

CARDIOVASCULAR PHYSIOLOGY

ECG

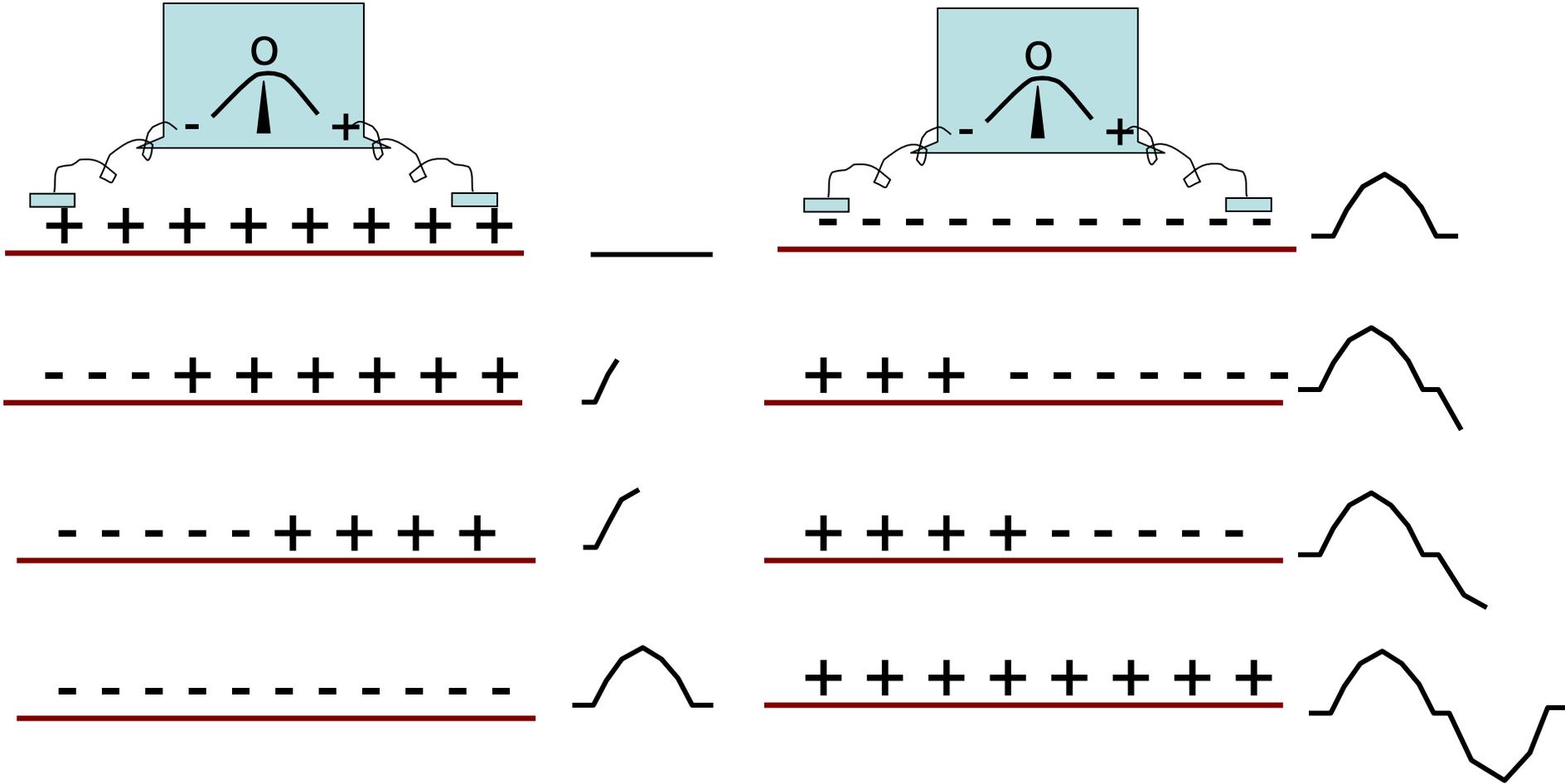
Dr. Ana-Maria Zagrean

Electrocardiogram (ECG)

ECG is a non-invasive method to record at the body surface the electrical activity of the heart.

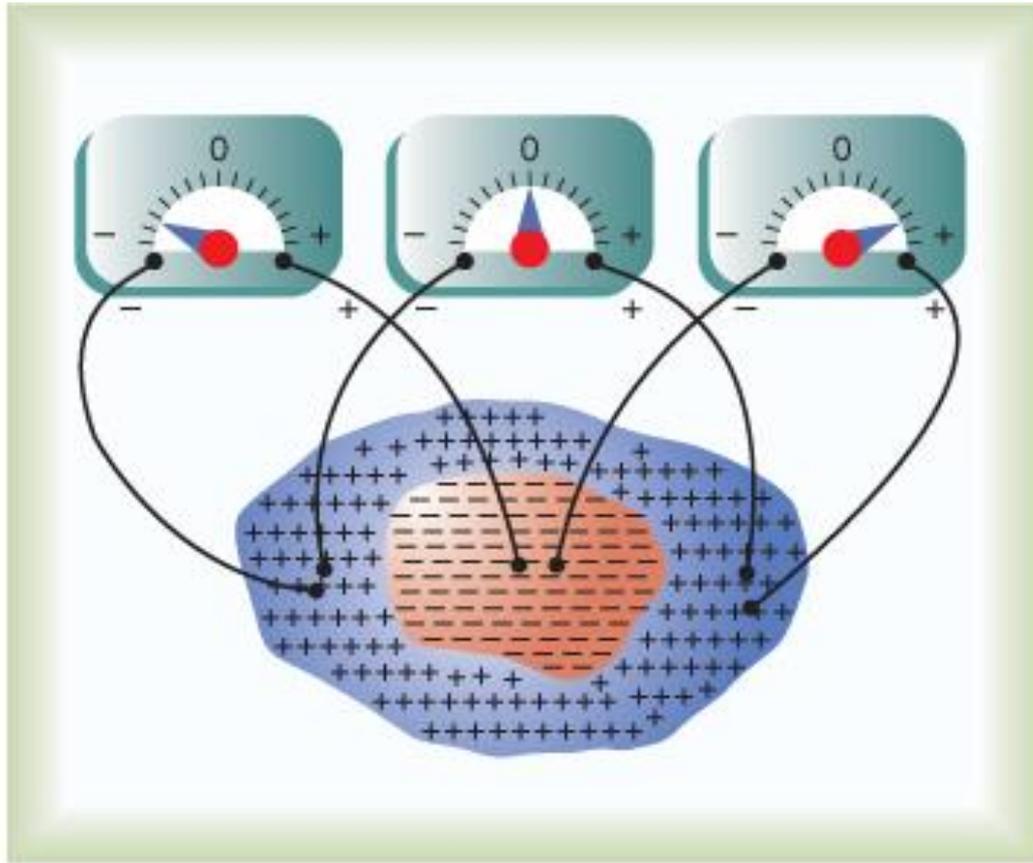
- the rate and regularity of heartbeats,
- the size and position of the chambers,
- the presence of any damage to the heart,
- the effects of drugs etc.

AP-ECG

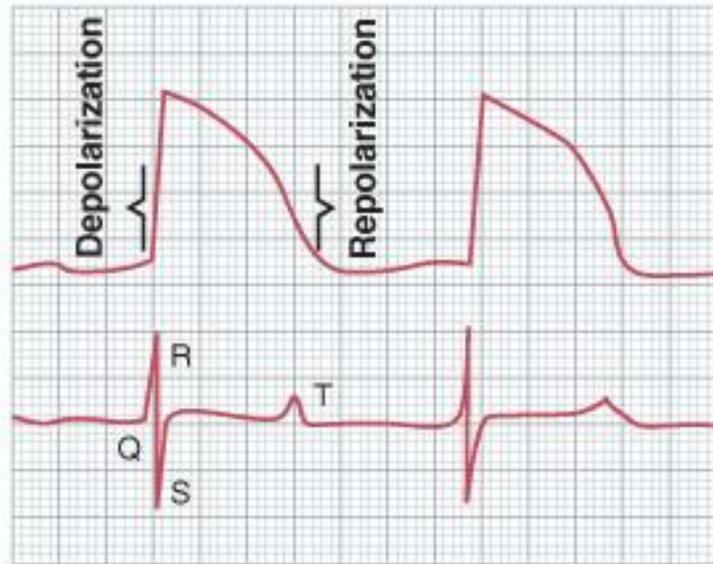


depolarization

repolarization



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



Monophasic action potential from a ventricular muscle fiber during normal cardiac function, showing rapid depolarization and then repolarization

Electrocardiogram trace recorded simultaneously.

Guyton & Hall: Textbook of Medical Physiology 11e - www.studentconsult.com

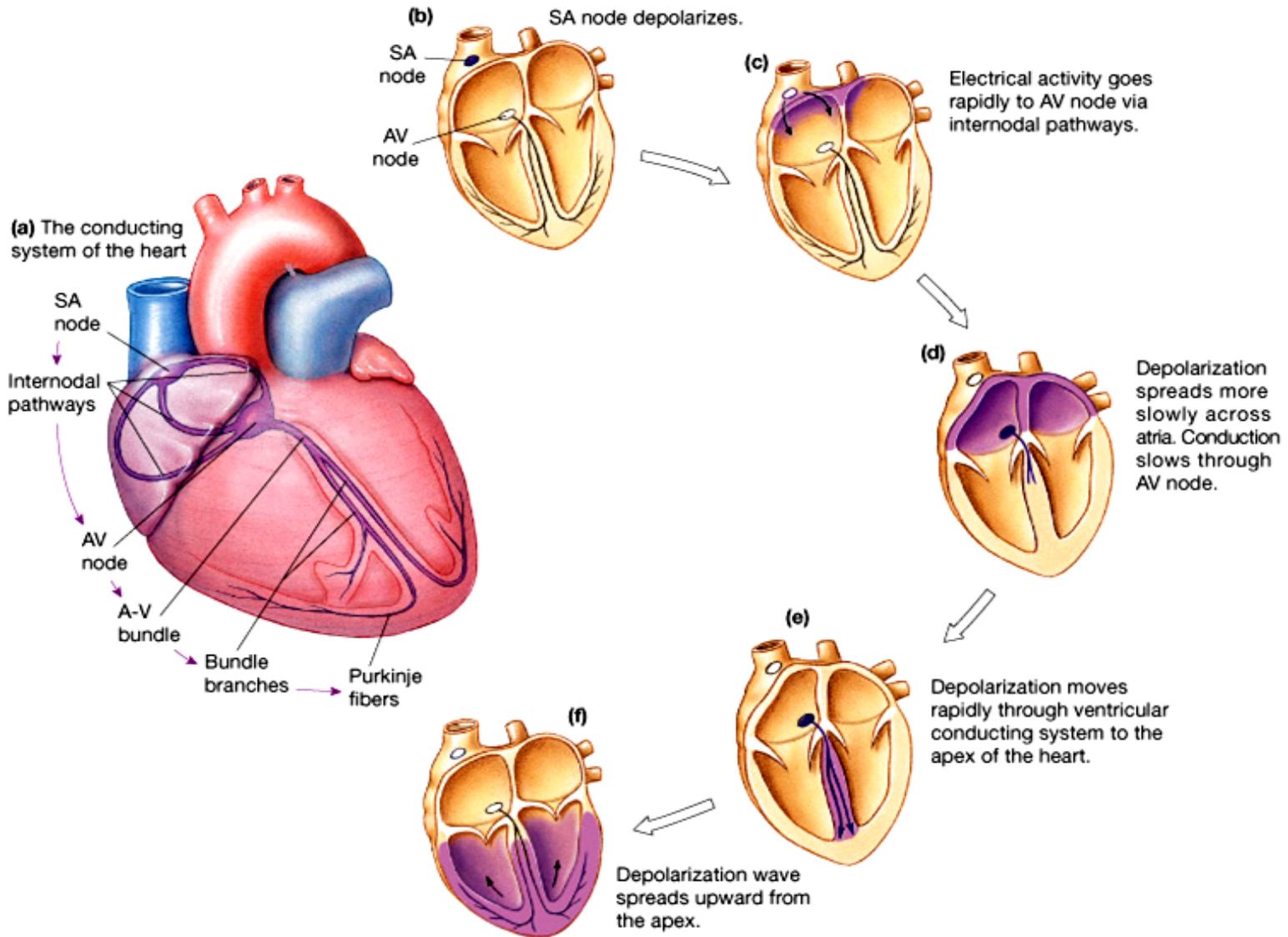
Tissue fluids conduct electricity...

