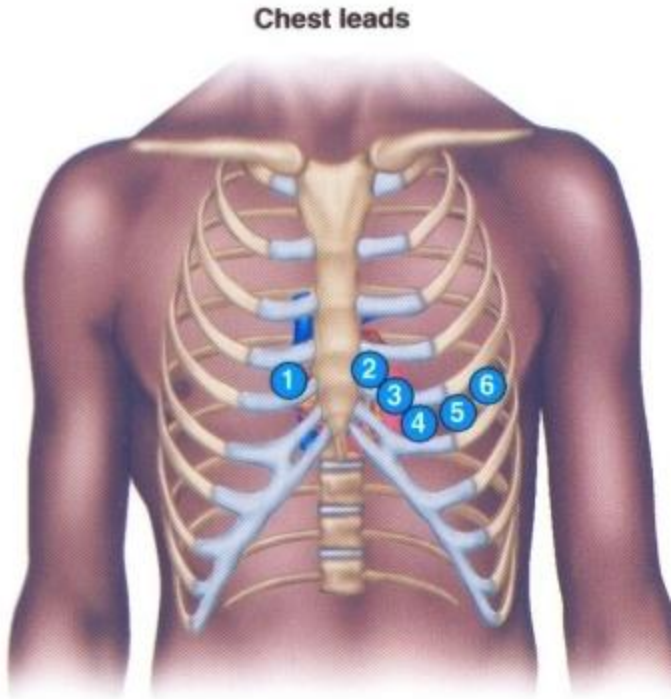
6 Precordial (Chest) Leads: Indifferent electrode (RA-LA-LL) vs. chest lead moved from position V_1 through position V_6.



Electrocardiogram leads



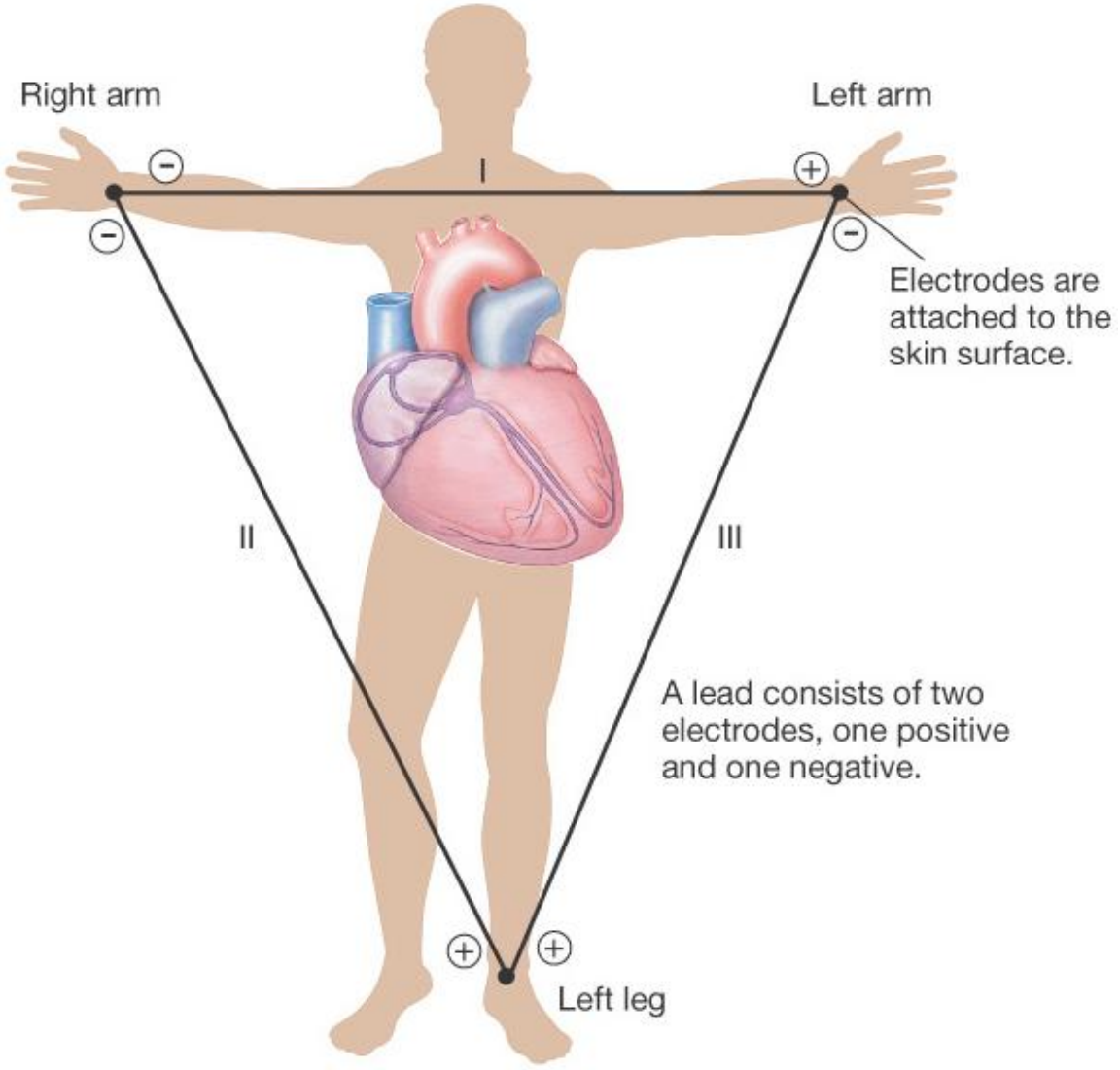
(a)



(b)

Electrocardiogram (ECG):Electrical Activity of the Heart

- Einthoven's triangle
- P-Wave – atria
- QRS- wave – ventricles
- T-wave – repolarization



Thank You

Electrocardiography – Normal 6

Faisal I. Mohammed, MD, PhD

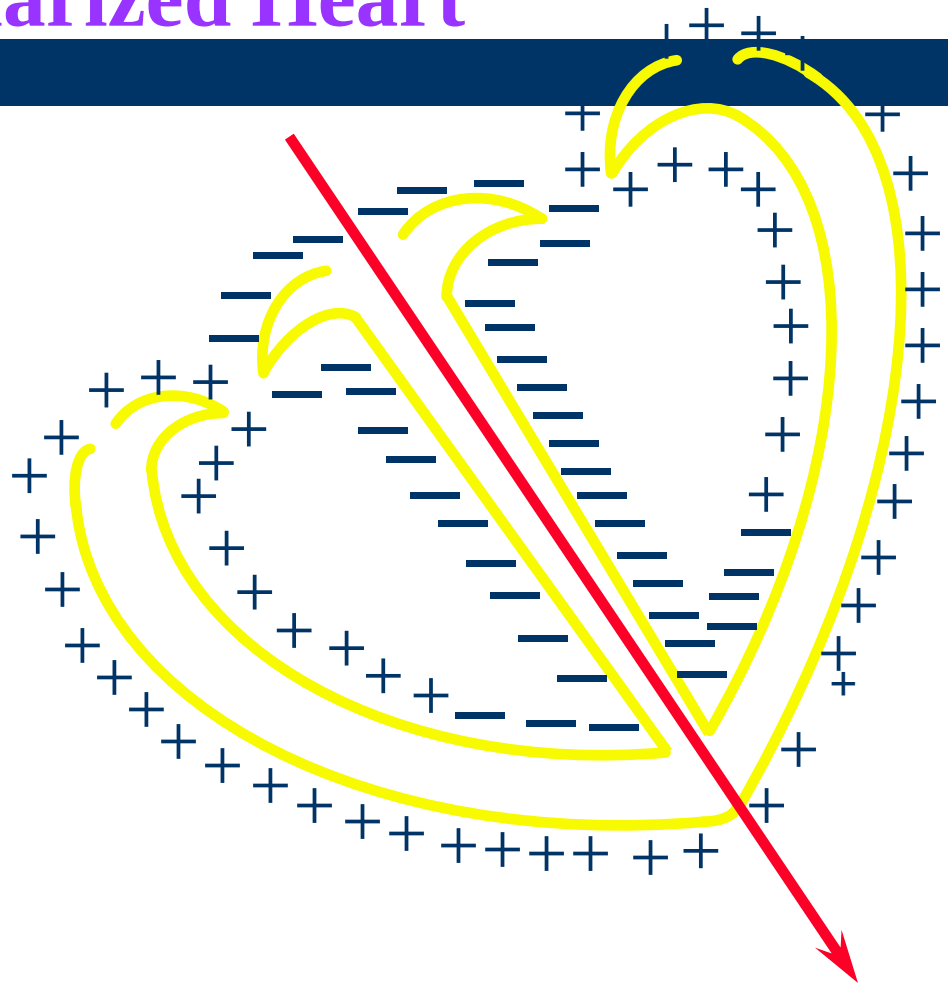
Objectives

- Recognize the normal ECG tracing
- Calculate the heart rate
- Determine the rhythm
- Calculate the length of intervals and determine the segments deflections
- Draw the Hexagonal axis of the ECG
- Find the mean electrical axis of QRS (Ventricular depolarization)

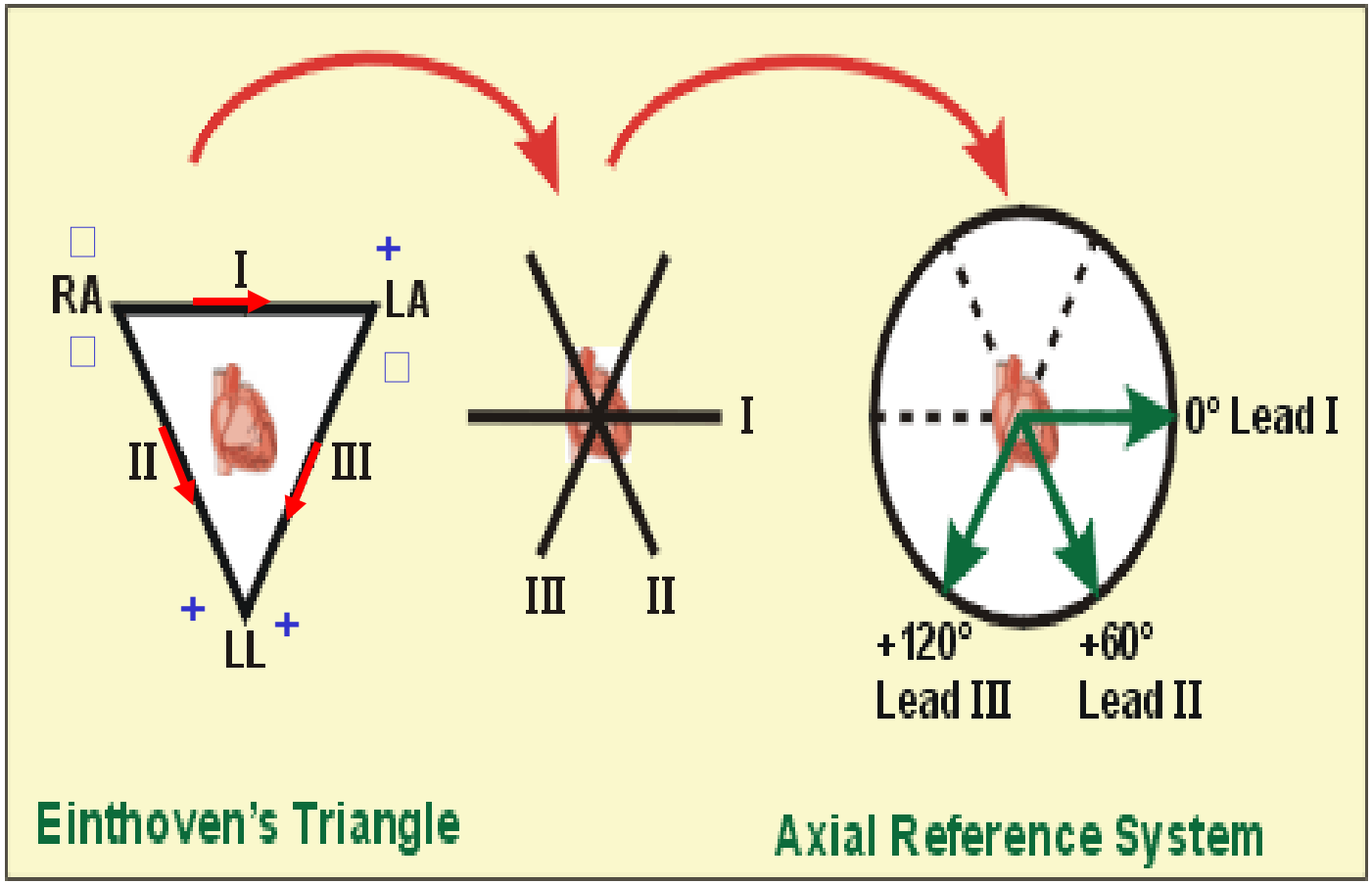
Principles of Vectorial Analysis of EKG's

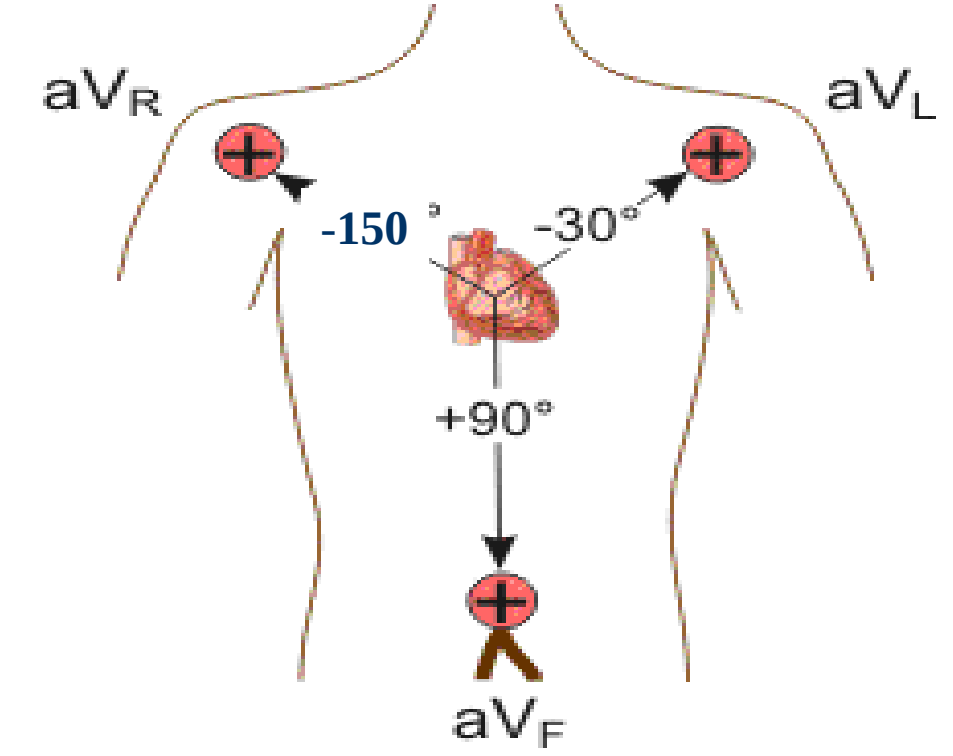
- The current in the heart flows from the area of depolarization to the polarized areas, and the electrical potential generated can be represented by a vector, with the *arrowhead pointing in the positive direction*.
- The length of the vector is *proportional to the voltage of the potential*.
- The generated potential at any instance can be represented by an *instantaneous mean vector*.
- The normal mean QRS vector is 60^{o} (-30° - 110°)

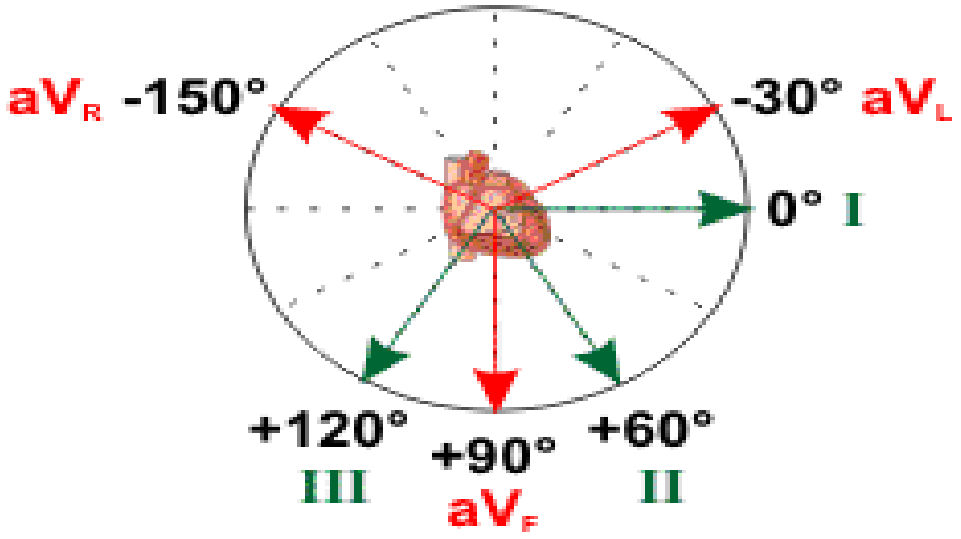
Mean Vector Through the Partially Depolarized Heart



Einthoven's triangle and law

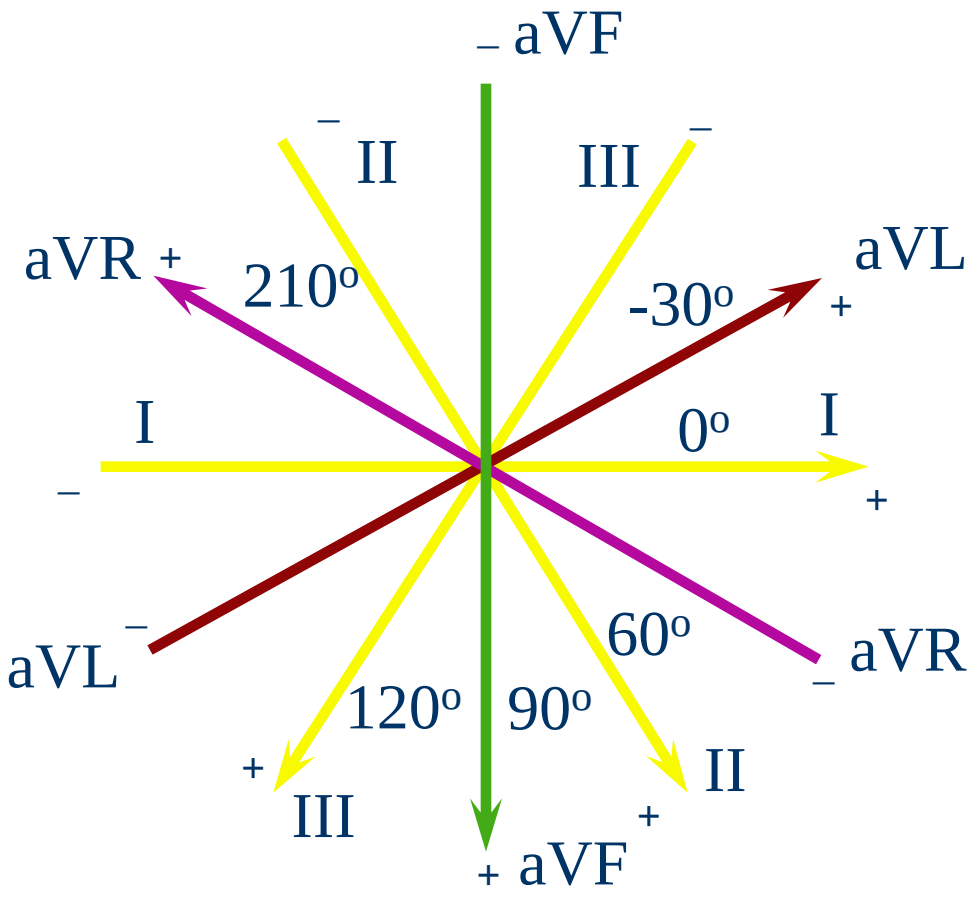



aVR
aVL
-150 °
-30°
+90°
aVF

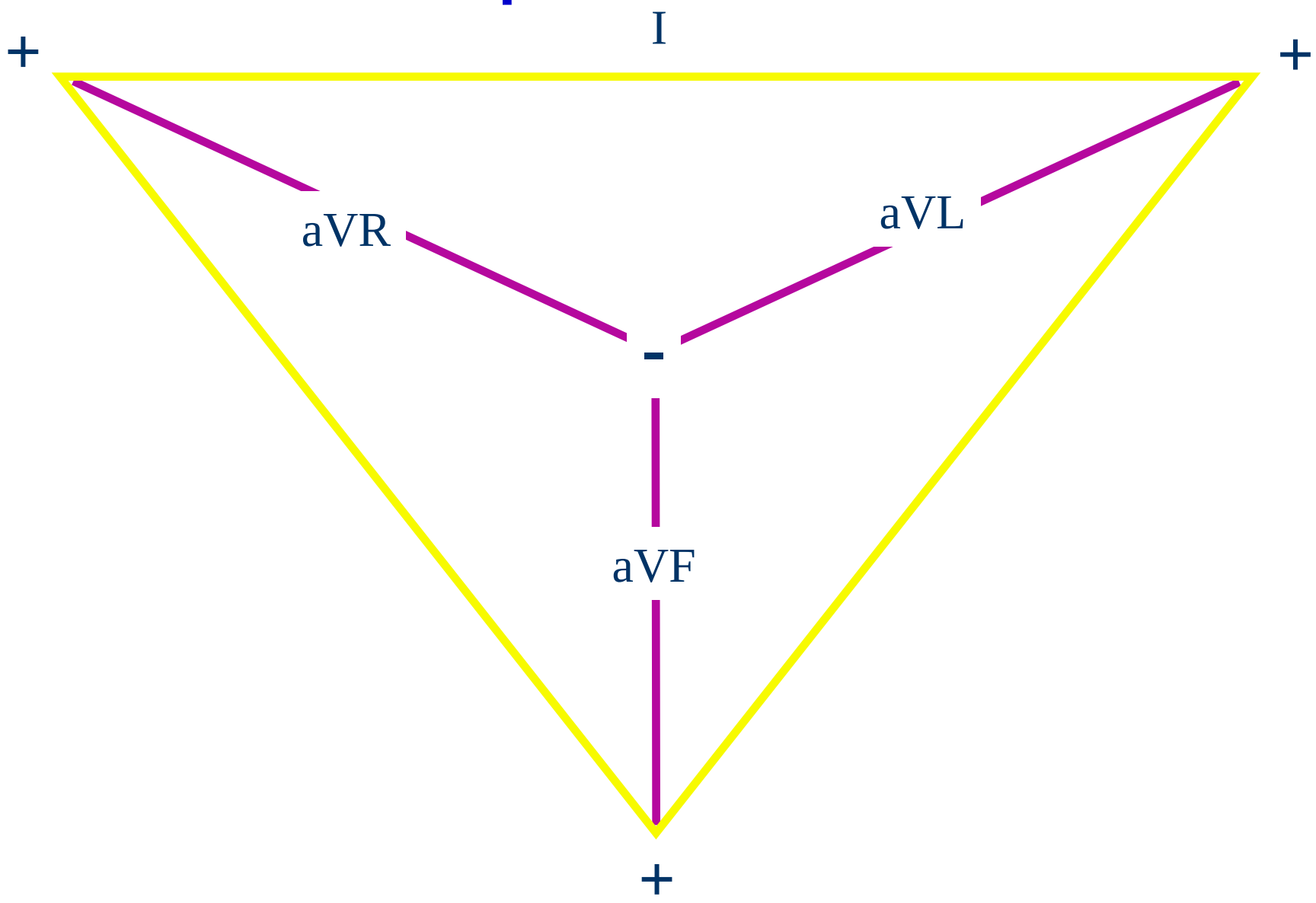

aVR -150°
-30° aVL
0° I
+120°
III
+90°
aVF
+60°
II

Principles of Vectorial Analysis of EKG's (cont'd)

Axes of the Three Bipolar and Augmented Leads



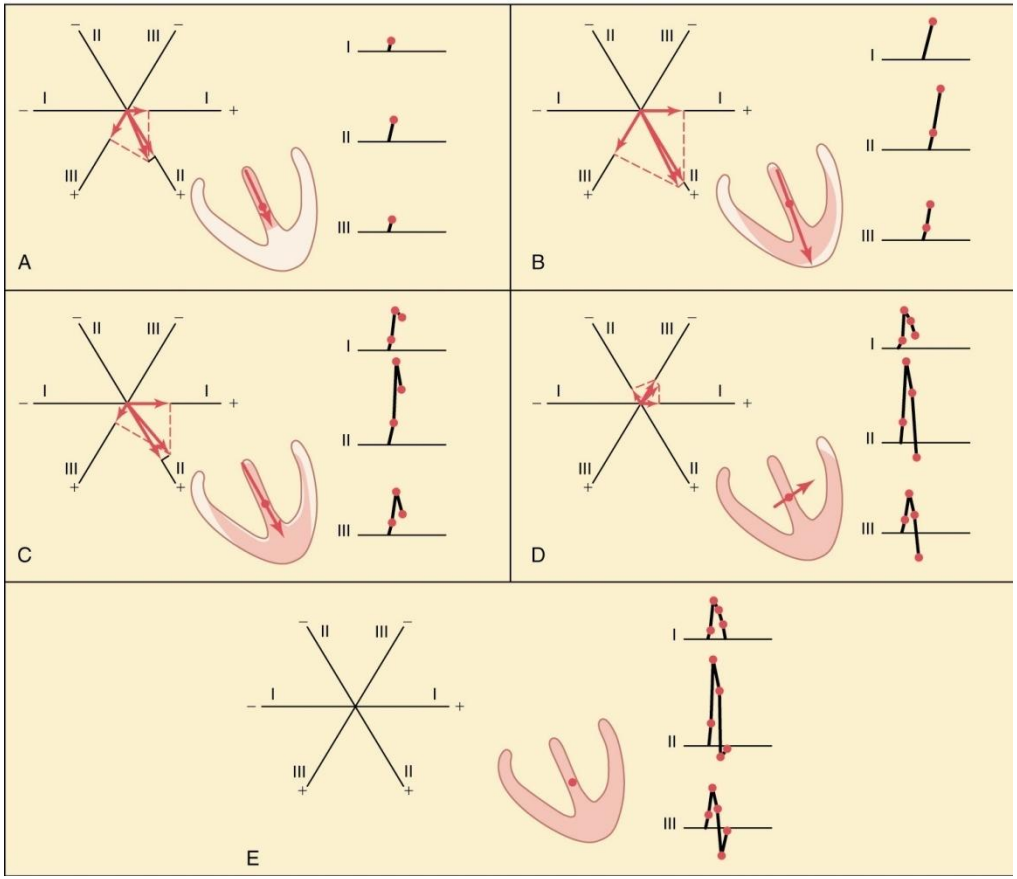
Axes of the Unipolar Limb Leads



Principles of Vectorial Analysis of EKG's (cont'd)

- *The axis of lead I is zero degrees* because the electrodes lie in the horizontal direction on each of the arms.
- *The axis of lead II is +60 degrees* because the right arm connects to the torso in the top right corner, and left leg connects to the torso in the bottom left corner.
- *The axis of lead III is 120 degrees.*

Principles of Vectorial Analysis of EKG's (cont'd)

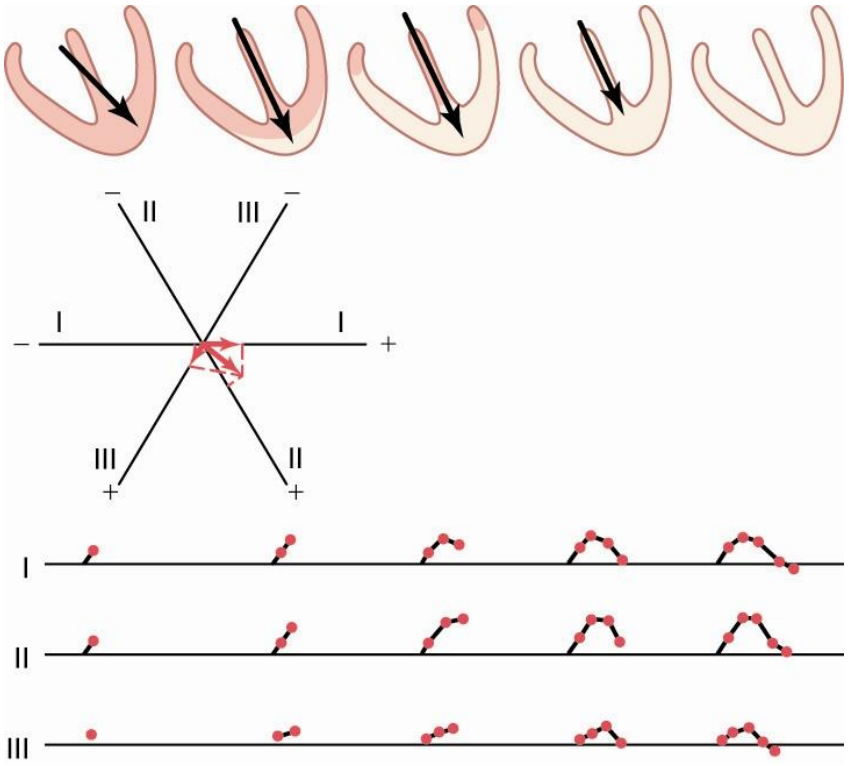


Principles of Vectorial Analysis of EKG's (cont'd)

- In figure B, the depolarization vector is large because half of the ventricle is depolarized.
- Lead II should be largest voltage when compared to I and III when the mean vector is 60^{o}.
- In figure C, left side is slower to depolarize.
- In figure D, the last part to depolarize is near the left base of the heart which gives a negative vector (S wave).
- Q wave is present if the left side of the septum depolarizes first.