ECG traces show the **sum** of all the electrical potentials generated by all the cells of the heart at any moment.

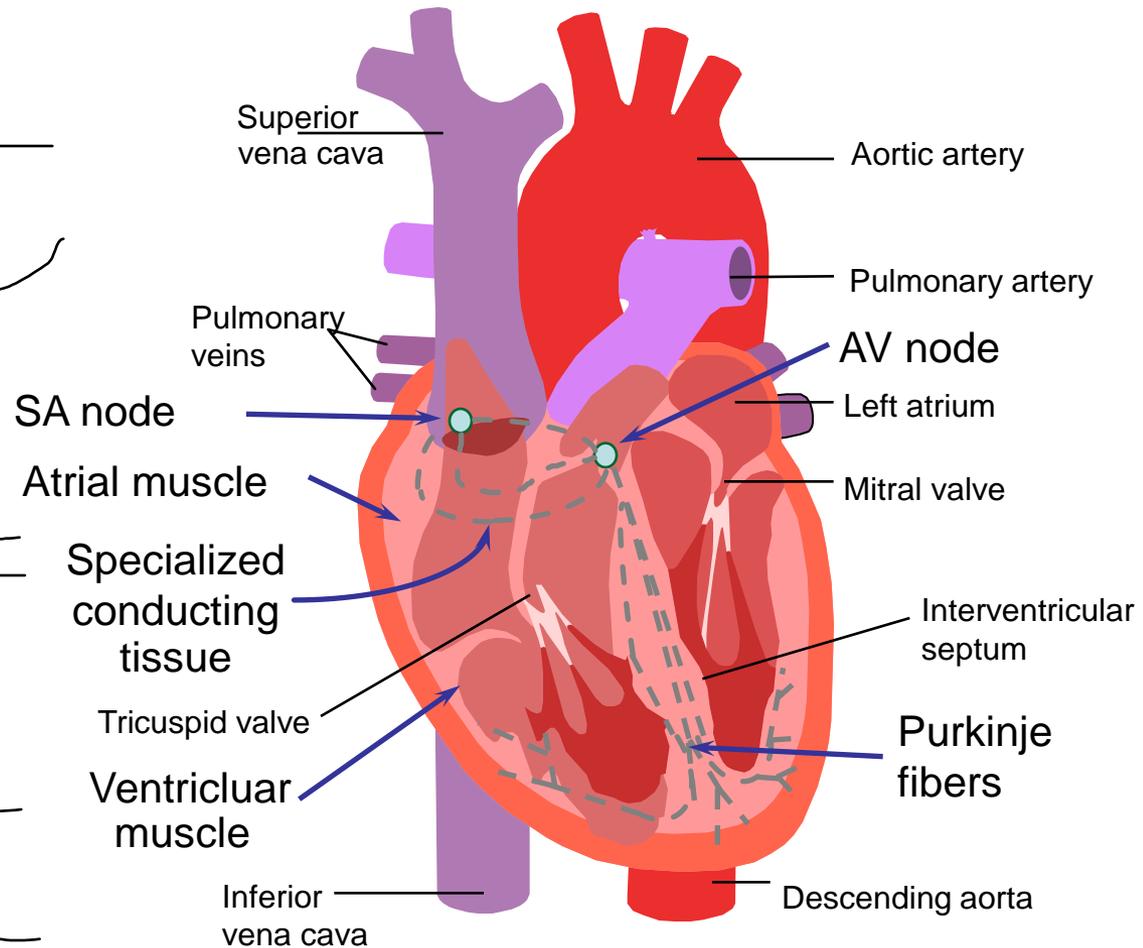
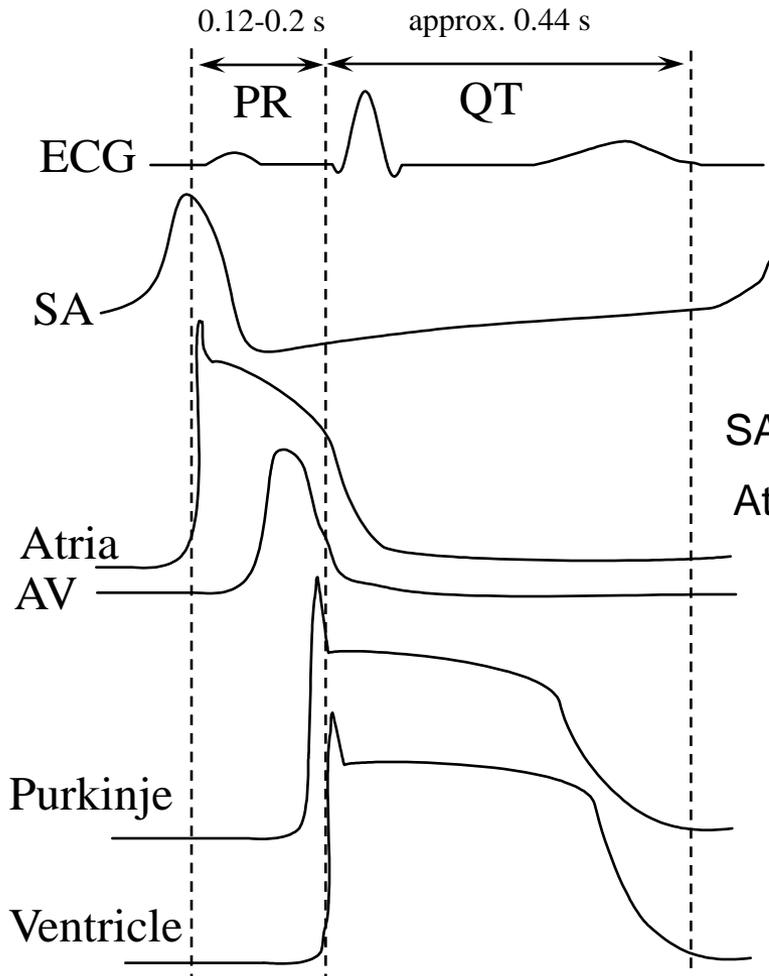
-Ventricular $AP_{\text{heart}} = 110 \text{ mV}$

-Ventricular $AP_{\text{skin}} = 1 \text{ mV}$

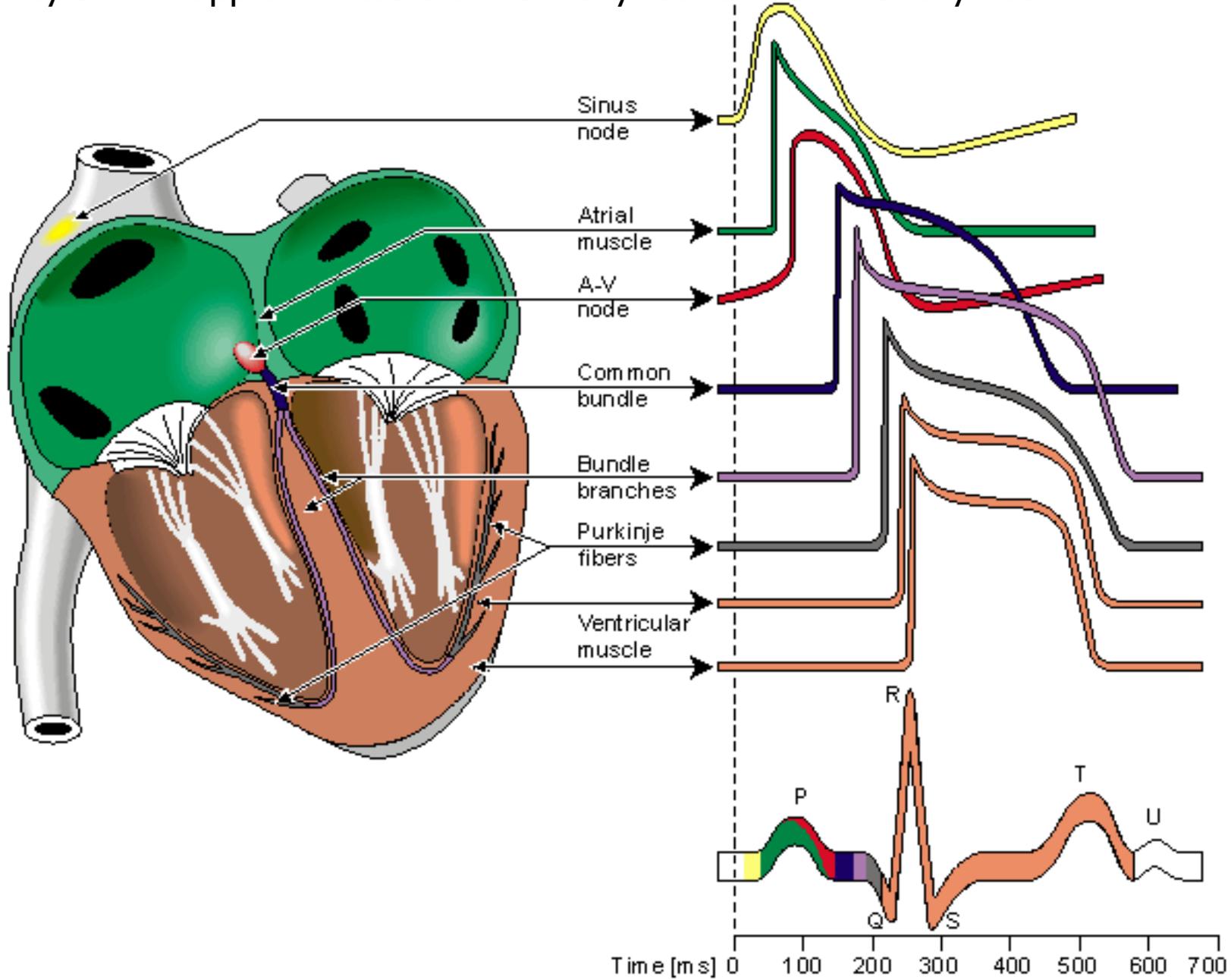
Electrical conduction in the heart



Action Potentials in the Heart



The different waveforms for each of the specialized cells found in the heart are shown. The latency shown approximates that normally found in the healthy heart.



ECG Leads

Classification

- polarity

- bipolar: - 3 Bipolar Limb Leads (Standard Leads): LI, LII, LIII

utilize a positive and a negative electrode between which electrical potentials are measured.

- unipolar: - 6 Chest Leads (Precordial Leads): V1 → V6

the positive recording electrode is placed on the anterior surface of the chest directly over the heart, and the negative electrode (*indifferent electrode*), is connected through equal electrical resistances to the right arm, left arm, and left leg all at the same time

- Augmented Leads (aVL, aVR, aVF)

two of the limbs are connected through electrical resistances to the negative terminal of the electrocardiograph, and the third limb is connected to the positive terminal.

- direction

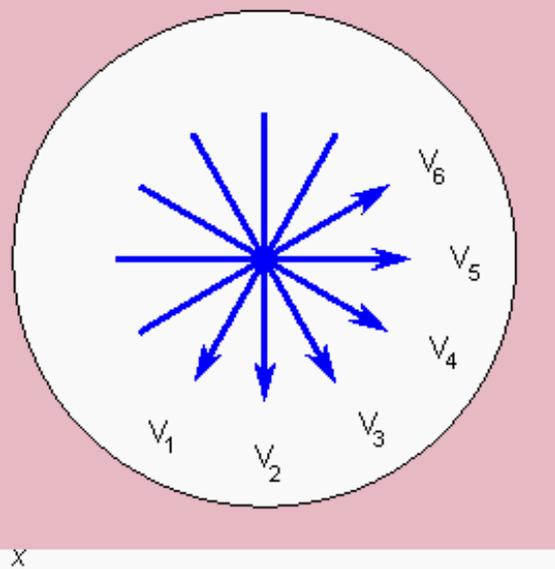
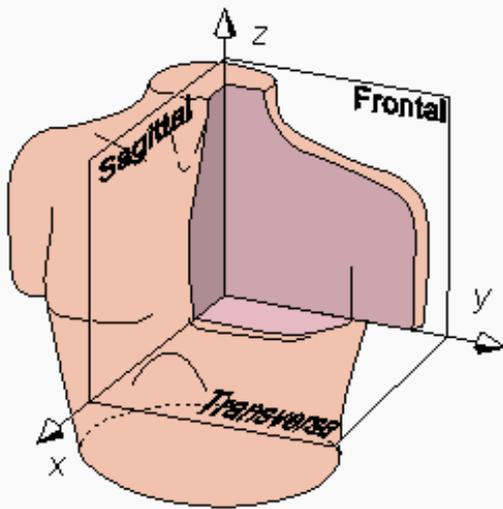
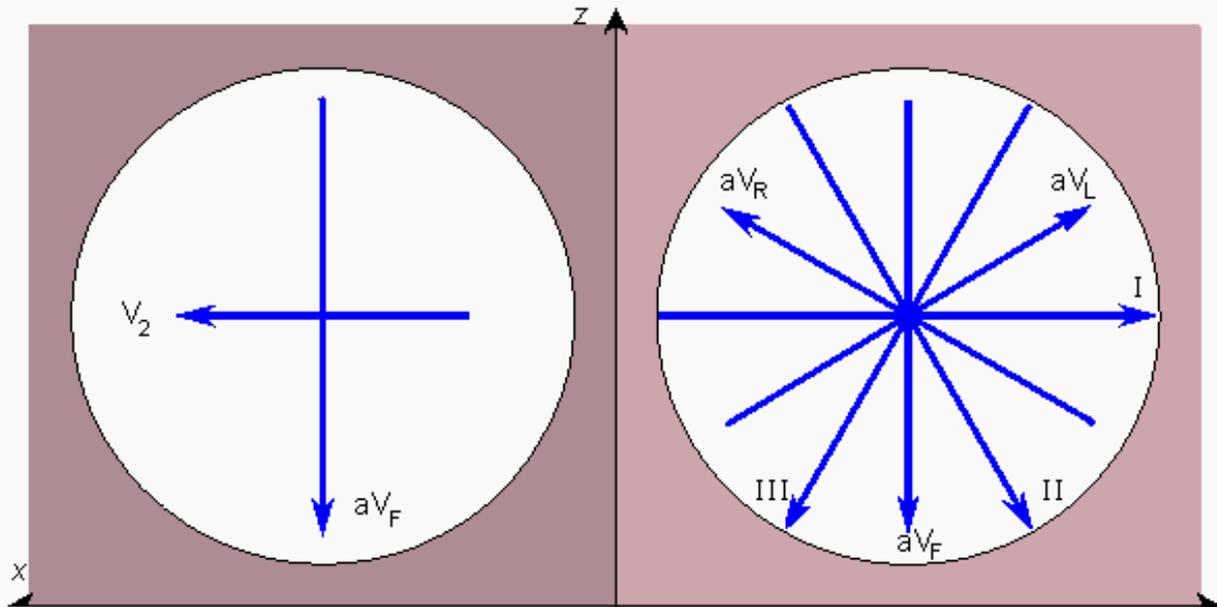
-frontal plane: standard bipolar leads, augmented leads

-horizontal plane: chest leads

ECG Leads

SAGITTAL PLANE

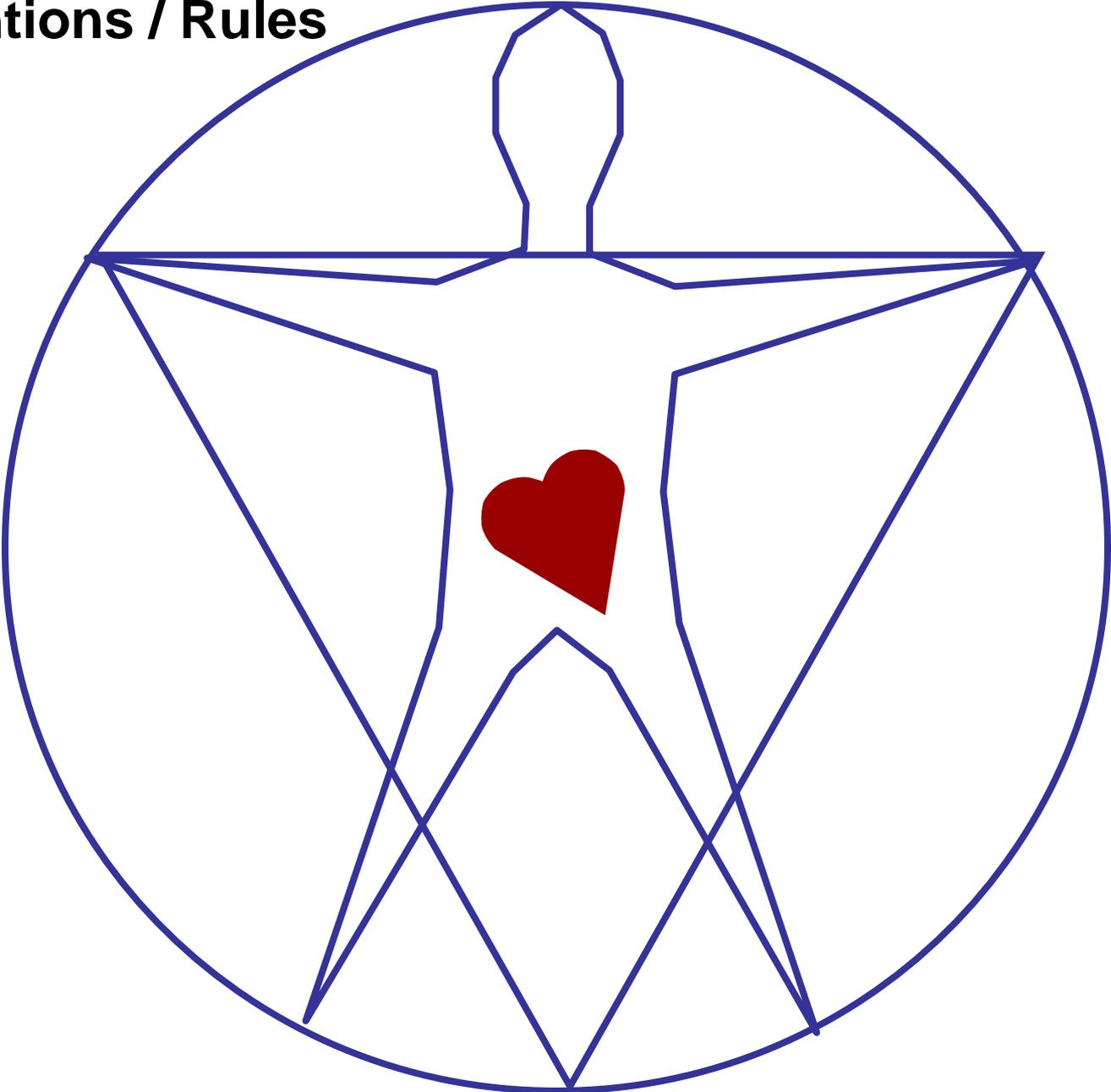
FRONTAL PLANE



TRANSVERSE PLANE

The projections of the lead vectors of the 12-lead ECG system in three orthogonal planes when one assumes the volume conductor to be spherical homogeneous and the cardiac source centrally located.