The T Wave (Ventricular Repolarization)

- First area to repolarize is near the apex of the heart.
- Last areas, in general, to depolarize are the first to repolarize.
- Repolarized areas will have a + charge first; therefore, a + net vector occurs and a positive T wave

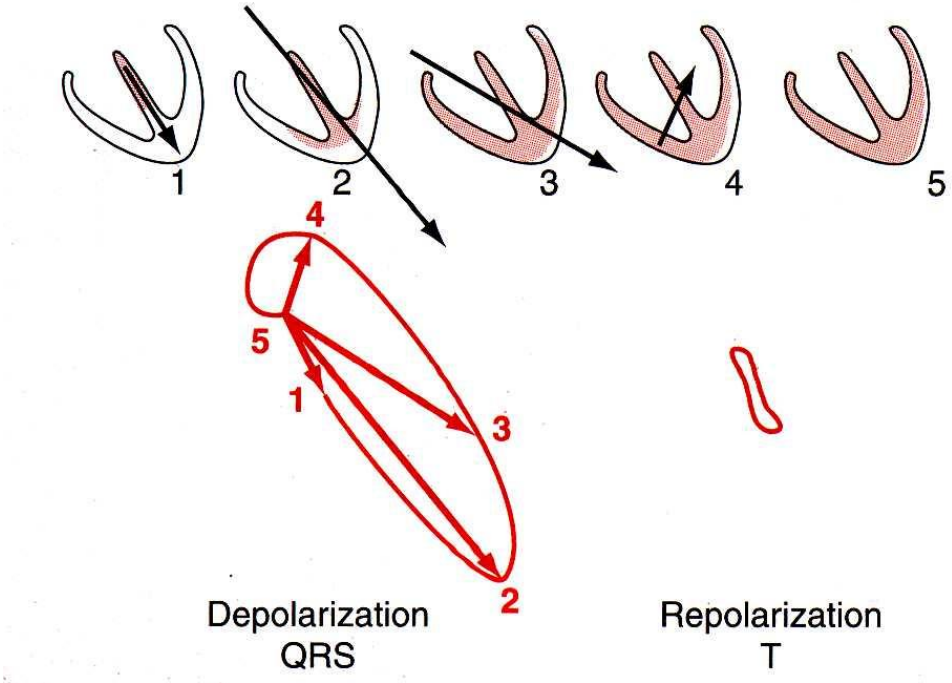


Atrial Depolarization (P-Wave) and Atrial Repolarization (Atrial T Wave)

- Atrial depolarization begins at sinus node and spreads toward A-V node.
- This should give a + vector in leads I, II, and III.
- Atrial repolarization can't be seen because it is masked by QRS complex.
- Atrial depolarization is slower than in ventricles, so first area to depolarize is also the first to repolarize. This gives a negative atrial repolarization wave in leads I, II, and III

Vectorcardiogram

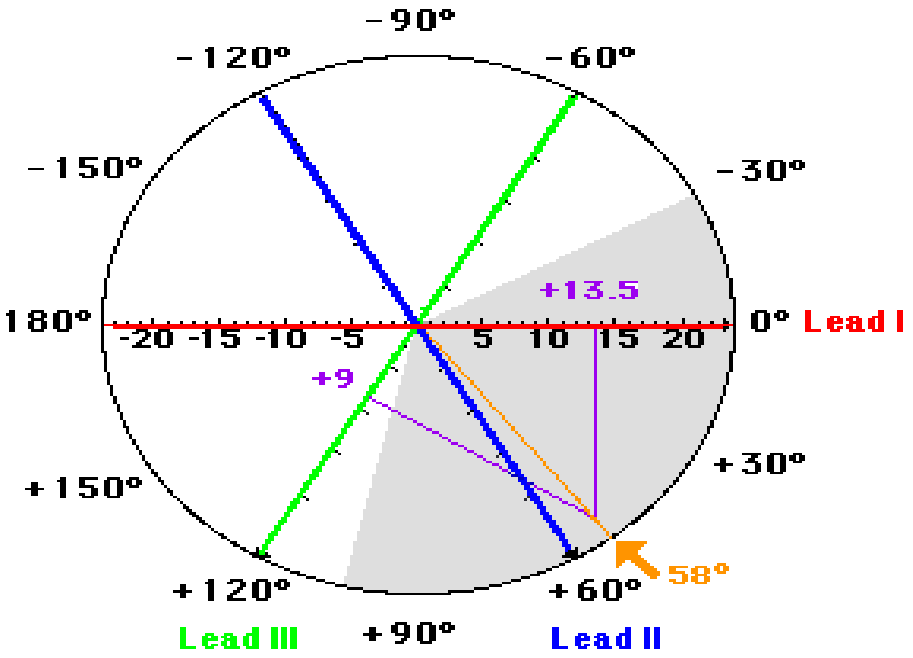
- This traces vectors throughout cardiac cycle.
- When half of the ventricle is depolarized, vector is largest.

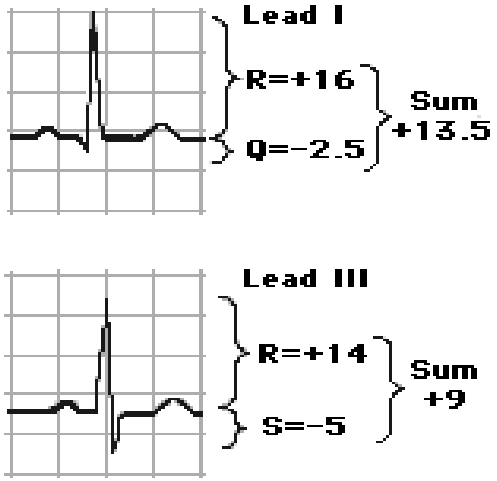


- Note zero reference point, number 5, is point of full depolarization

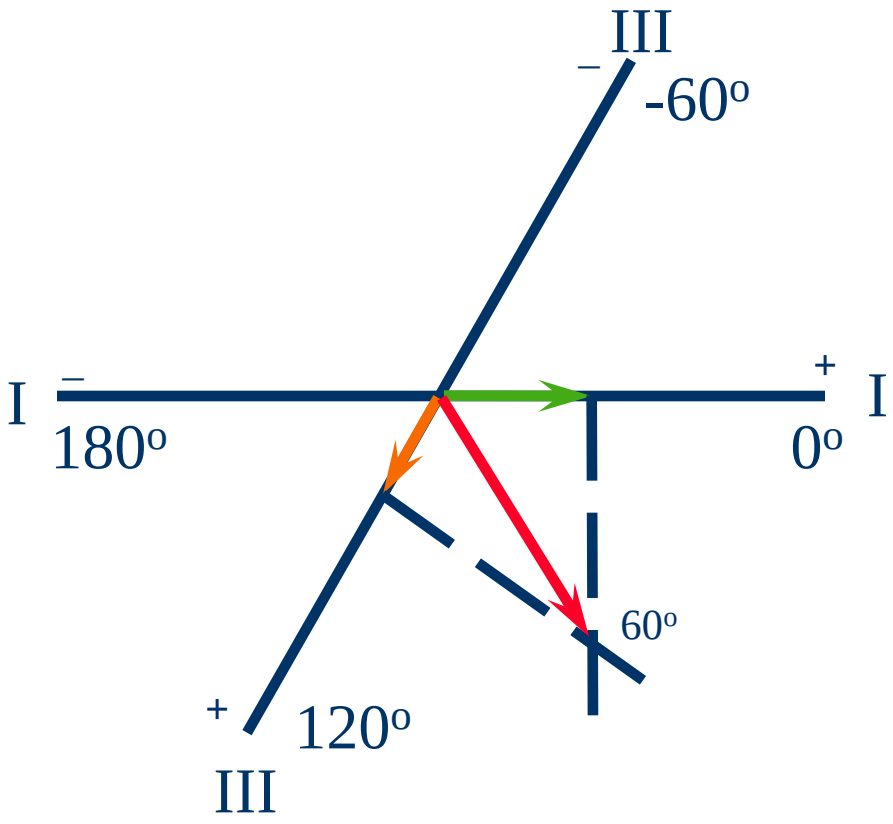
Determining Mean Electrical Axis

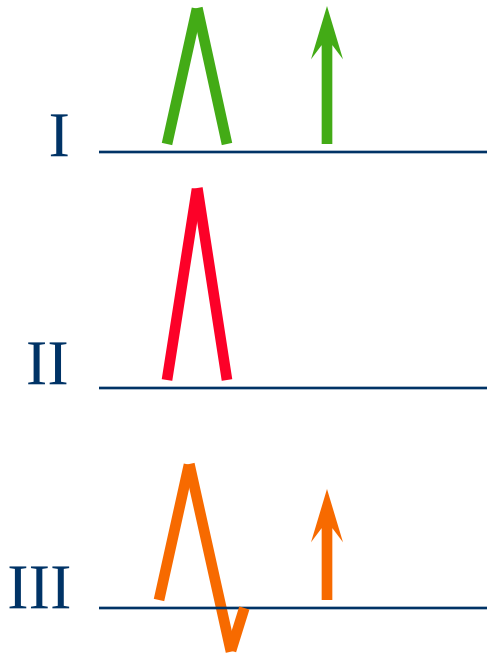
- Use 2 different leads
- Measure the sum of the height and the negative depth of the QRS complex
- Measure that vaule in mm onto the axis of the lead and draw perpendicular lines
- The intersection is at the angle of the mean axis.

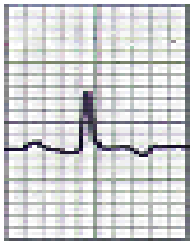




Plot of the Mean Electrical Axis of the Heart from Two Electrocardiographic Leads