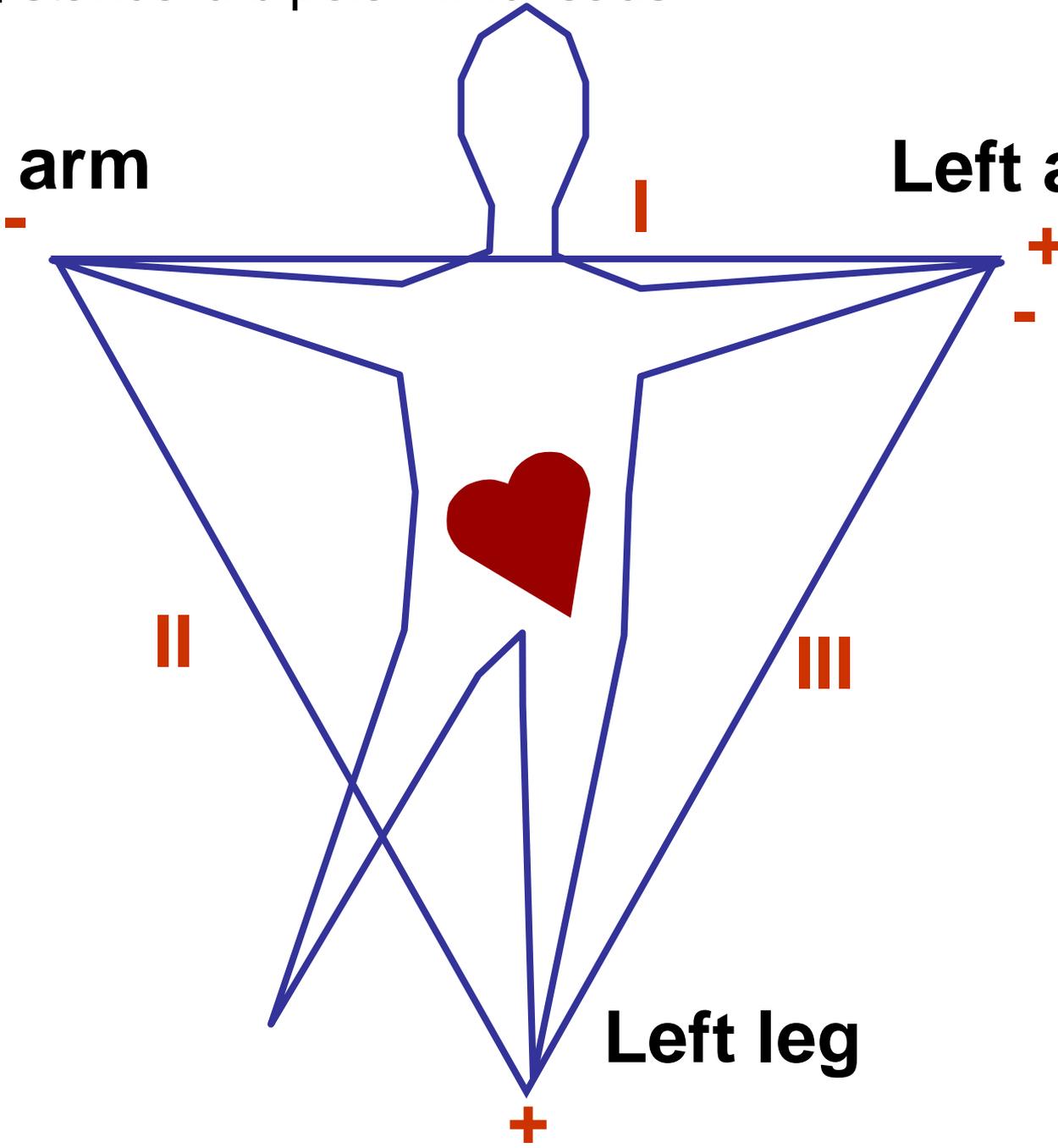
Conventions / Rules



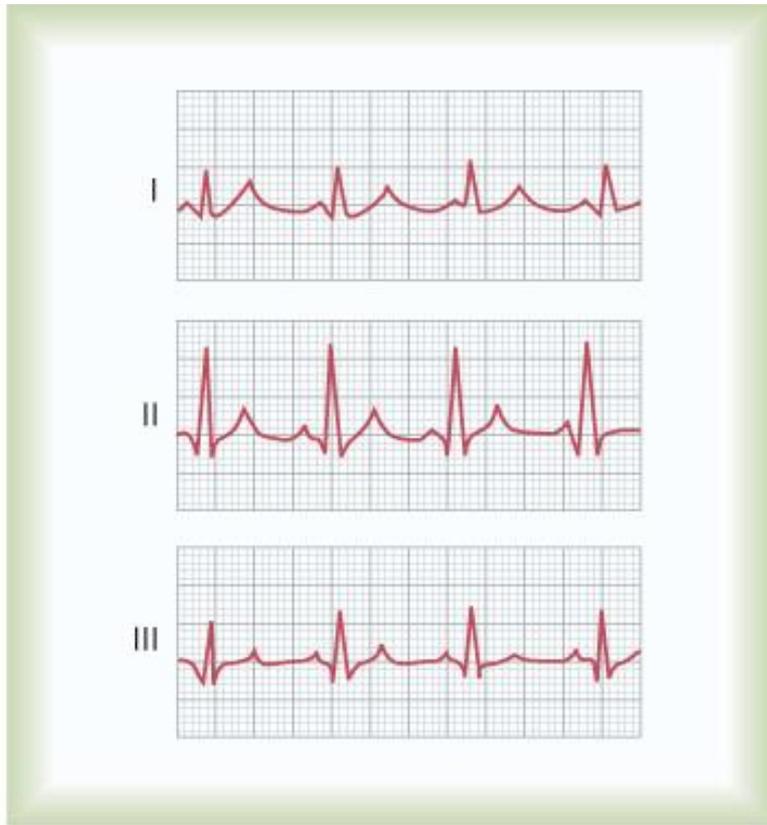
Rules: standard bipolar limb leads

Right arm

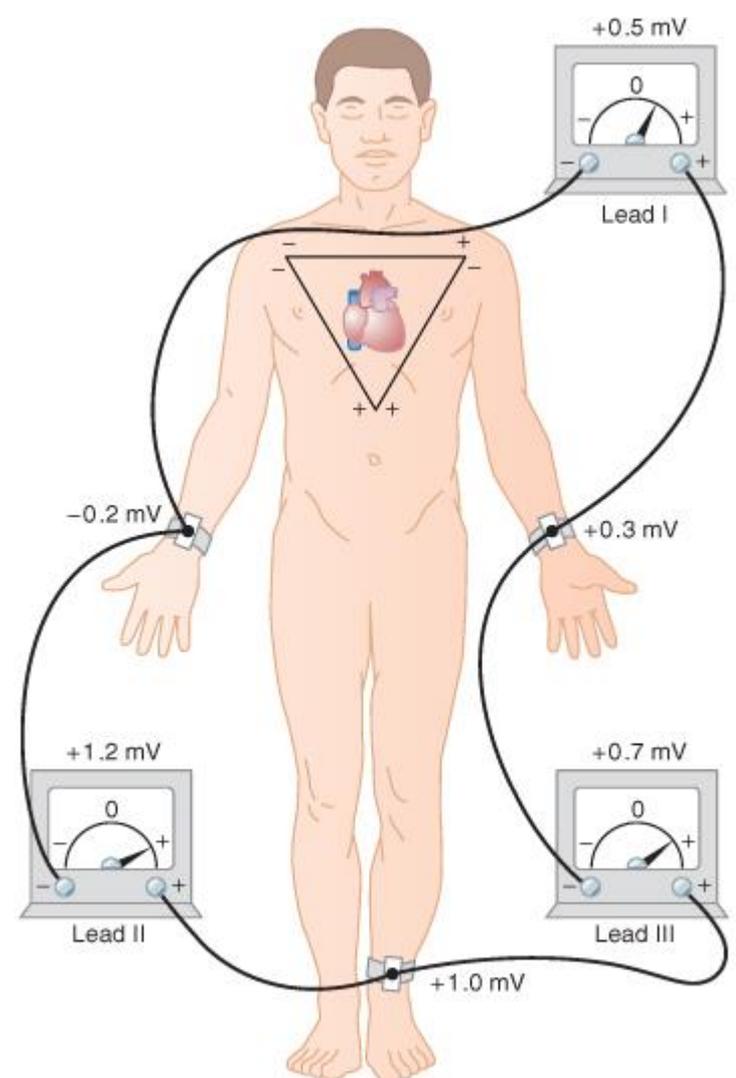
Left arm



Left leg



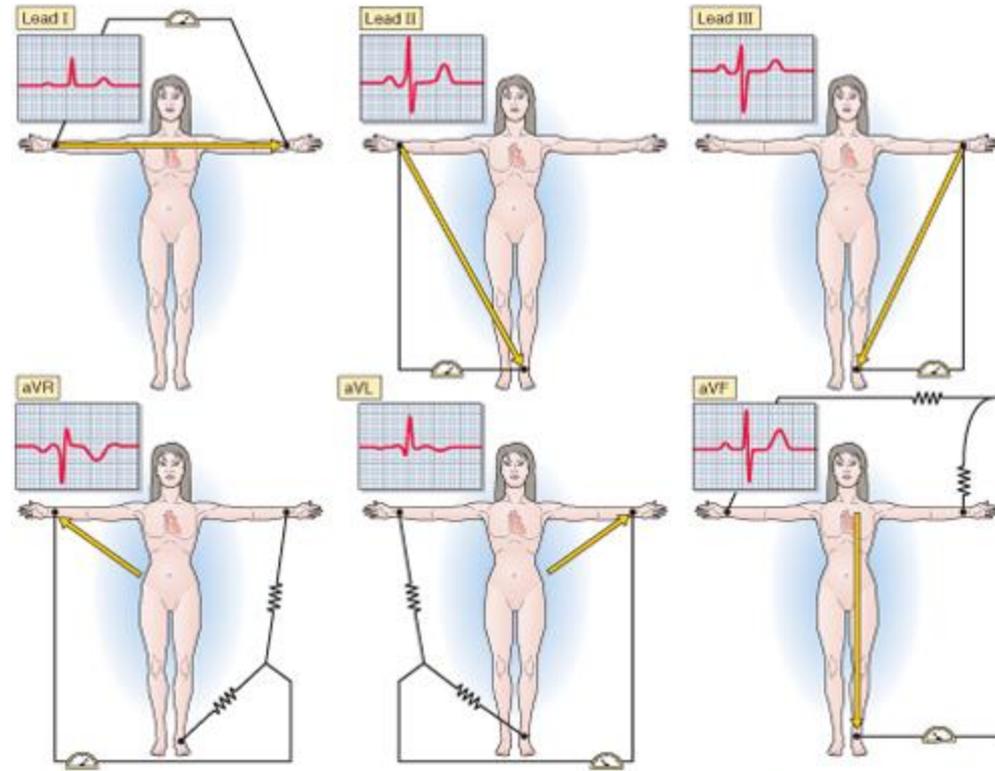
Elsevier. Guyton & Hall: Textbook of Medical Physiology 11e - www.student



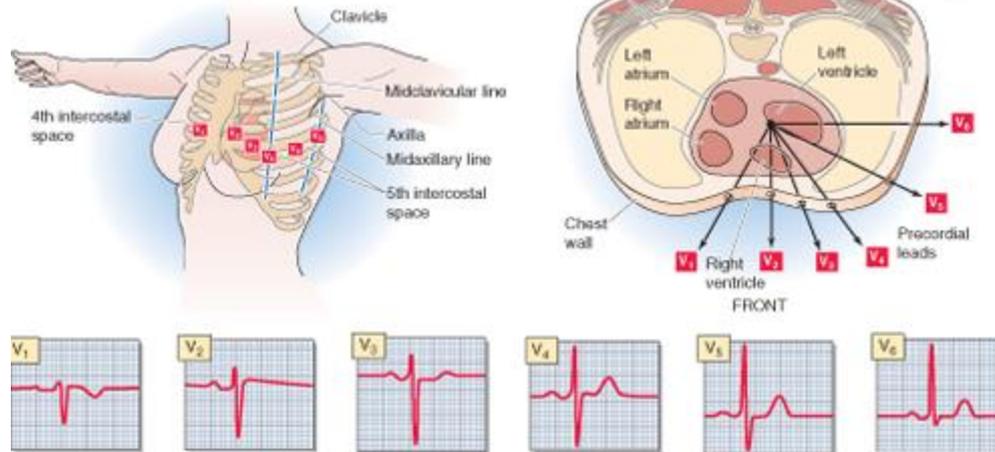
Bipolar Standard Leads:

- Lead I - from the right arm to the left arm
- Lead II - from the right arm to the left leg
- Lead III - from the left arm to the left leg

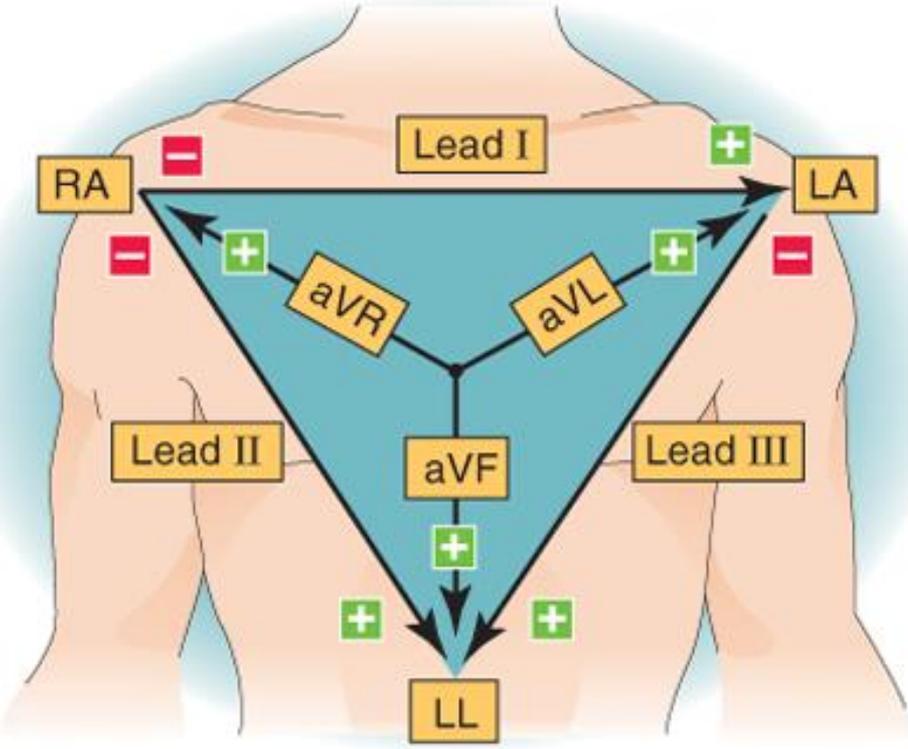
A FRONTAL PLANE LEADS



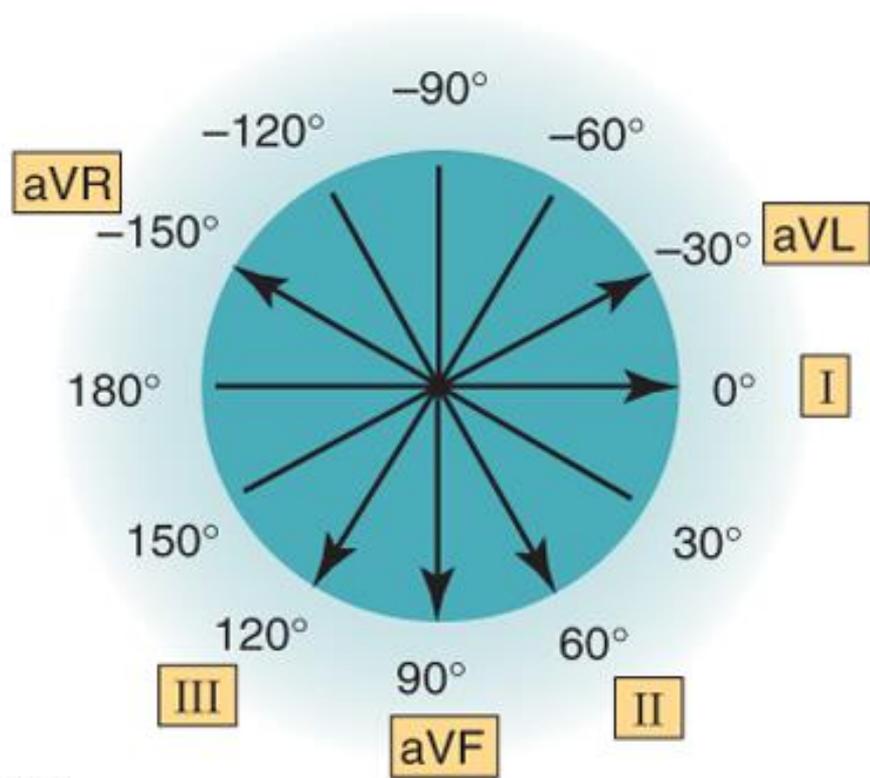
B TRANSVERSE PLANE-PRECARDIAL LEADS



A EINTHOVEN'S TRIANGLE



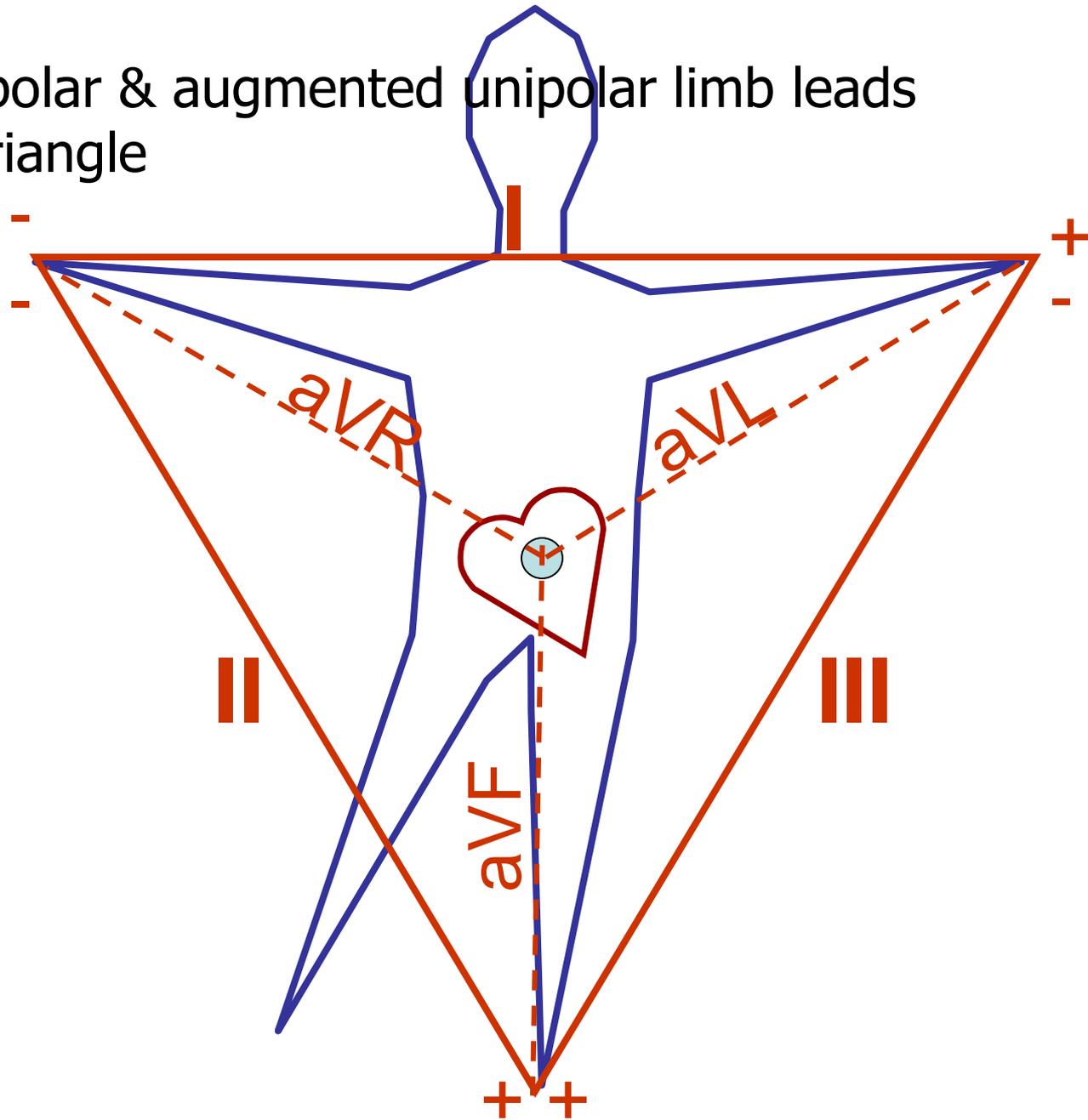
B CIRCLE OF AXES

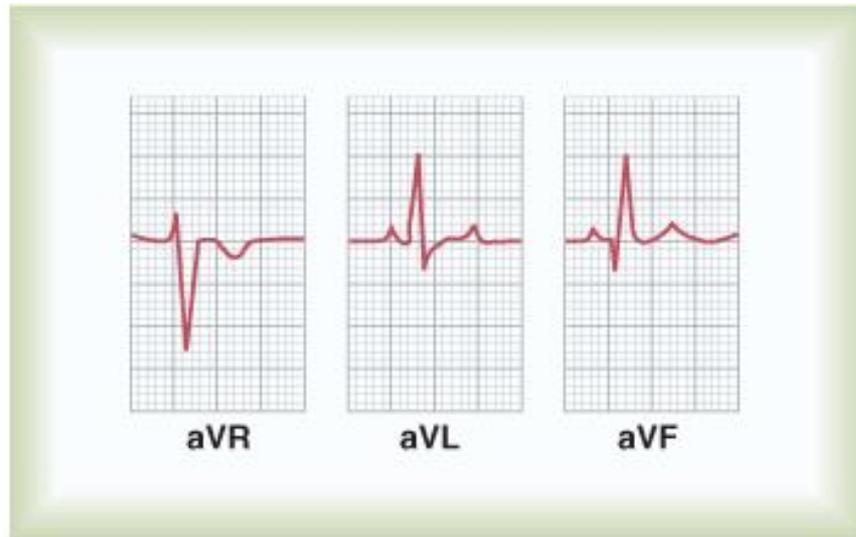


Boron & Boulpaep: Medical Physiology, 2nd Edition.
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Rules:

standard bipolar & augmented unipolar limb leads
Einthoven triangle





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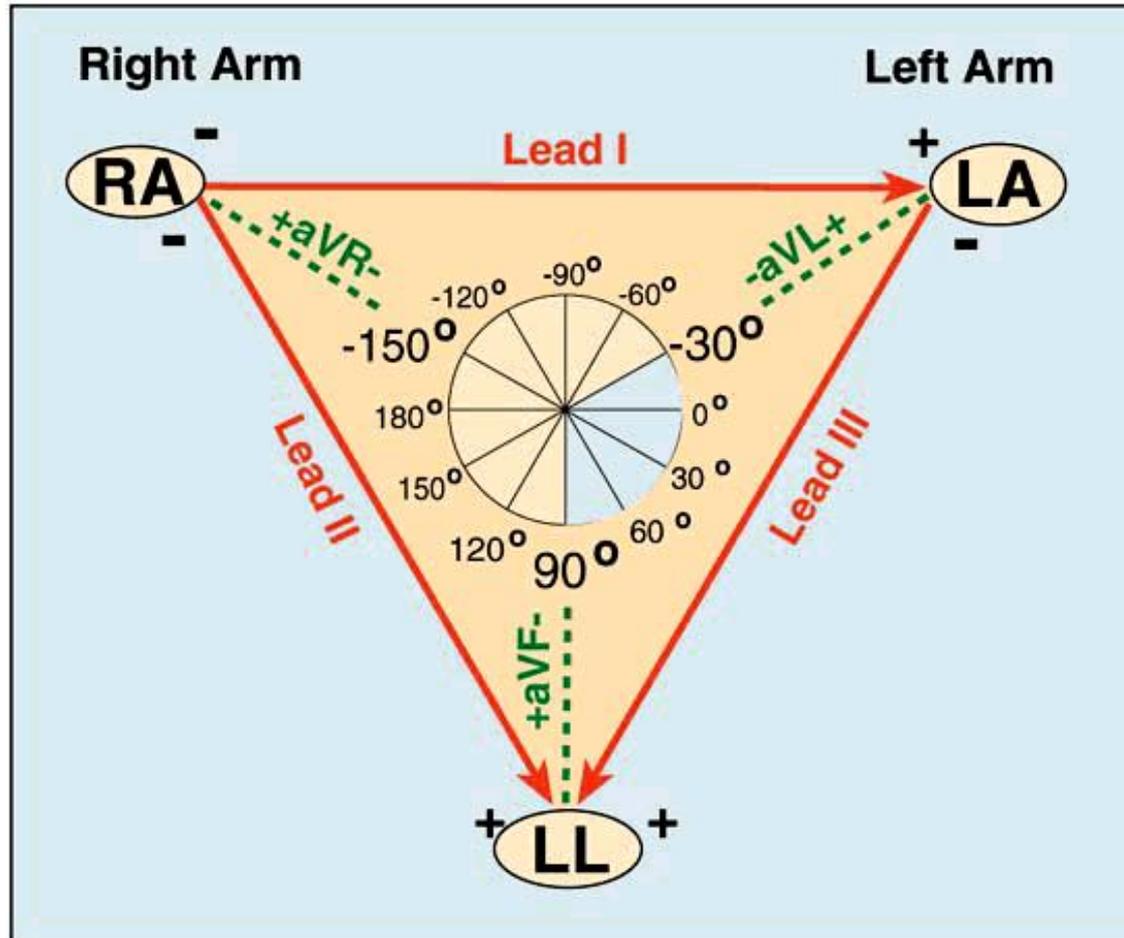
Augmented Unipolar Limb Leads:

aVR lead - the positive terminal is on the right arm; inverted !

aVL lead - the positive terminal is on the left arm;

aVF lead - the positive terminal is on the left leg.