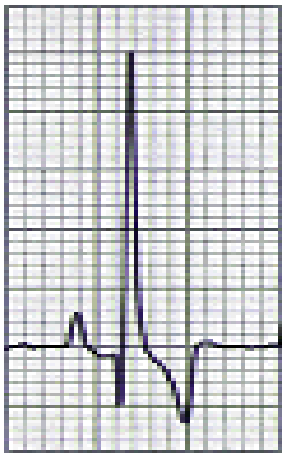






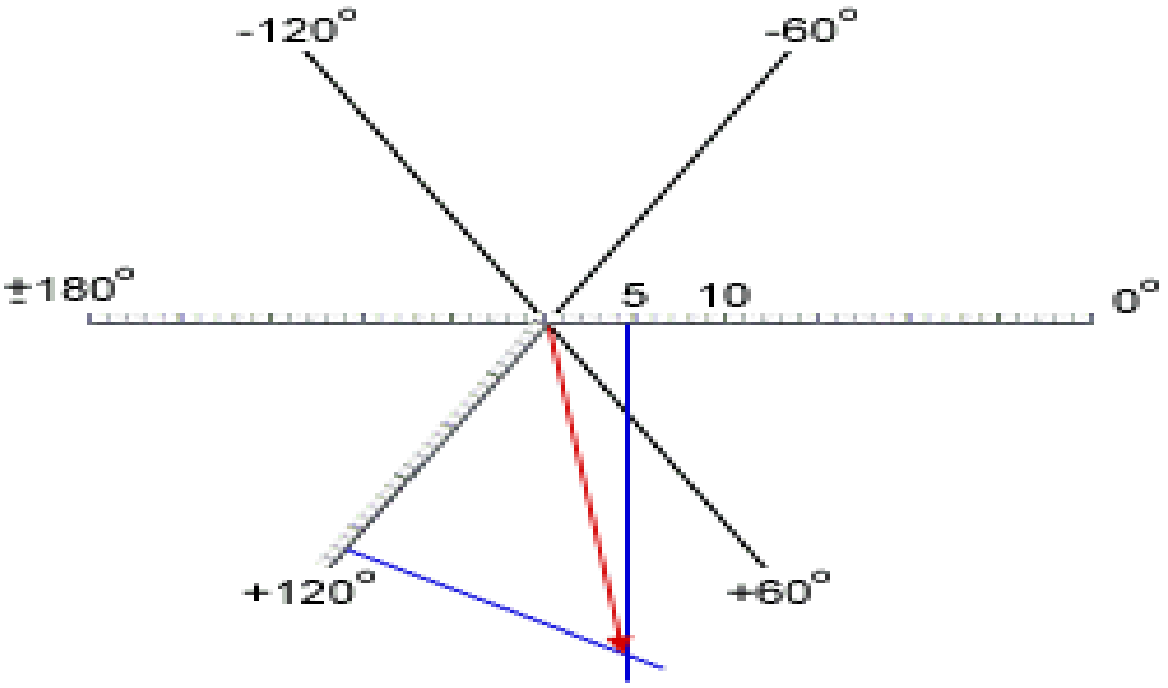
Lead I

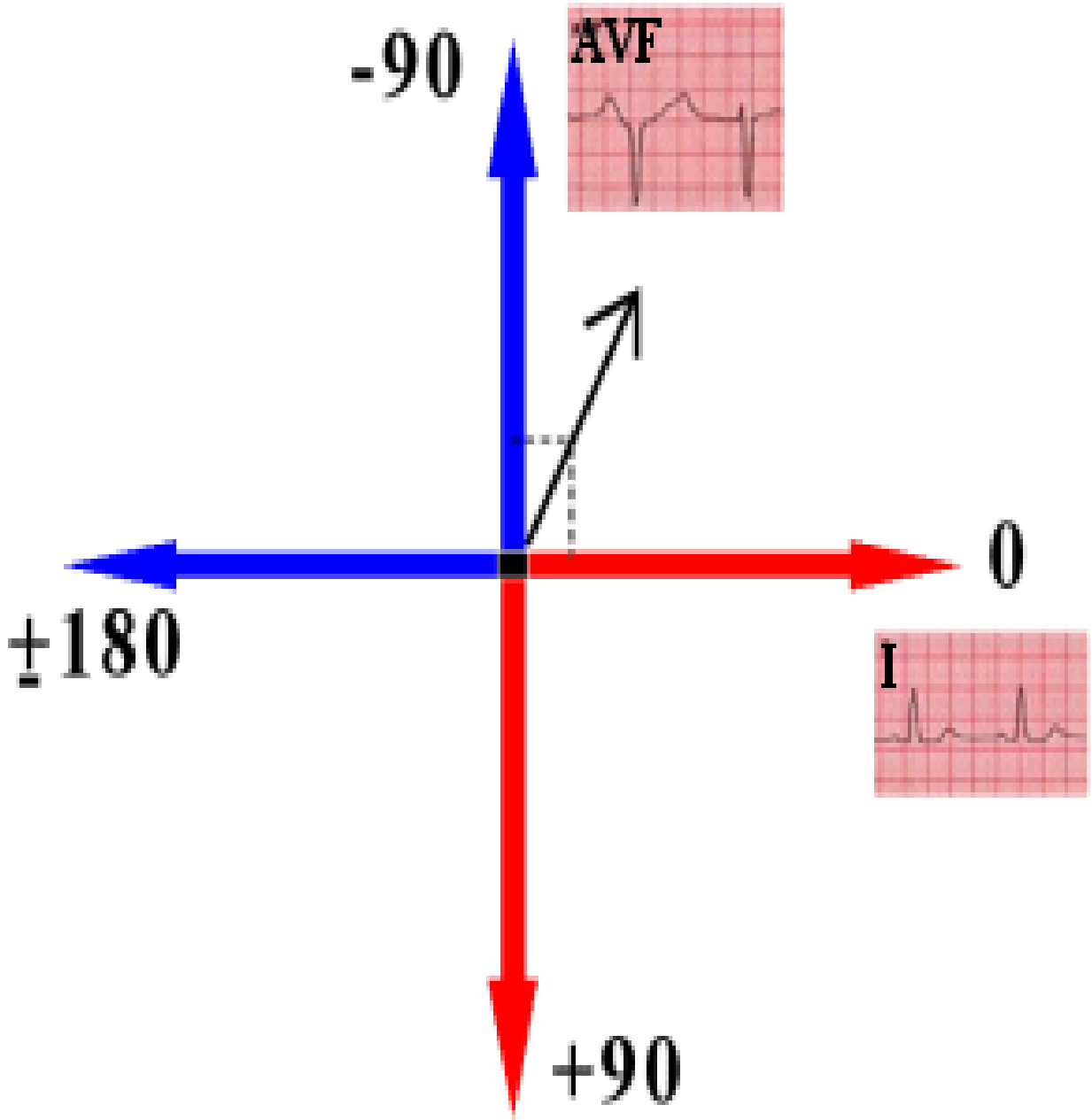
Q = - 0.5
R = +5
+4.5

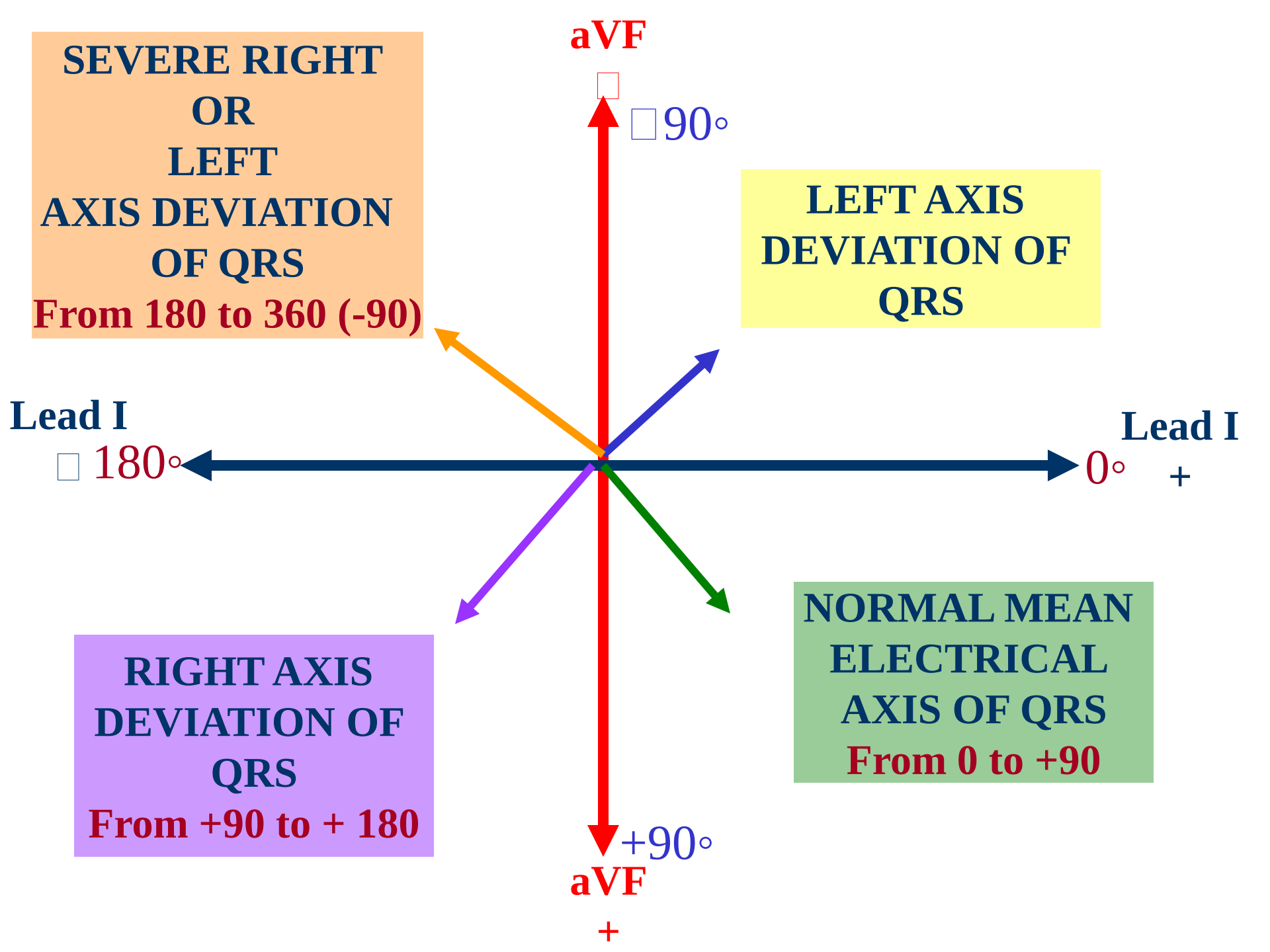


Lead III

Q = - 4
R = +26
+22



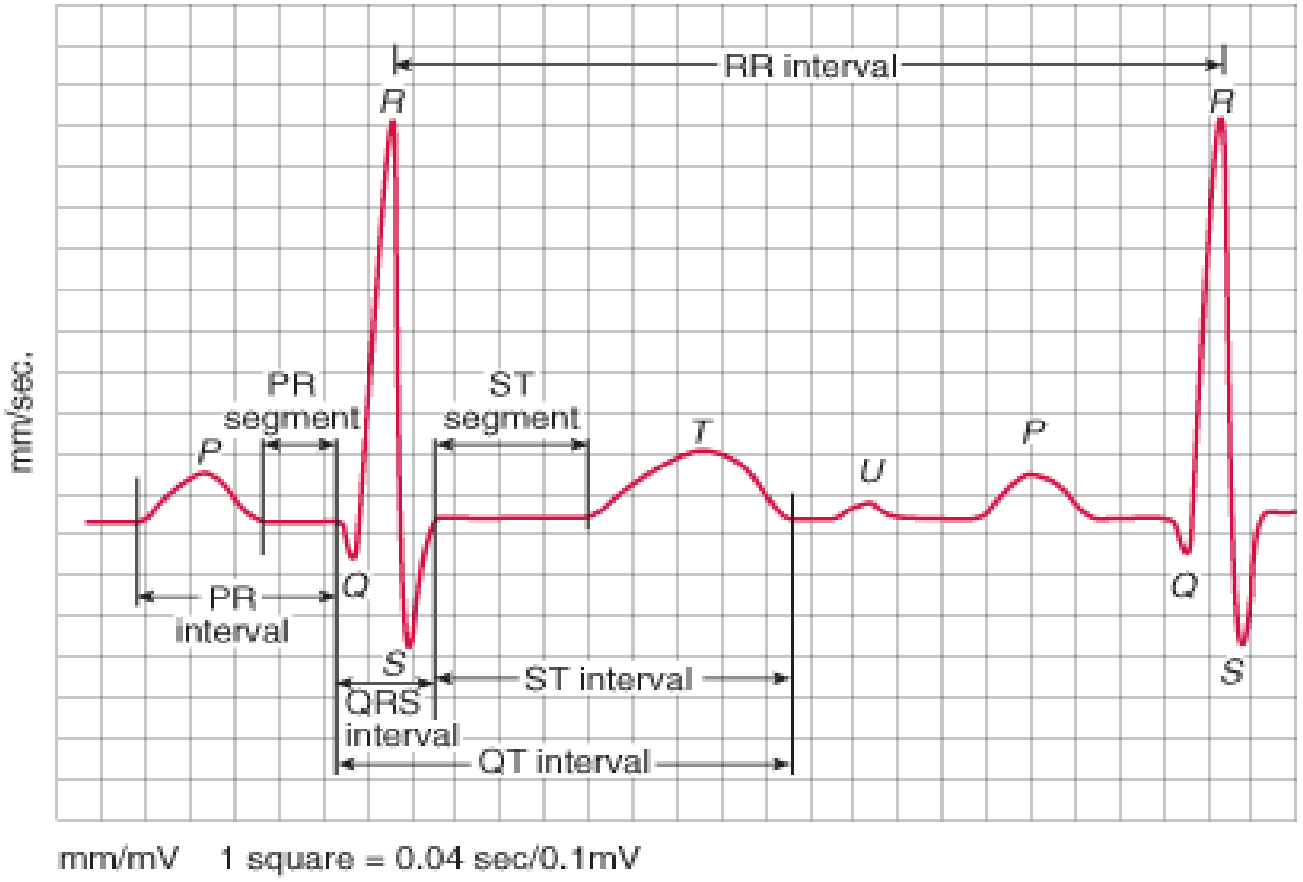

-90
AVF
0
±180
I
+90


SEVERE RIGHT
OR
LEFT
AXIS DEVIATION
OF QRS
From 180 to 360 (-90)
aVF
90◦
LEFT AXIS
DEVIATION OF
QRS
Lead I
180◦
Lead I
0◦
+
NORMAL MEAN
ELECTRICAL
AXIS OF QRS
From 0 to +90
RIGHT AXIS
DEVIATION OF
QRS
From +90 to + 180
+90◦
aVF
+

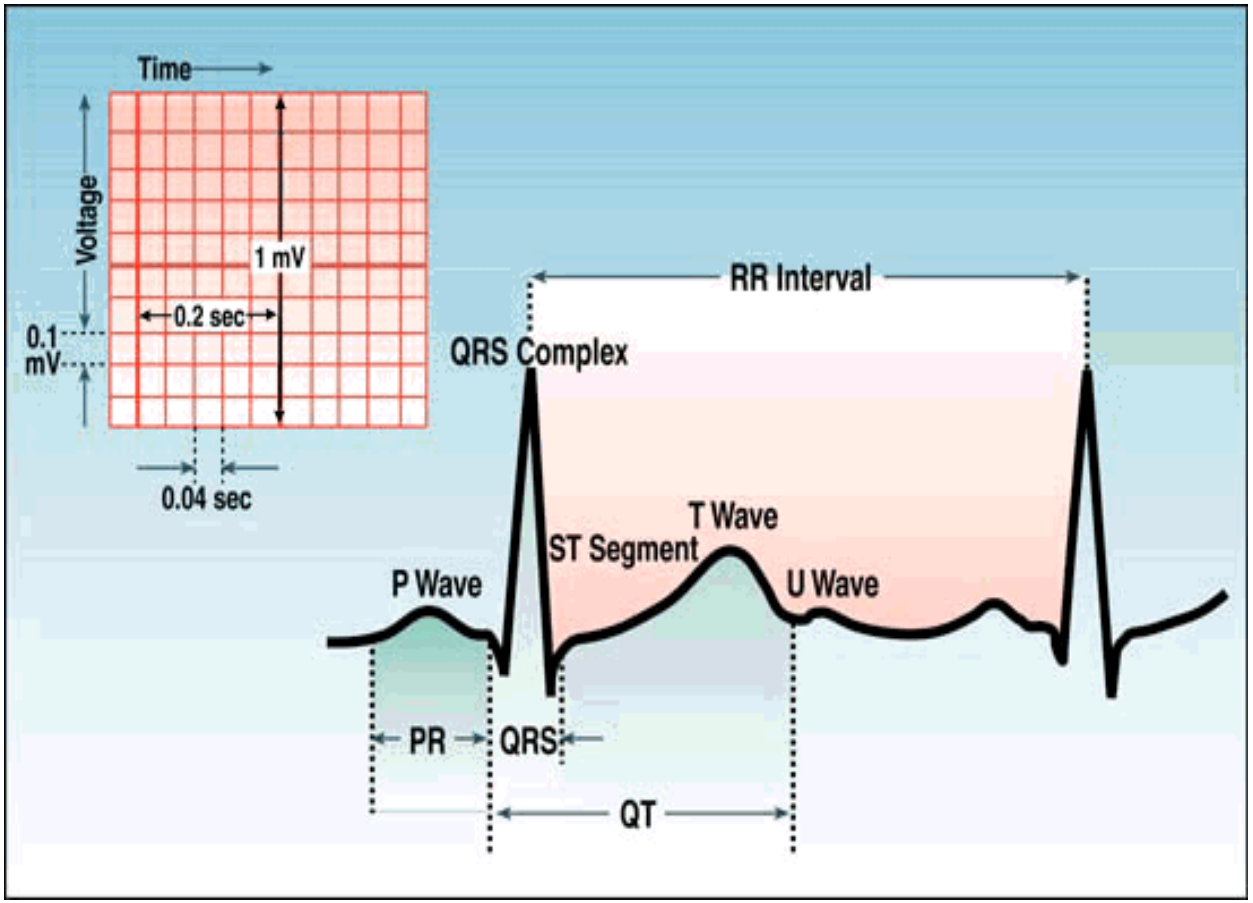
Heart Rate Calculation

- R-R interval = 0.83 sec
- Heart rate = $\frac{(60\ \text{sec})}{(0.83\ \text{sec})} = 72$ beats/min
  min beat