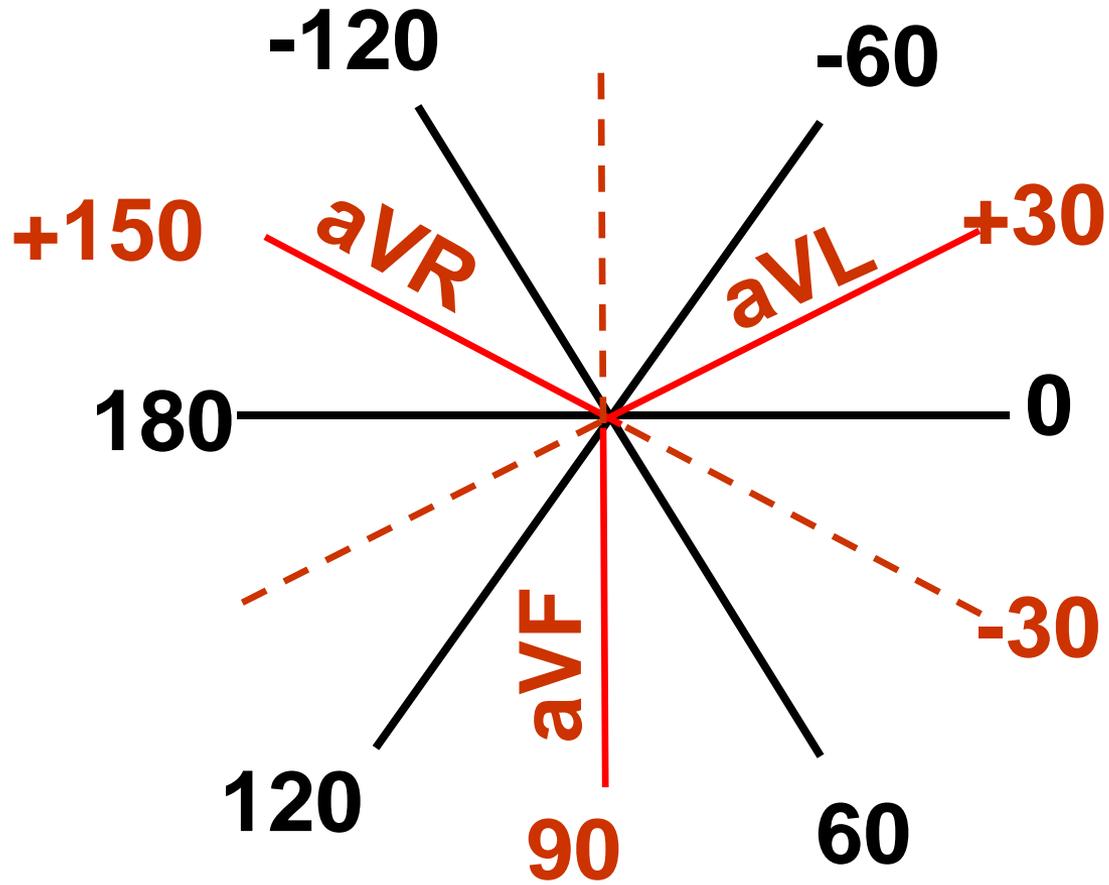
Frontal plane leads



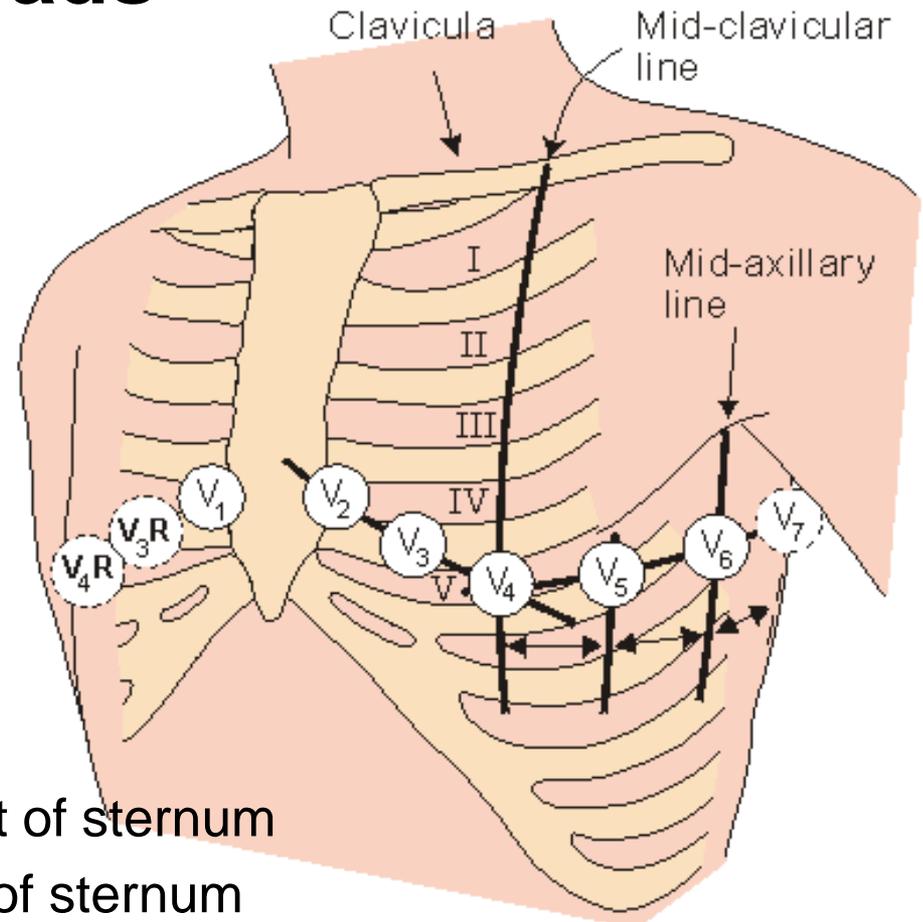
Einthoven's Triangle

Each of the 6 frontal plane leads has a negative and positive orientation ('+' and '-' signs). Lead I (and to a lesser extent Leads aVR and aVL) are right ↔ left in orientation. Lead aVF (and to a lesser extent Leads II and III) are superior ↔ inferior in orientation.

Leads



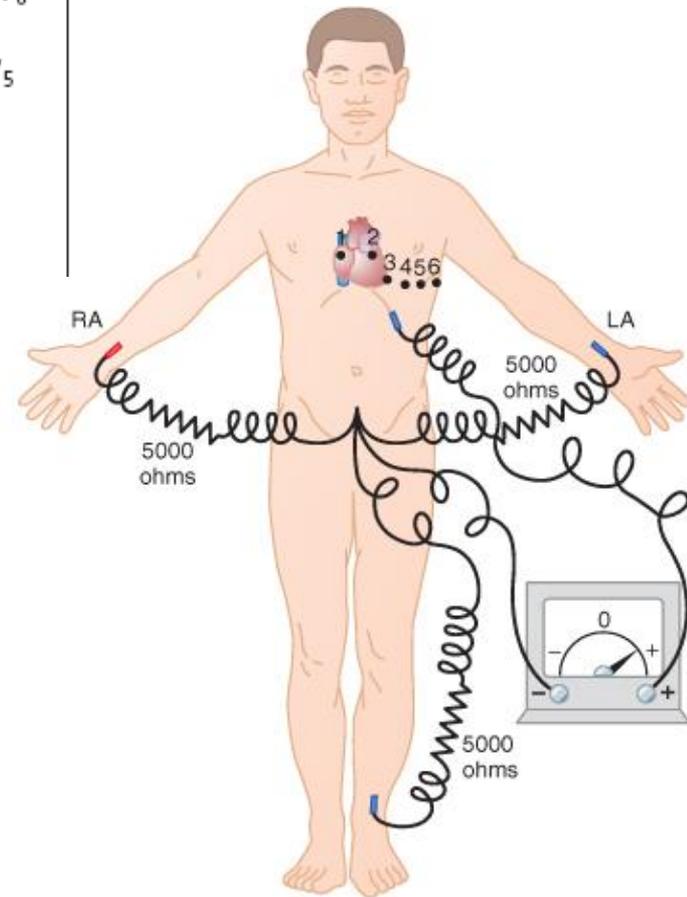
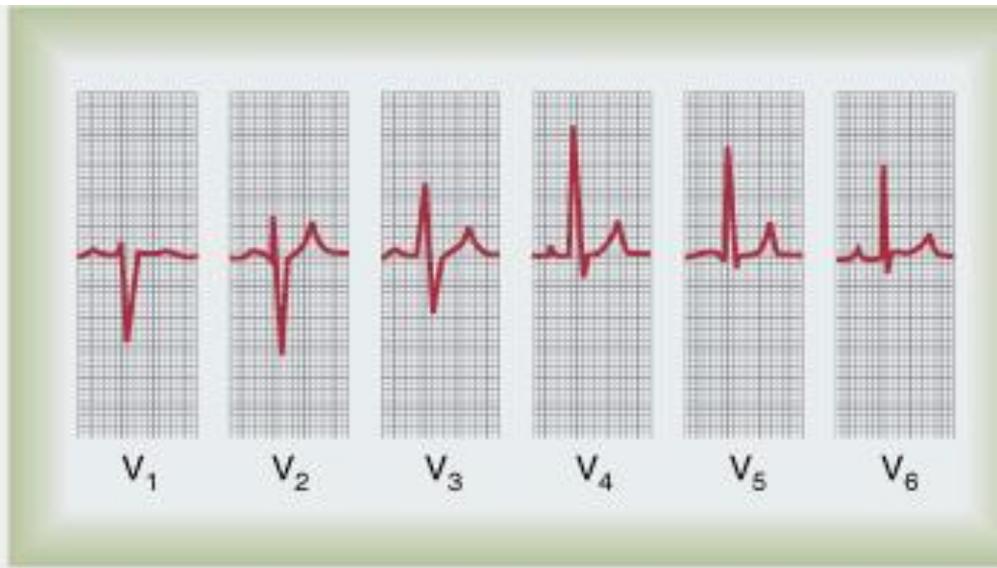
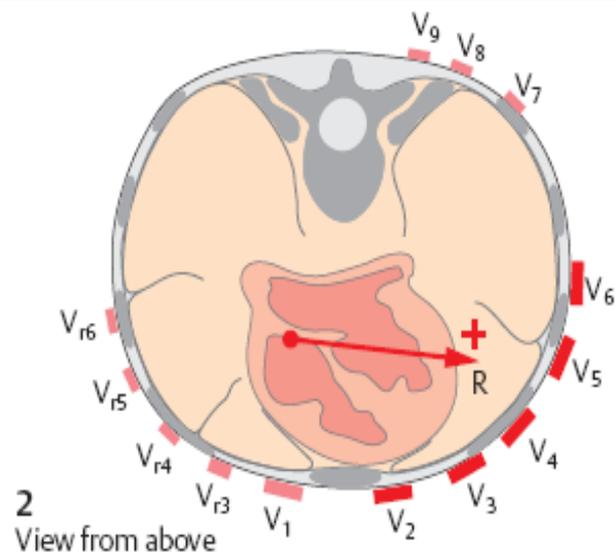
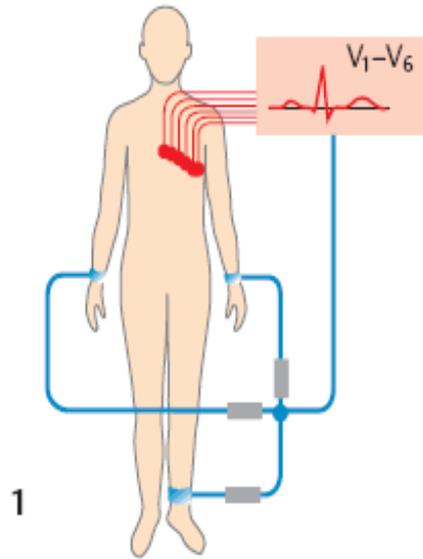
Precordial / chest leads (Wilson)



Unipolar Precordial Leads:

- V1- 4th intercostal space to the right of sternum
- V2- 4th intercostal space to the left of sternum
- V3- halfway between V2 and V4
- V4- 5th intercostal space in the left mid-clavicular line
- V5- 5th intercostal space in the left anterior axillary line
- V6- 5th intercostal space in the left mid axillary line

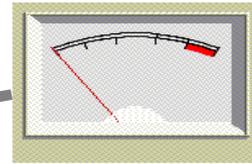
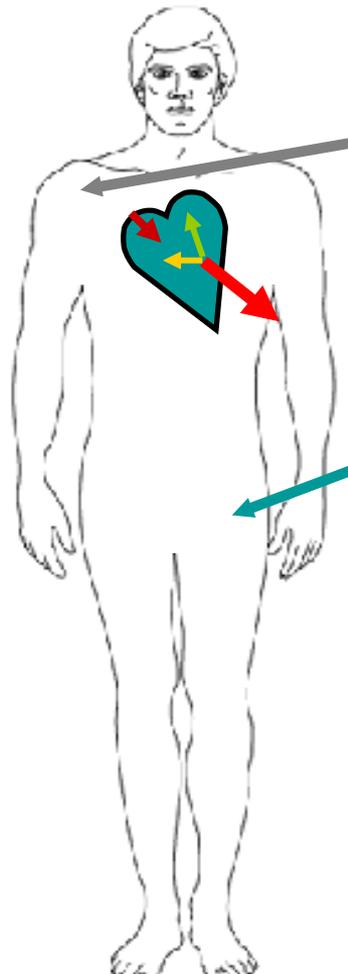
F. Wilson chest leads (unipolar)



The normal electrocardiogram

Right Arm

"Lead II"