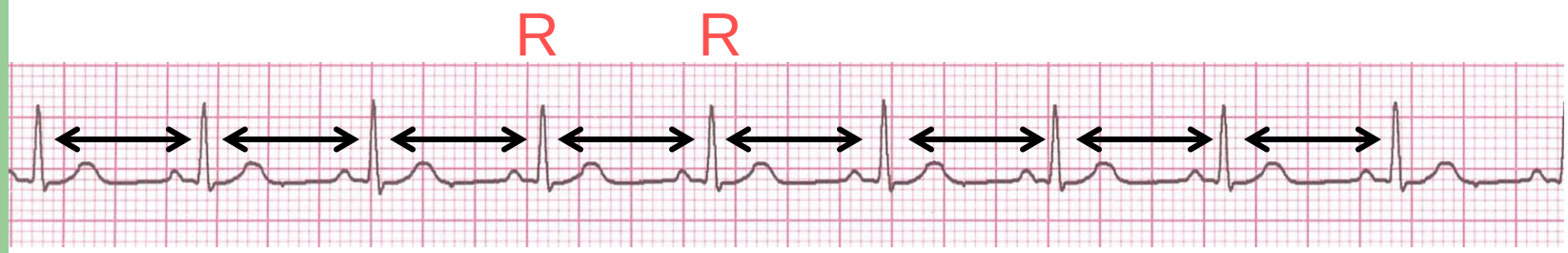
ECG Calculations



ECG Calculations



Determine regularity



- Look at the R-R distances (using a caliper or markings on a pen or paper).
- Regular (are they equidistant apart)? Occasionally irregular? Regularly irregular? Irregularly irregular? Interpretation?

Regular

Thank You

Electrocardiography – Abnormalities (Arrhythmias) 7

Faisal I. Mohammed, MD, PhD

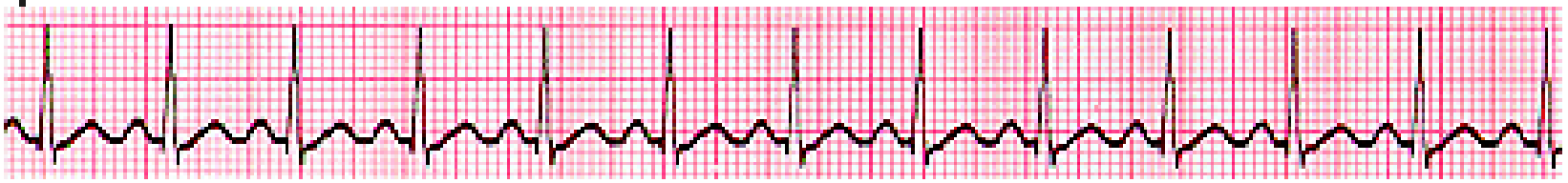
Causes of Cardiac Arrythmias

- Abnormal rhythmicity of the pacemaker
- Shift of pacemaker from sinus node
- Blocks at different points in the transmission of the cardiac impulse
- Abnormal pathways of transmission in the heart
- Spontaneous generation of abnormal impulses from any part of the heart

Abnormal Sinus Rhythms

- Tachycardia means a fast heart rate usually greater than 100 beats /min.
- Caused by (1) increased body temperature, (2) sympathetic stimulation (such as from loss of blood and the reflex stimulation of the heart), and (3) toxic conditions of the heart

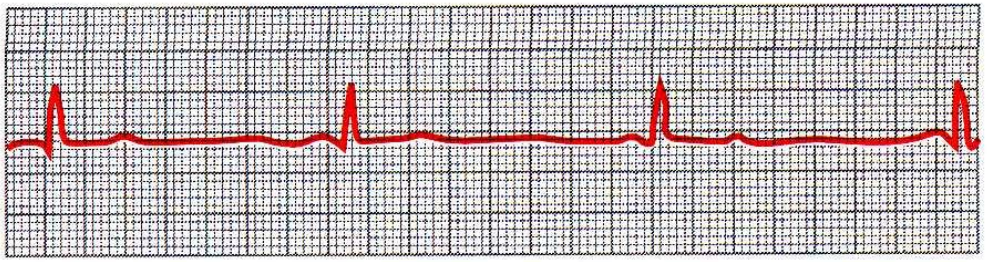
Sinus Tachycardia



- Etiology: SA node is depolarizing faster than normal, impulse is conducted normally.
- Remember: sinus tachycardia is a response to physical or psychological stress, not a primary arrhythmia.

Abnormal Sinus Rhythms (cont'd)

- Bradycardia means a slow heart rate usually less than 60 beats /min
- Present in athletes who have a large stroke volume
- Can be caused by vagal stimulation, one example of which is the carotid sinus syndrome



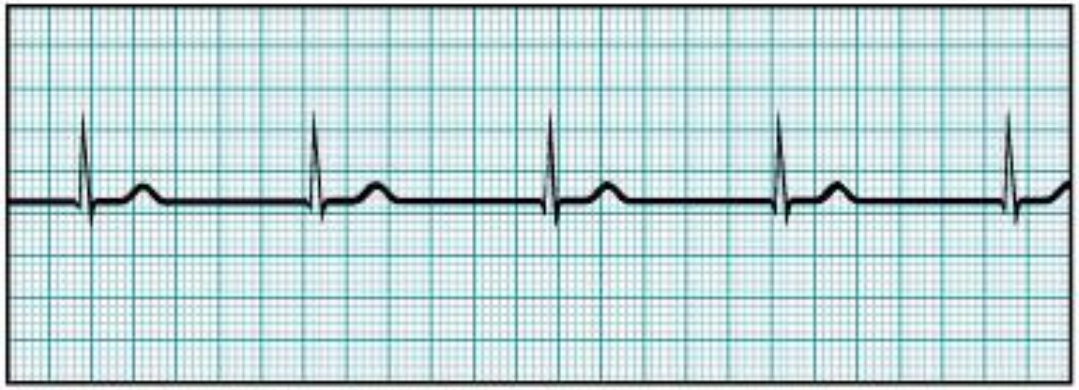
Heart Rate?

Sinus Bradycardia

- Etiology: SA node is depolarizing slower than normal, impulse is conducted normally (i.e. normal PR and QRS interval) rate is slower than 60/beats per minute

ECGs, Normal and Abnormal

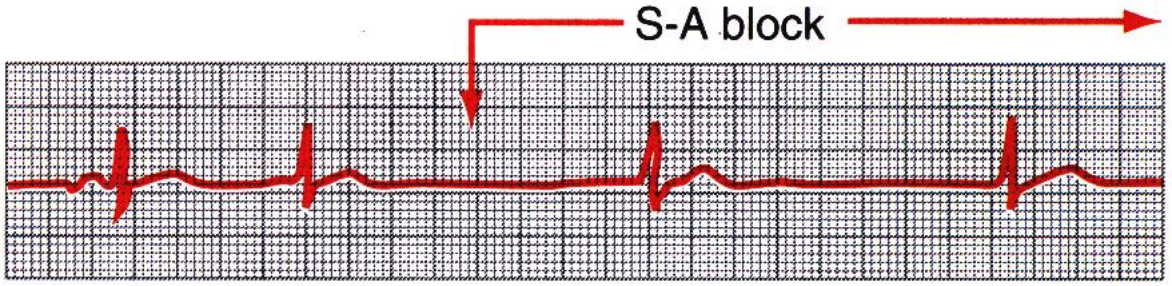
(a) Sinus rhythm (normal)



(b) Nodal rhythm – no SA node activity

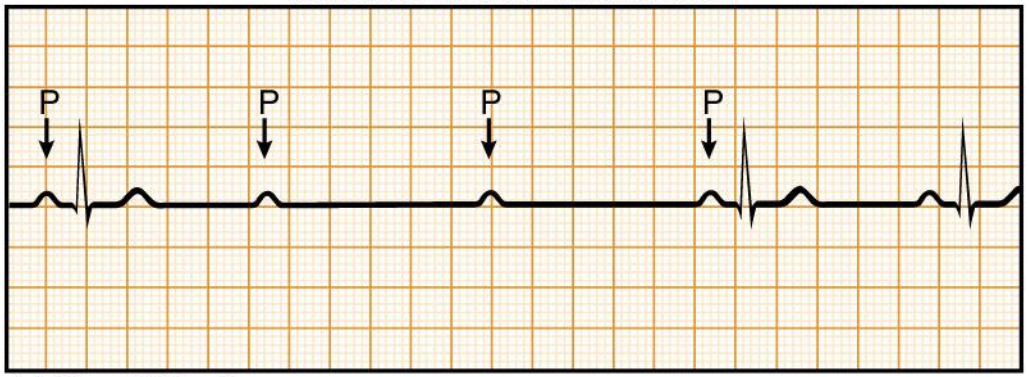
Sinoatrial Block

- In rare instances impulses from S-A node are blocked.
- This causes cessation of P waves.
- New pacemaker is region of heart with the fastest discharge rate, usually the A-V node.



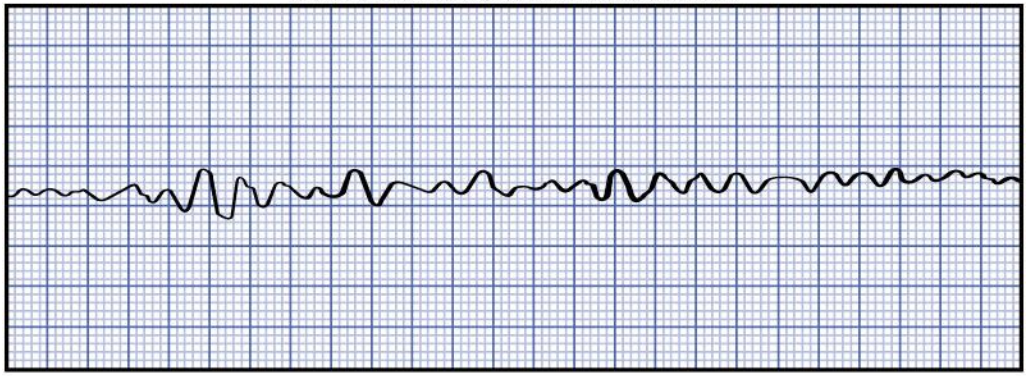
Note: no P waves and slow rate

ECGs, Abnormal



(c) Heart block

Arrhythmia: conduction failure at AV node



(e) Ventricular fibrillation

No pumping action occurs

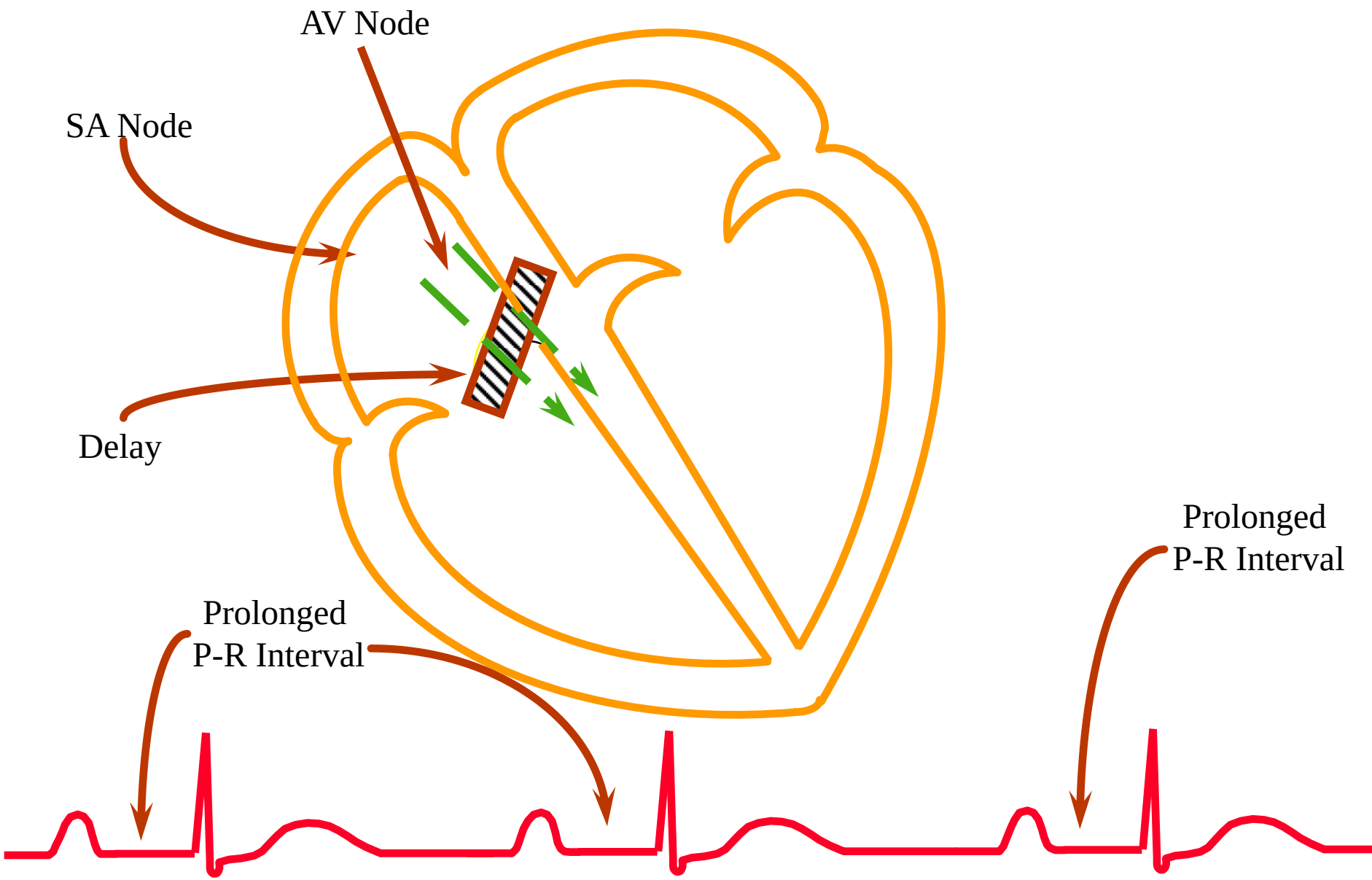
Atrioventricular Block

- **Impulses through A-V node and A-V bundle (bundle of His) are slowed down or blocked due to :**
  - (1) Ischemia of A-V nodal or A-V bundle fibers (can be caused by coronary ischemia)
  - (2) Compression of A-V bundle (by scar tissue or calcified tissue)
  - (3) A-V nodal or A-V bundle inflammation
  - (4) Excessive vagal stimulation

Incomplete Heart Block: First Degree Block

- Normal P-R interval is 0.16 sec
- If P-R interval is > 0.20 sec, first degree block is present (but P-R interval seldom increases above 0.35 to 0.45 sec)

First Degree Heart Block



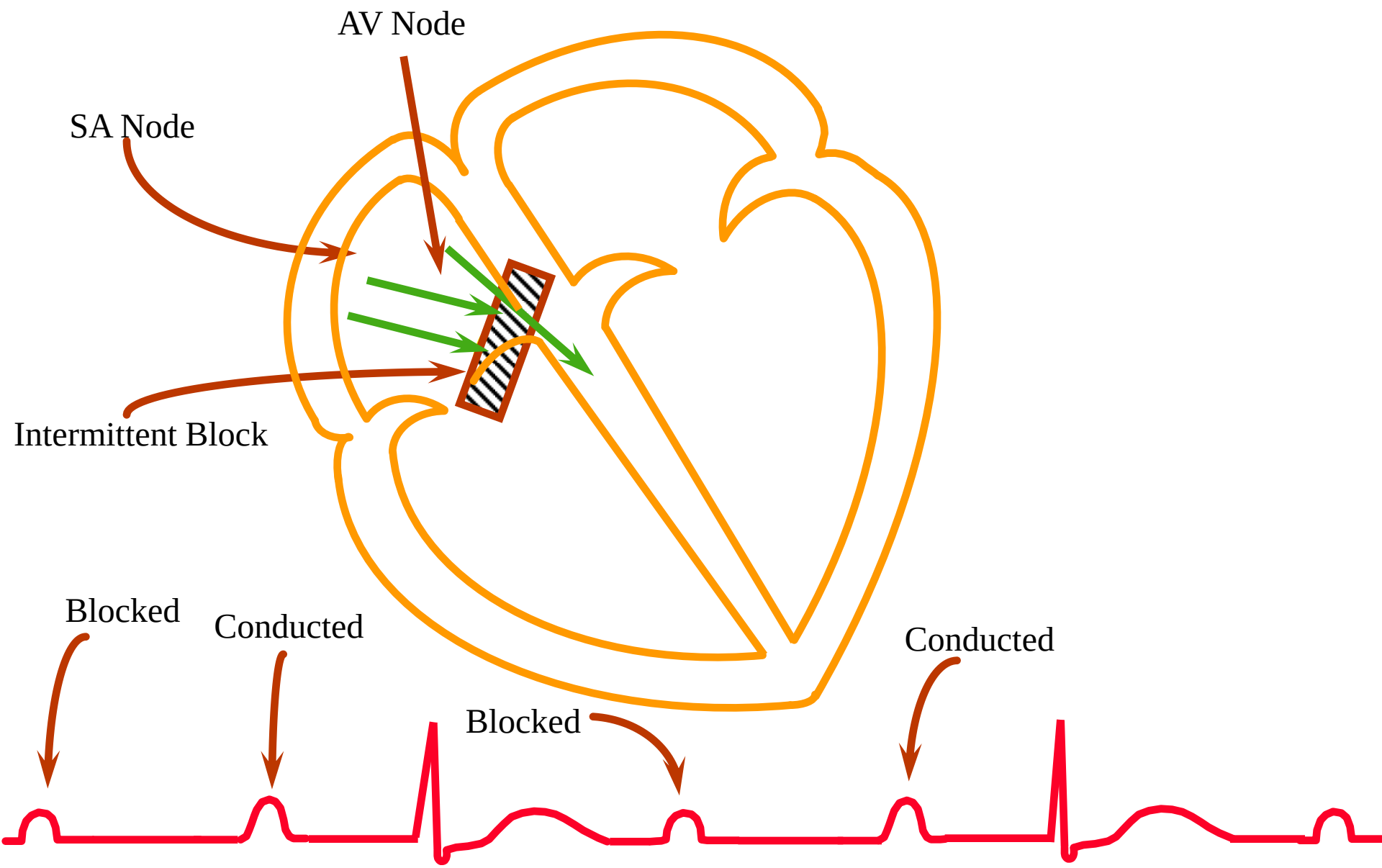
1st Degree AV Block

- Etiology: Prolonged conduction delay in the AV node or Bundle of His.

Second Degree Incomplete Block

- P-R interval increases to 0.25 - 0.45 sec
- Some impulses pass through the A-V node and some do not thus causing “dropped beats”.
- Atria beat faster than ventricles.

Second Degree Heart Block

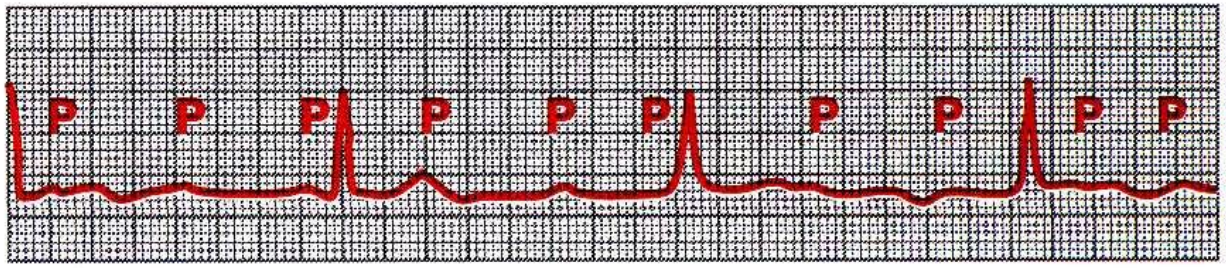


2nd Degree AV Block,

- Etiology: Each successive atrial impulse encounters a longer and longer delay in the AV node until one impulse (usually the 3rd or 4th) fails to make it through the AV node.

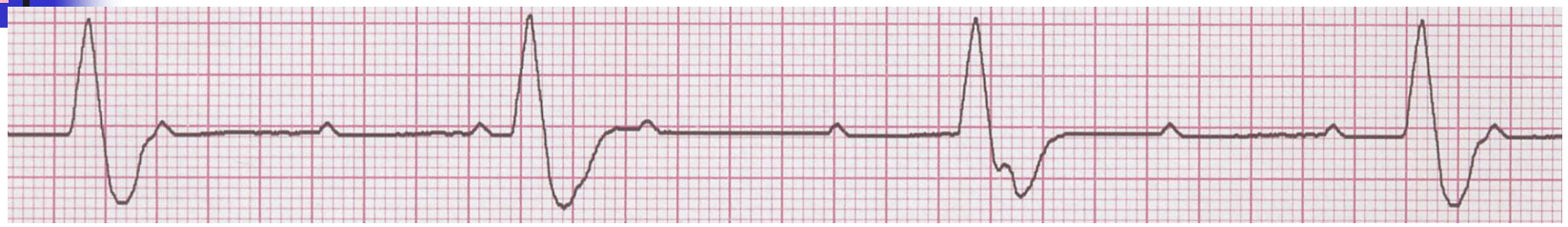
Third Degree Complete Block

- Total block through the A-V node or A-V bundle
- P waves are completely dissociated from QRST complexes
- Ventricles escape and A-V nodal rhythm ensues



HR = 37

3rd Degree AV Block



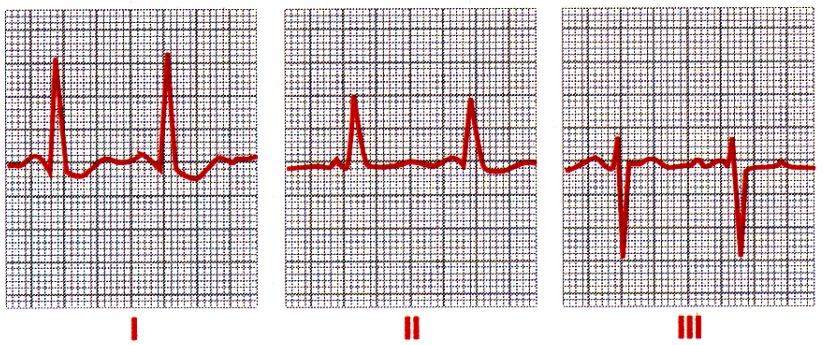
- Etiology: There is complete block of conduction in the AV junction, so the atria and ventricles form impulses independently of each other. Without impulses from the atria, the ventricles own intrinsic pacemaker beats at around 15 - 40 beats/minute.

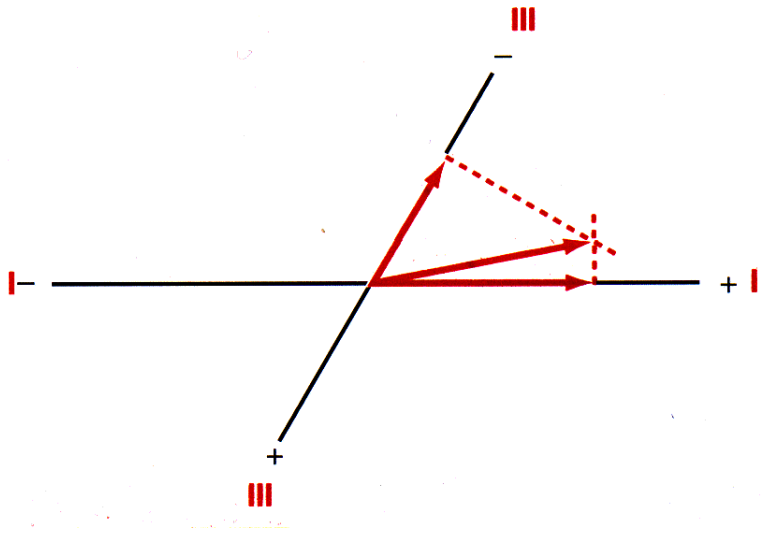
Stokes-Adams Syndrome

- Complete A-V block comes and goes.
- Ventricles stop contracting for 5-30 sec because of overdrive suppression meaning they are used to atrial drive.
- Patient faints because of poor cerebral blood flow
- Then, ventricular escape occurs with A-V nodal or A-V bundle rhythm (15-40 beats /min).
- Artificial pacemakers connected to right ventricle are provided for these patients.

Factors Causing Electrical Axis deviation

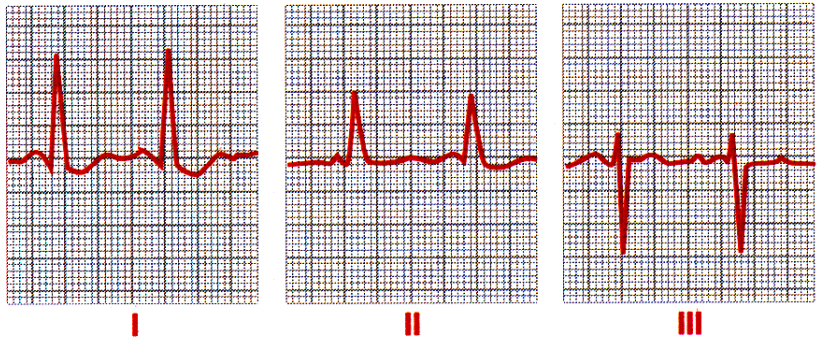
- Changes in heart position: left shift caused by expiration, lying down and excess abdominal fat, short and obese.
- Right shift caused by thin and tall person

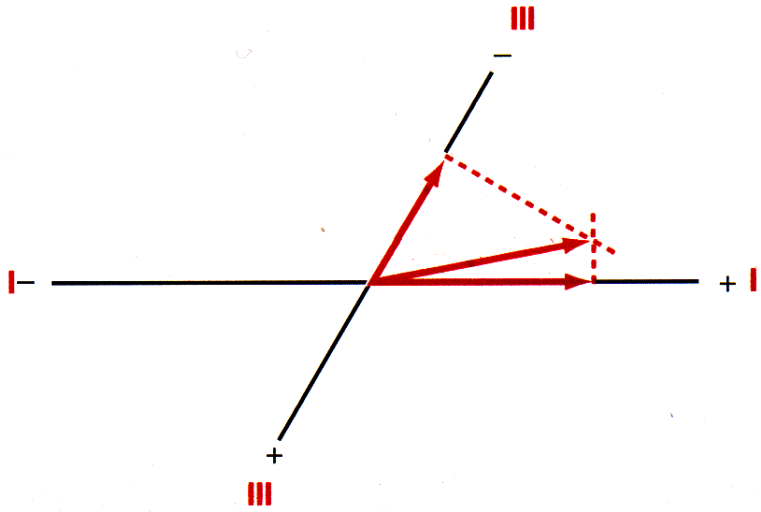




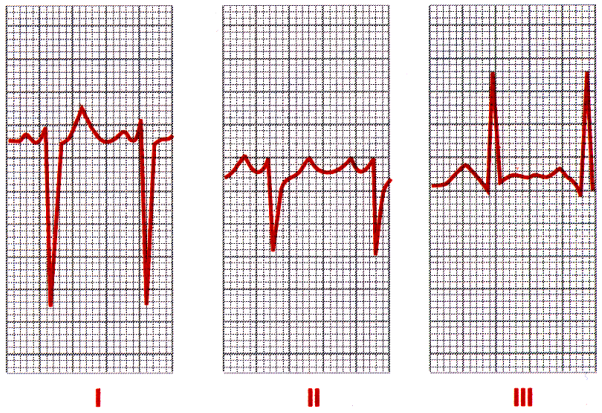
Factors Causing Electrical Axis Deviation cont'd

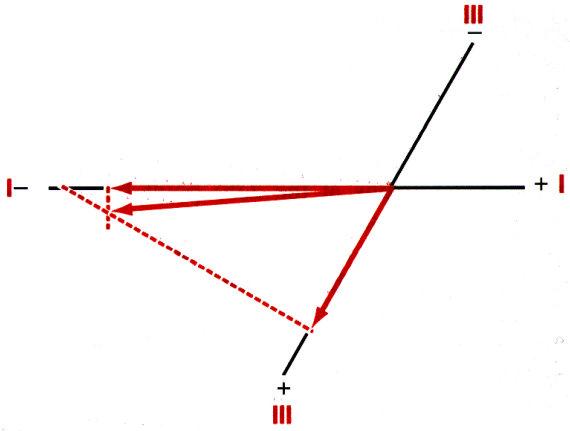
- Hypertrophy of left ventricle (left axis shift) caused by hypertension, aortic stenosis or aortic regurgitation causes slightly prolonged QRS and high voltage.