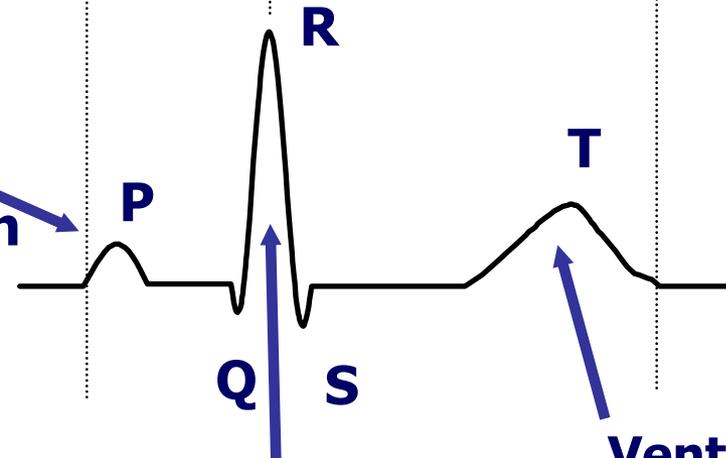


Left Leg

**Atrial muscle
depolarization**

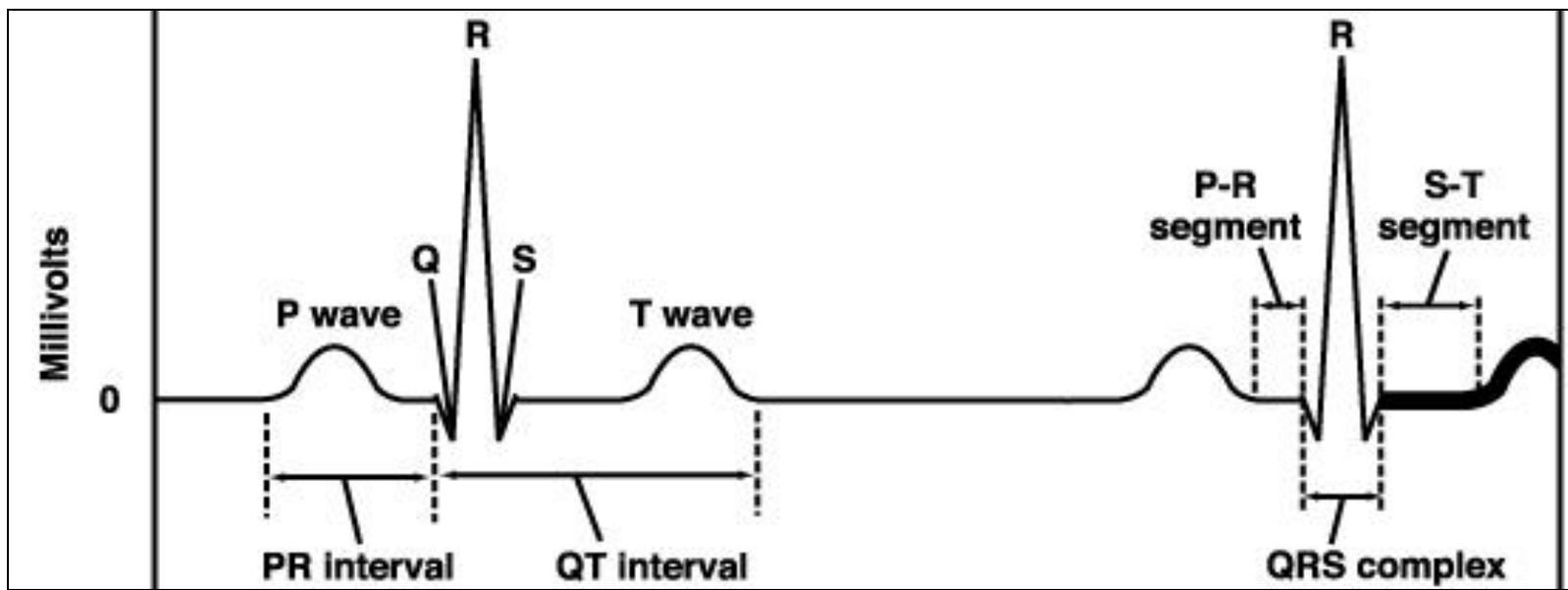
0.12-0.2 s
PR

0.35 - 0.44 s
QT



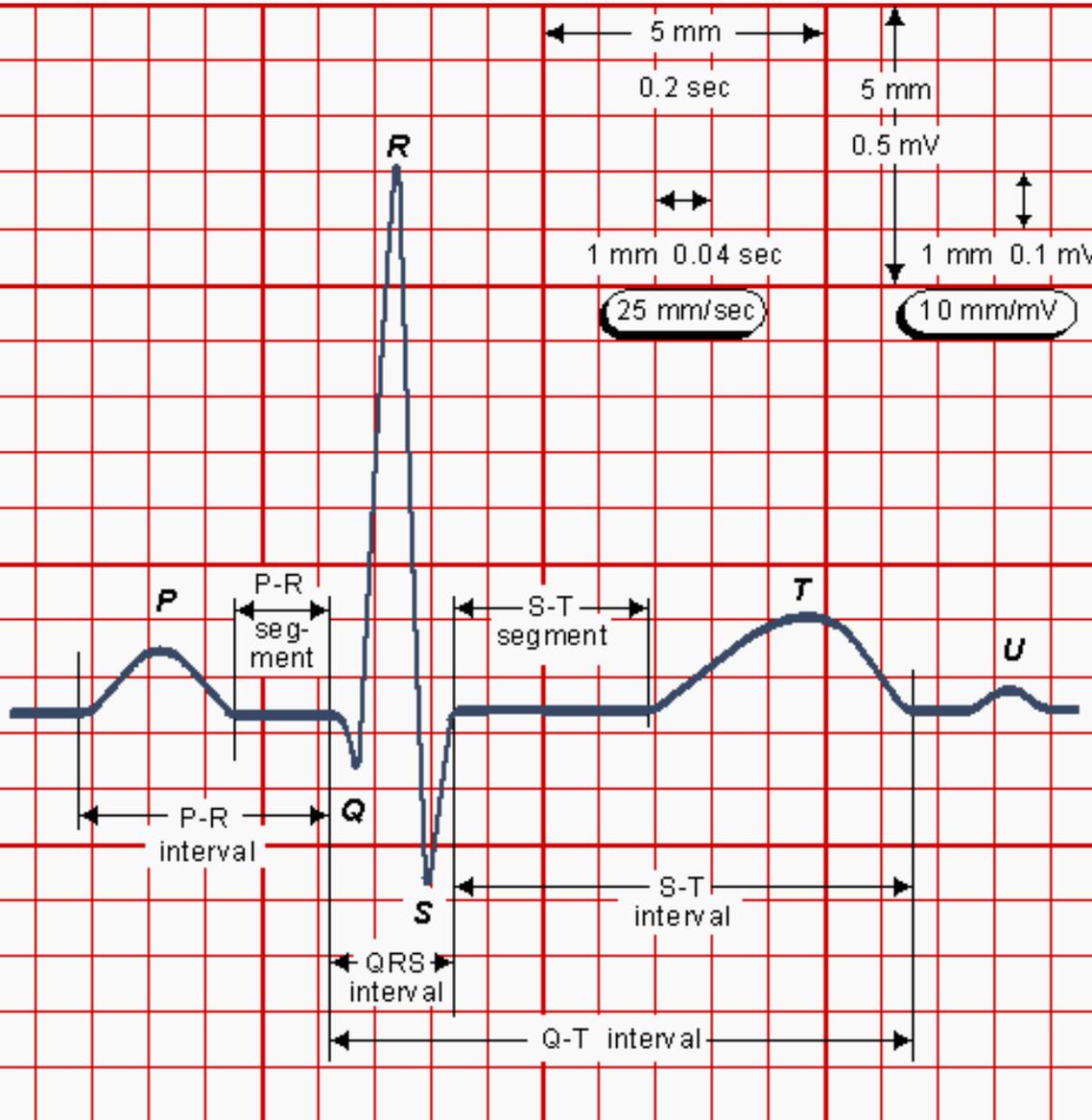
**Ventricular muscle
depolarization**

**Ventricular
muscle
repolarization**



- ECG normally, consists of **3 waves**:
 - **P wave** = Represents atrial depolarization
 - Atria begin contracting about 0.1 sec after P wave begins
 - **QRS complex** = Represents ventricular depolarization
 - Why is it a larger signal than the P wave?
 - Ventricular contraction shortly after the peak of the R wave
 - **T wave** = Indicates ventricular repolarization
 - Why do we not see a wave corresponding to atrial repolarization?

The normal electrocardiogram



Waves:

P wave – A depolarization

QRS complex

– V depolarization

q or **Q** – first negative wave

R or **r** – first positive wave

s – second negative wave

R' – if second positive wave

QS – if there is a single large negative wave

Segments: PR, ST, TP

Intervals: PR, QT, ST

Nomenclature and Durations of ECG Waves (Boron & Boulpaep: Medical Physiology)

The various **waves** of the ECG are named P, Q, R, S, T, and U:

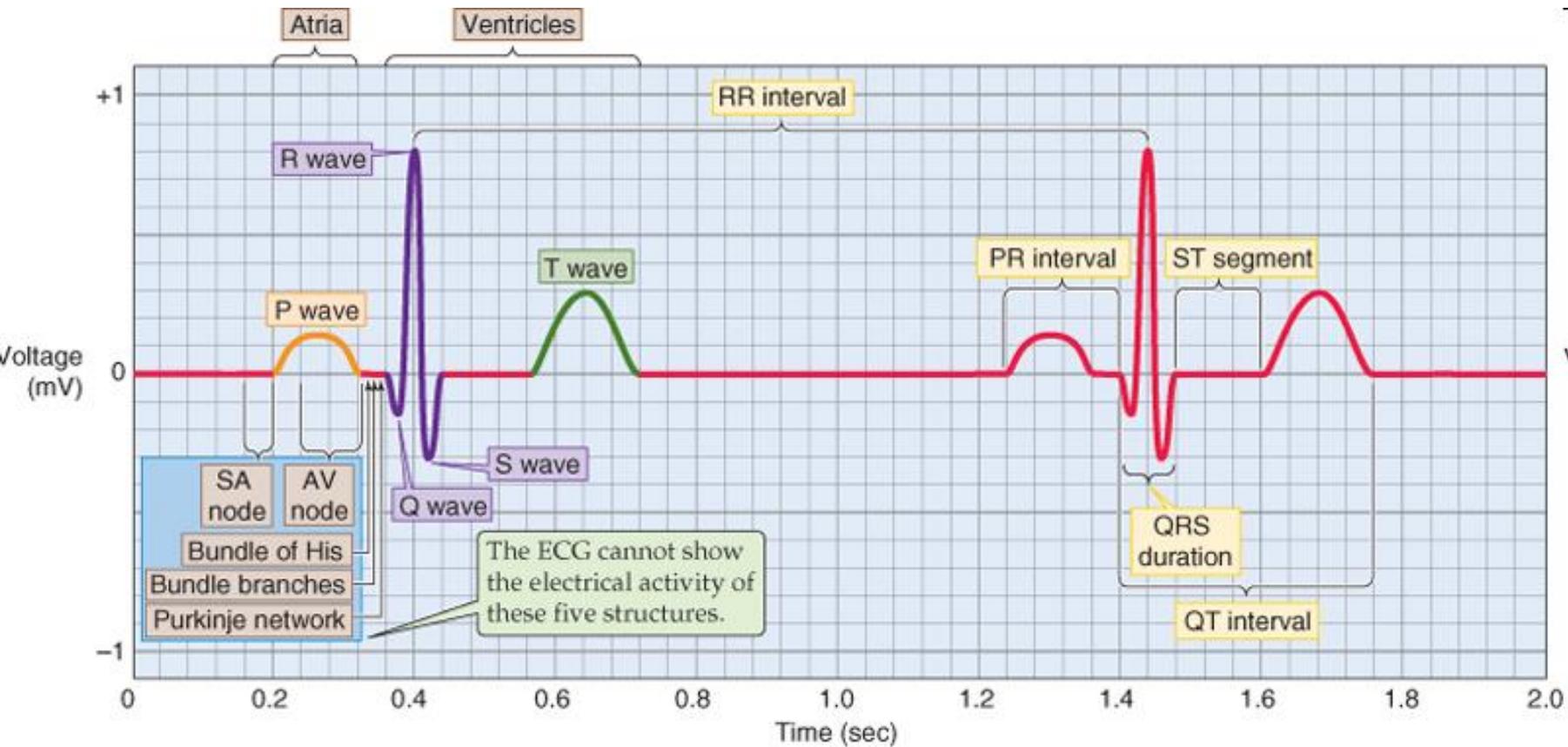
- **P wave:** a small, usually positive, deflection before the QRS complex
- **QRS complex:** a group of waves that may include a Q wave, an R wave, and an S wave; note, however, that not every QRS complex consists of all three waves
- **Q wave:** the initial negative wave of the QRS complex
- **R wave:** the first positive wave of the QRS complex, or the single wave if the entire complex is positive
- **S wave:** the negative wave following the R wave
- **QS wave:** the single wave if the entire complex is negative
- **R' wave:** extra positive wave, if the entire complex contains more than two or three deflections
- **S' wave:** extra negative wave, if the entire complex contains more than two or three deflections
- **T wave:** a deflection that occurs after the QRS complex and the following isoelectric segment (i.e., the ST segment that we define later)
- **U wave:** a small deflection sometimes seen after the T wave (usually of same sign as the T wave)

In addition to the totally *qualitative* wave designations defined previously, cardiologists may use upper- and lowercase letters as a gauge of the amplitude of Q, R, and S waves:

- **Capital letters Q, R, S** are used for deflections of relatively large amplitude.
- **Lowercase letters q, r, s** are used for deflections of relatively small amplitude. For instance: an **rS** complex indicates a small R wave followed by a large S wave.

The various **intervals** are

- **PR interval:** measured from the beginning of the P wave to the beginning of the QRS complex; normal duration is 0.12 and 0.2 s (three to five small boxes on the recording)
- **QRS interval:** measured from the beginning to the end of the QRS complex, as defined previously; normal duration is <0.12 s
- **QT interval:** measured from the beginning of the QRS complex to the end of the T wave; the QT interval is an index of the length of the overall ventricular action potential; duration depends on heart rate because the action potential shortens with increased heart rate
- **RR interval:** the interval between two consecutive QRS complexes; duration is equal to the duration of the cardiac cycle
- **ST segment:** from the end of the QRS complex to the beginning of the T wave



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How to record an ECG?