Factors Causing Electrical Axis Deviation (cont'd)

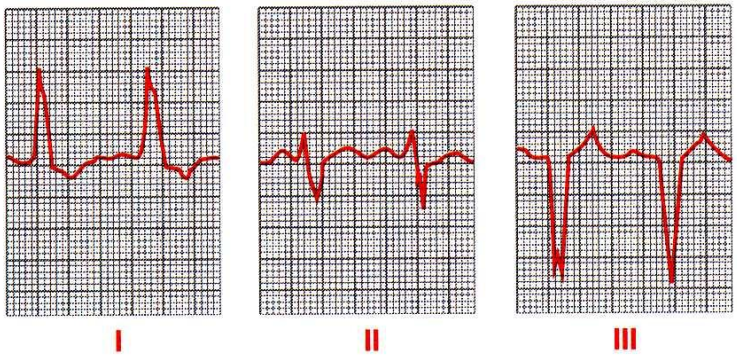


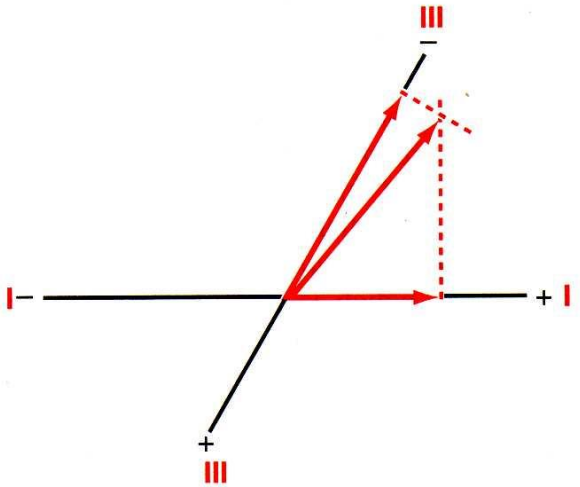


- Hypertrophy of right ventricle (right axis shift) caused by pulmonary hypertension, pulmonary valve stenosis, interventricular septal defect. All cause slightly prolonged QRS and high voltage.

Factors Causing Electrical Axis Deviation …cont'd

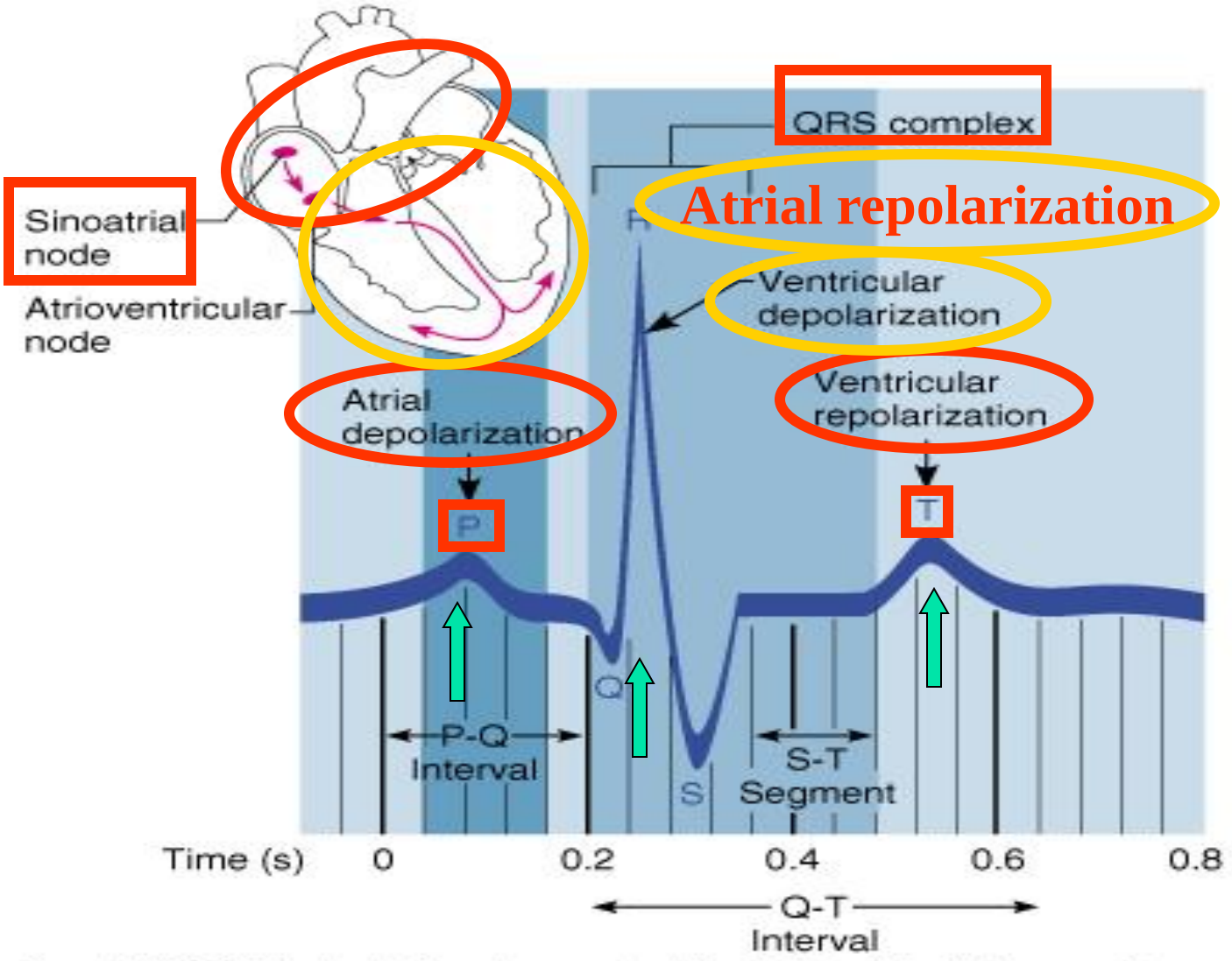
- Bundle branch block-**Left** bundle branch block causes **left** axis shift because **right** ventricle depolarizes much faster than **left** ventricle. QRS complex is prolonged. By the same token **Right** bundle branch block causes **right** axis deviation.





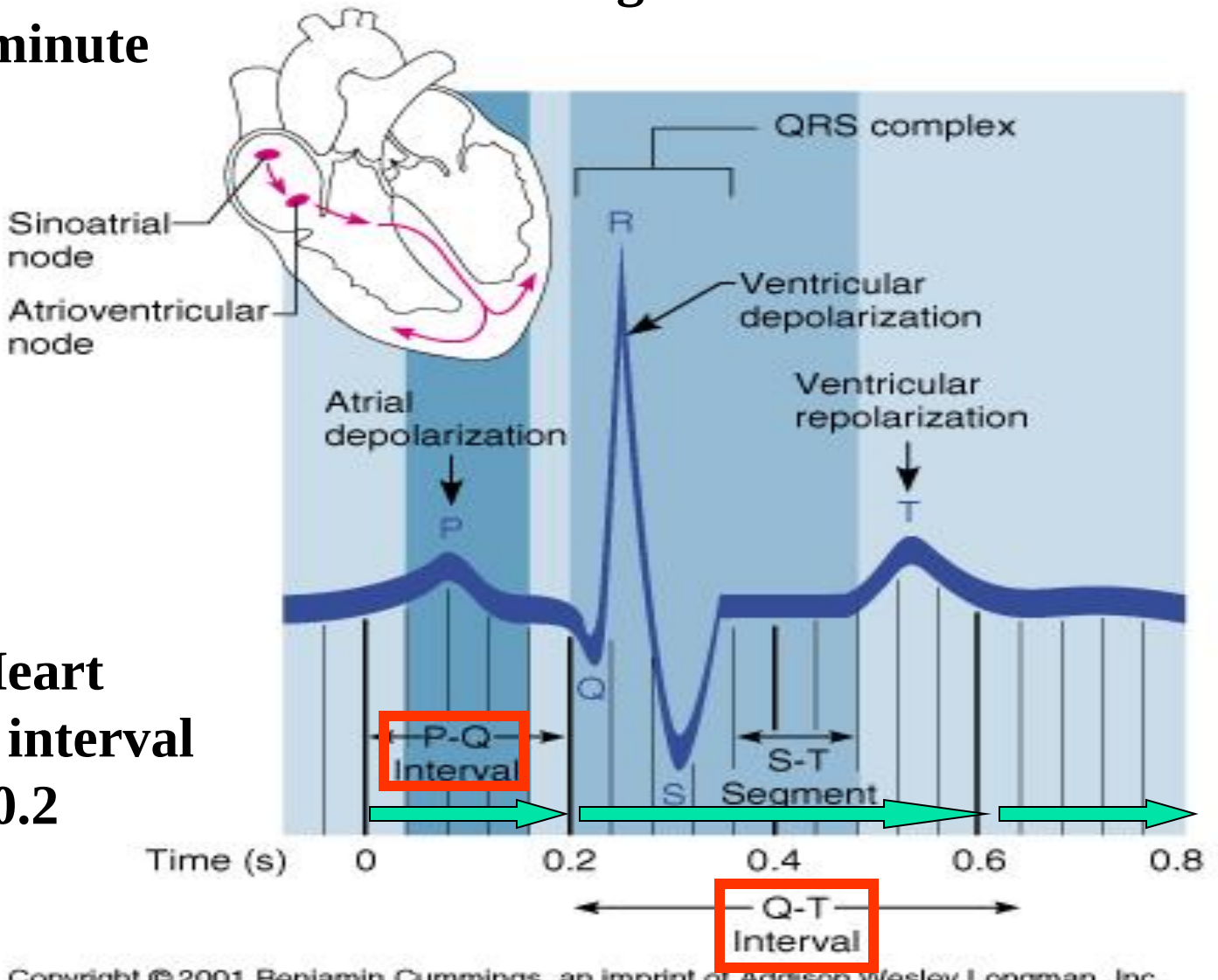
ECG Deflection Waves

(Pacemaker)



ECG Deflection Waves

60 seconds ÷ 0.8 seconds = resting heart rate of 75 beats/minute

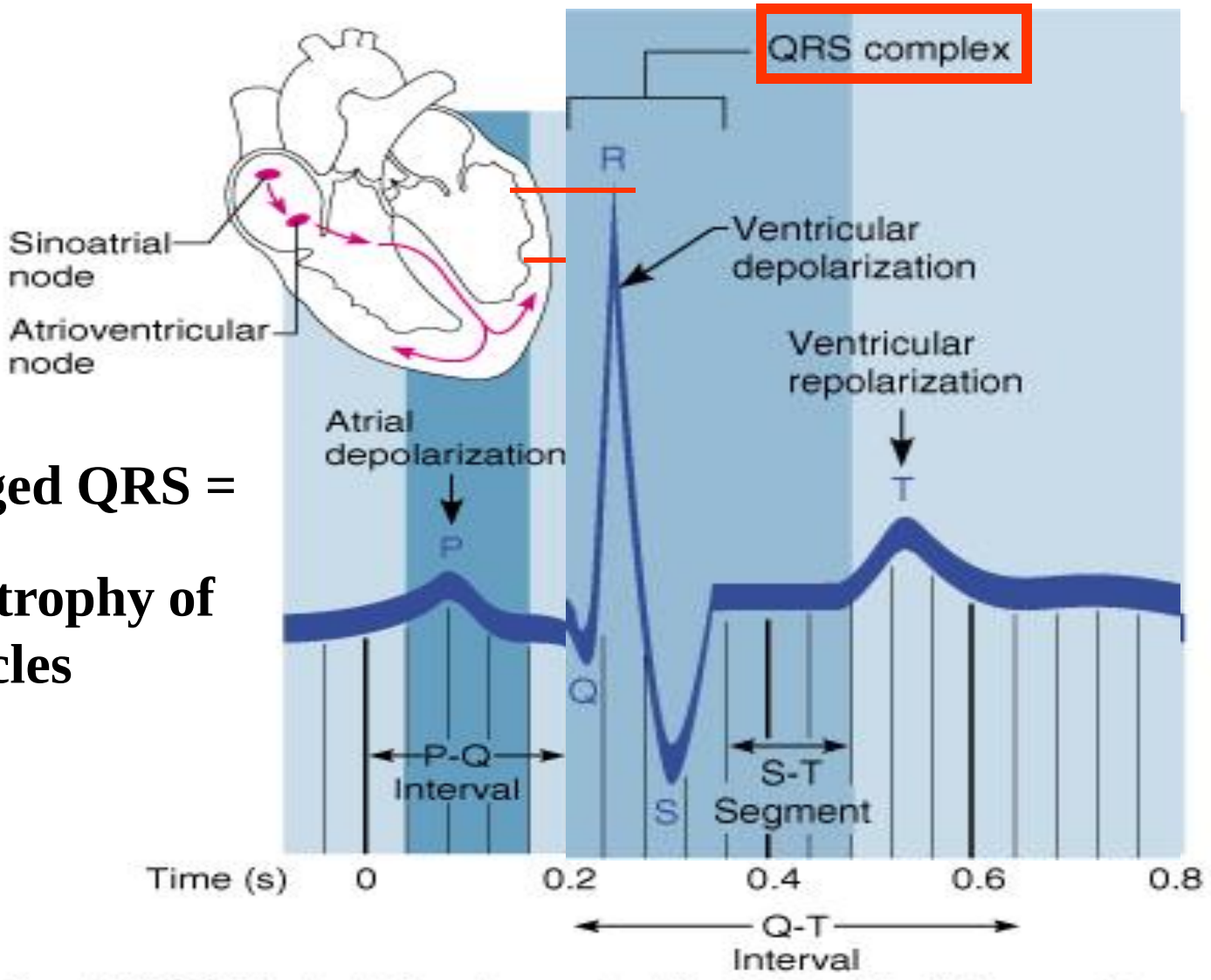


1st Degree Heart Block = P-Q interval longer than 0.2 seconds.

ECG Deflection Wave irregularities

Enlarged QRS =

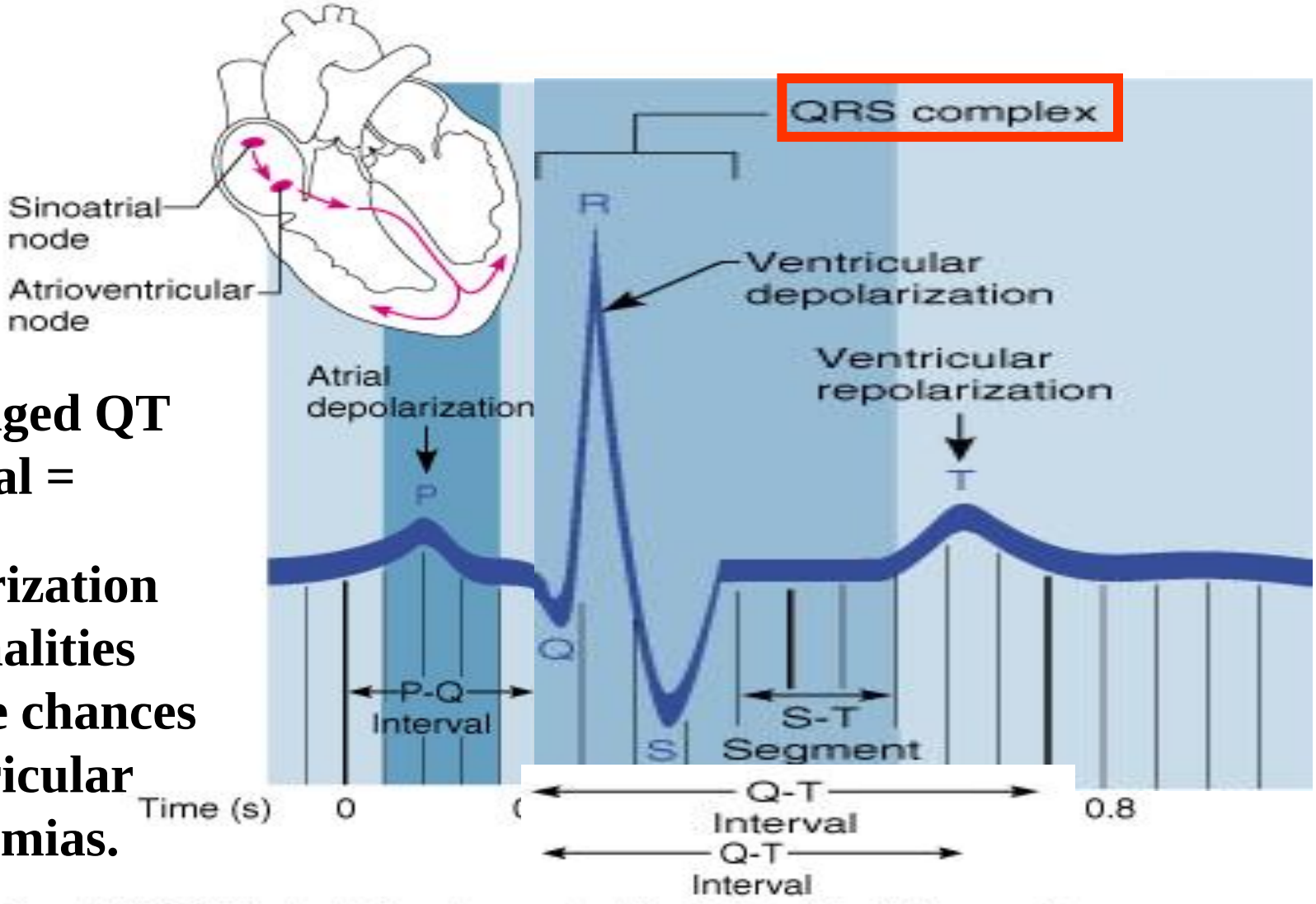
Hypertrophy of ventricles



ECG Deflection Wave Irregularities

Prolonged QT Interval =

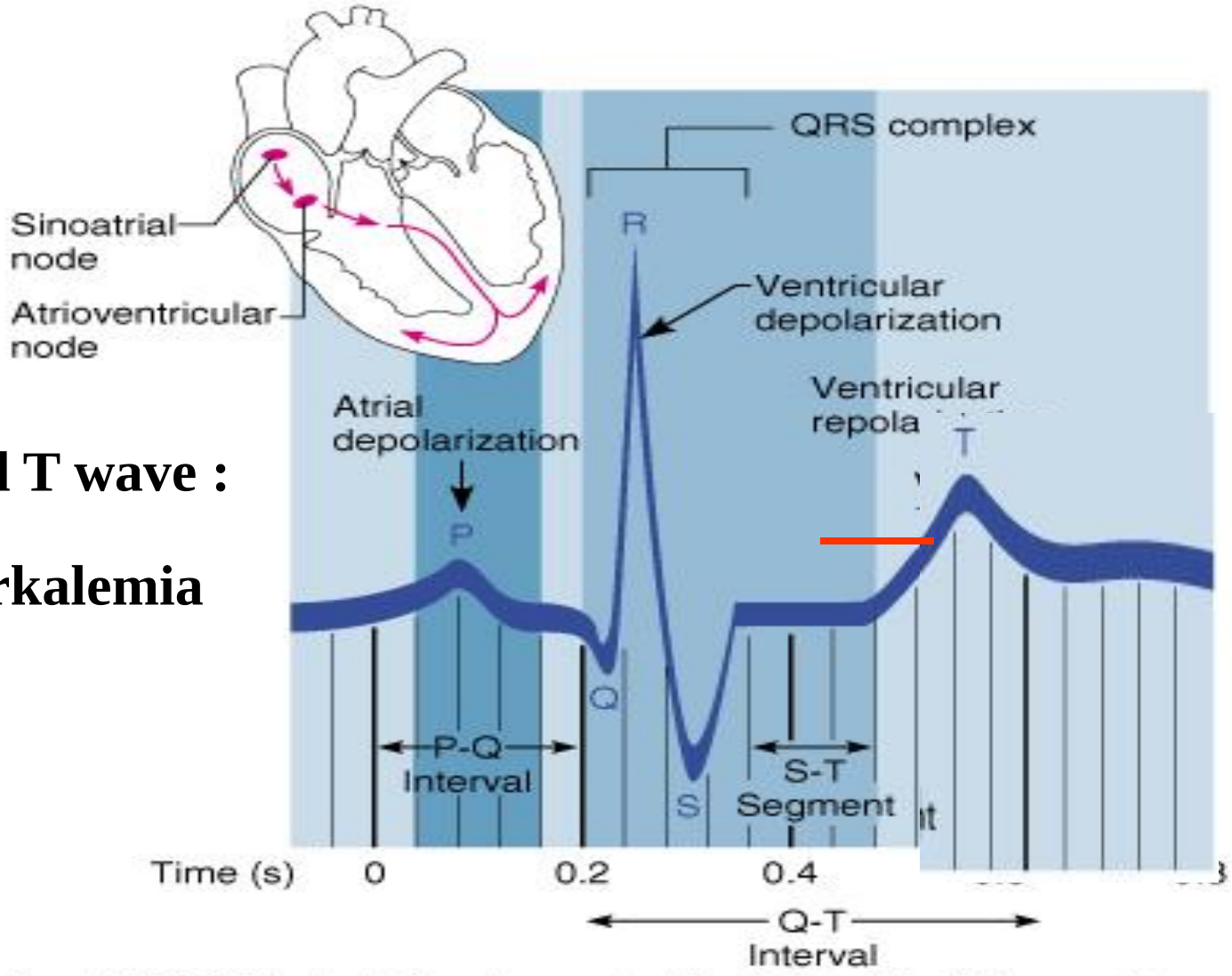
Repolarization abnormalities increase chances of ventricular arrhythmias.



ECG Deflection Wave Irregularities

Elevated T wave :

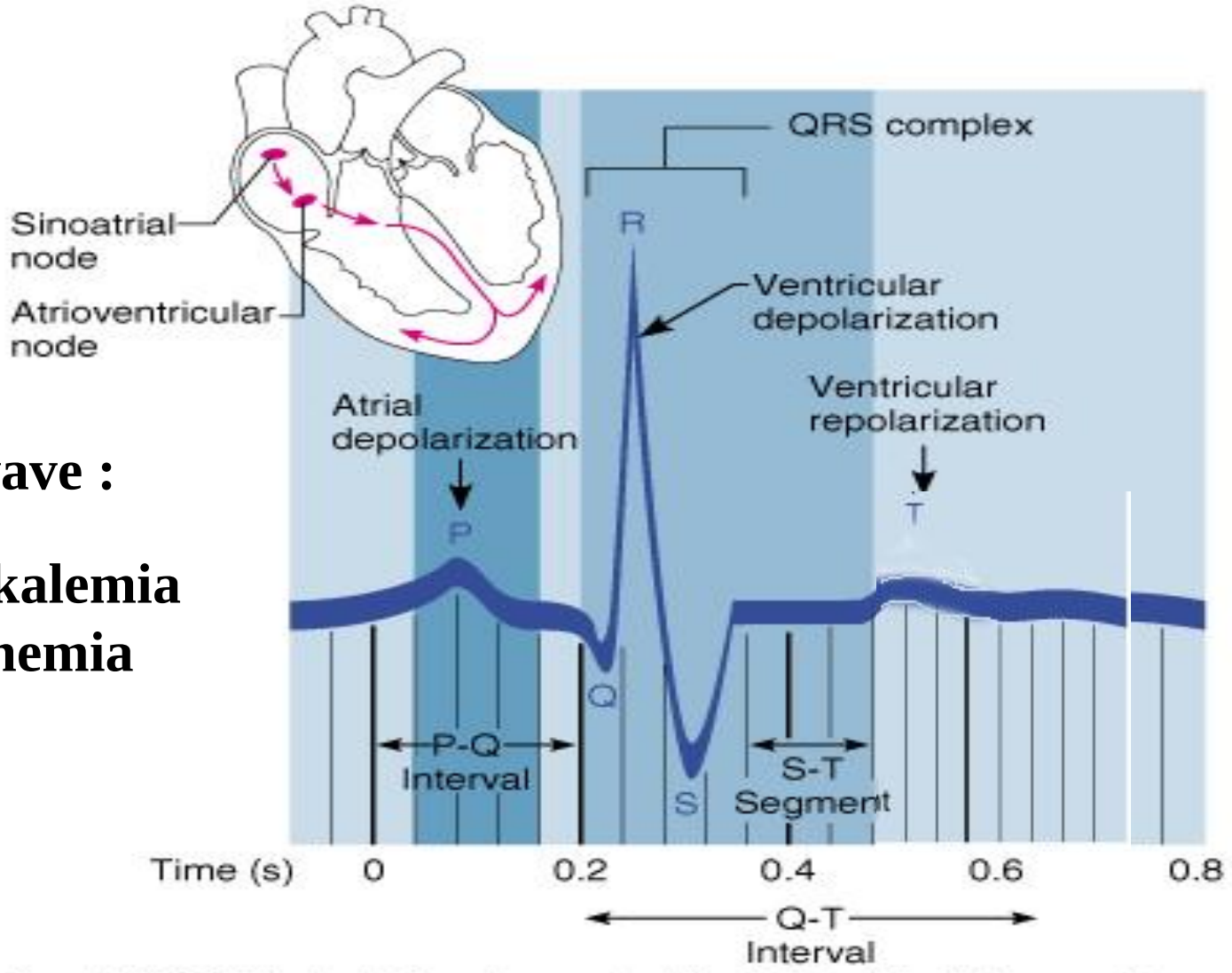
Hyperkalemia



ECG Deflection Wave Irregularities

Flat T wave :

Hypokalemia or ischemia



Increased Voltages in Standard Bipolar Limb Leads

- If sum of voltages of Leads I-III is greater than 4 mV, this is considered to be a high voltage EKG.
- Most often caused by increased ventricular muscle mass (hypertension, marathon runner).

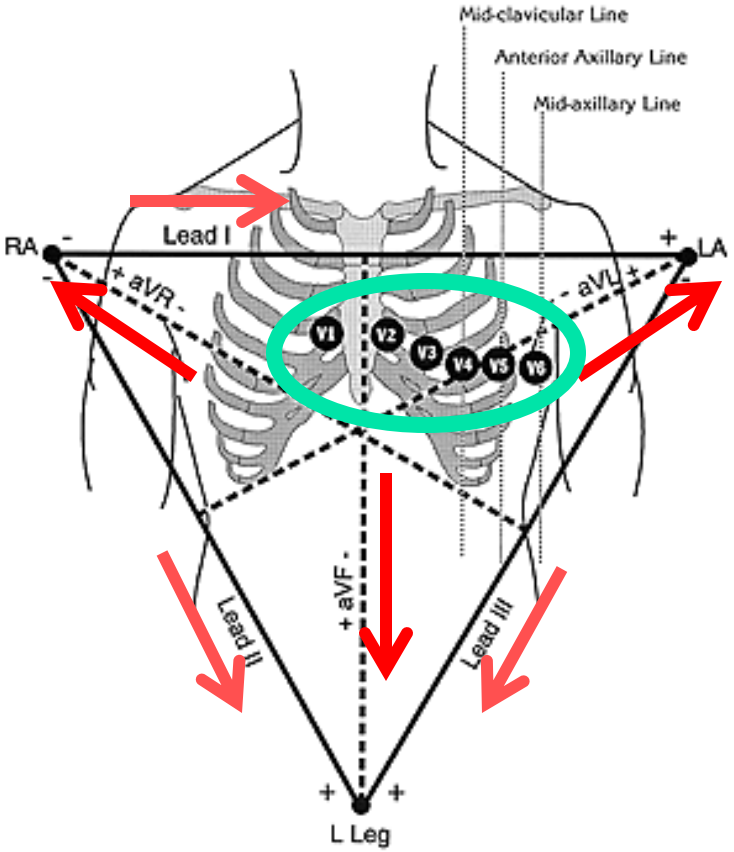
Decreased Voltages in Standard Bipolar Limb Leads

- Cardiac muscle abnormalities (old infarcts causing decreased muscle mass, low voltage EKG, and prolonged QRS).
- Conditions surrounding heart (fluid in pericardium, pleural effusions, emphysema).

The 12-Leads

The 12-leads include:

- 3 Limb leads
  (I, II, III)
- 3 Augmented leads
  (aVR, aVL, aVF)
- 6 Precordial leads
  (V_1- V_6)



Thank You