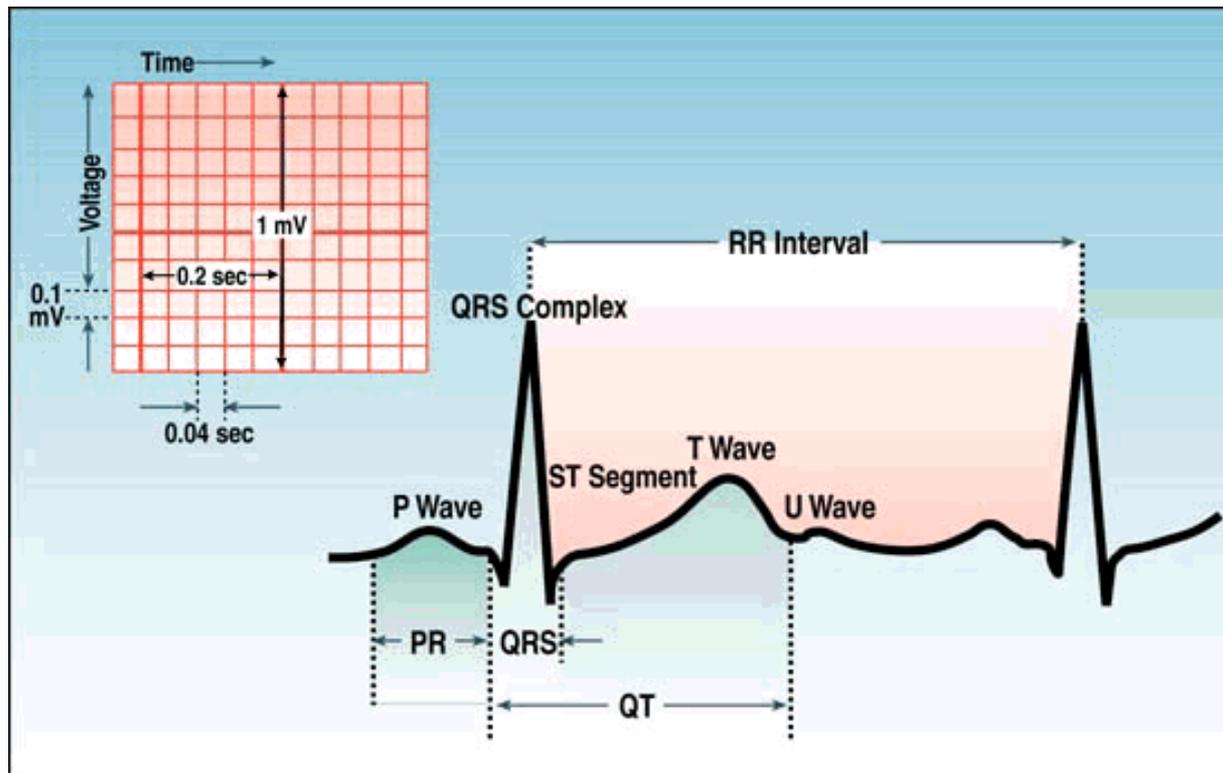
- Put electrodes on the skin, on arms, legs and chest in order to record in different leads (don't forget the ground electrode)
- Standardization of the recording:

calibration lines on the recording paper:

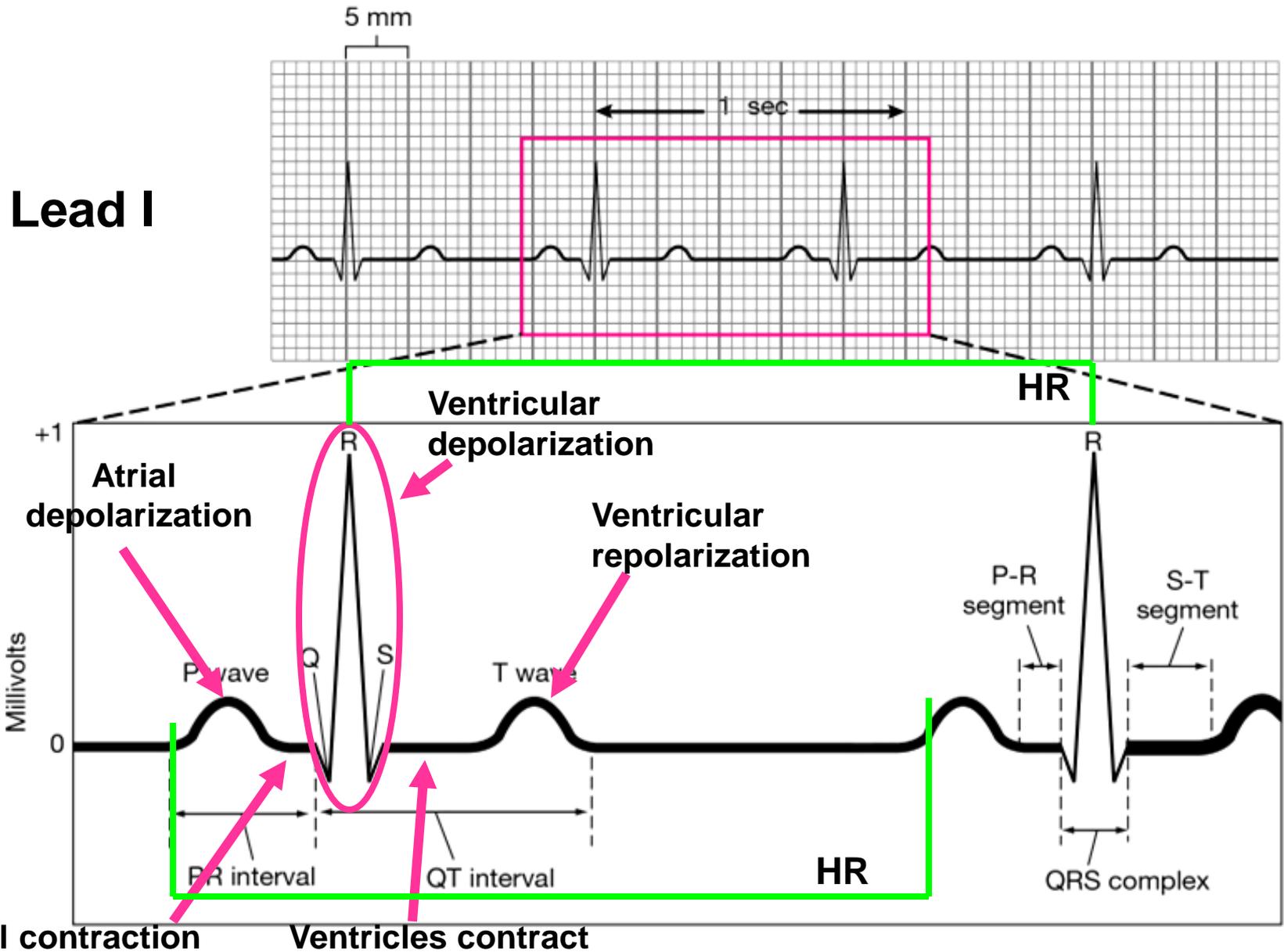
horizontal lines: 10 small divisions upward/downward = ± 1 mV

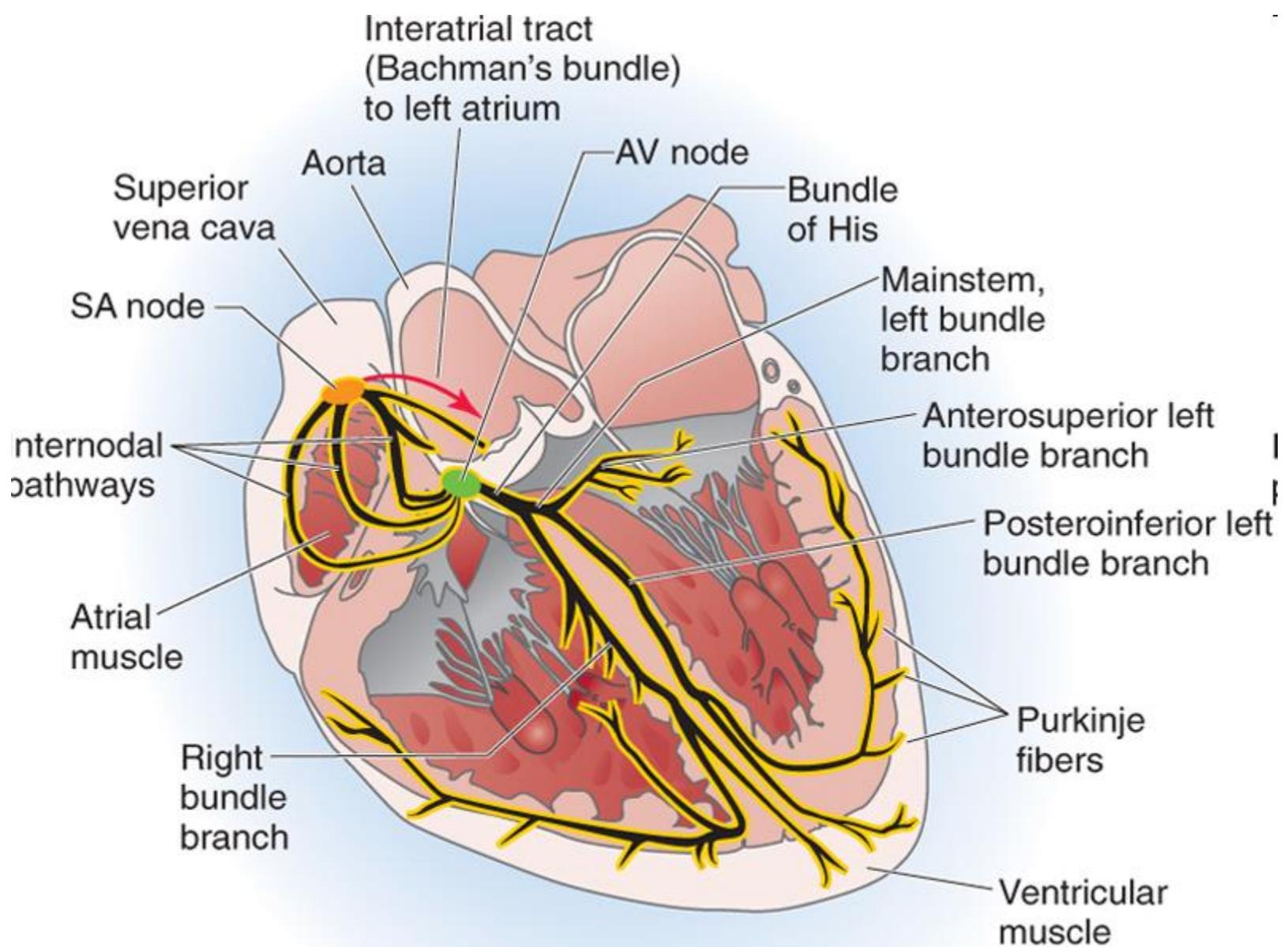
vertical lines: 0.04 sec = 1 smaller interval

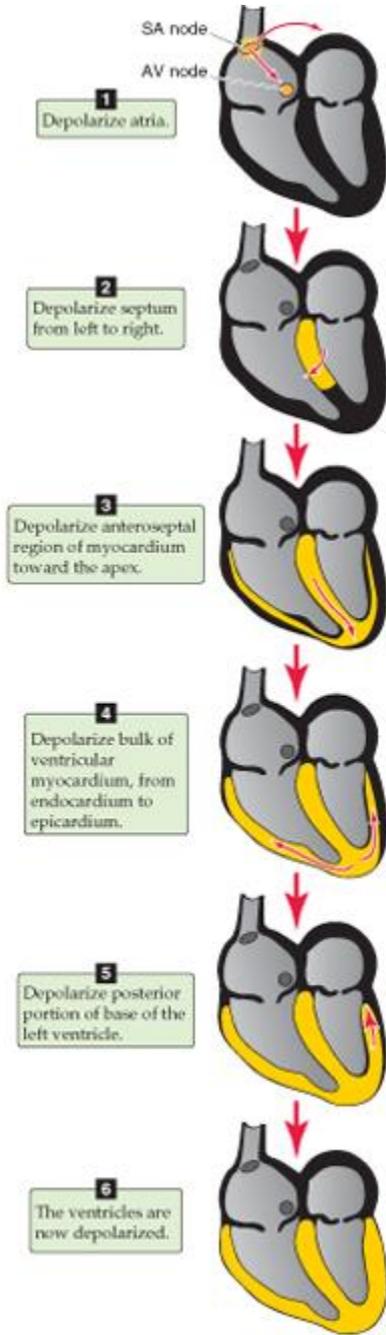
for a paper speed of 25 mm/sec



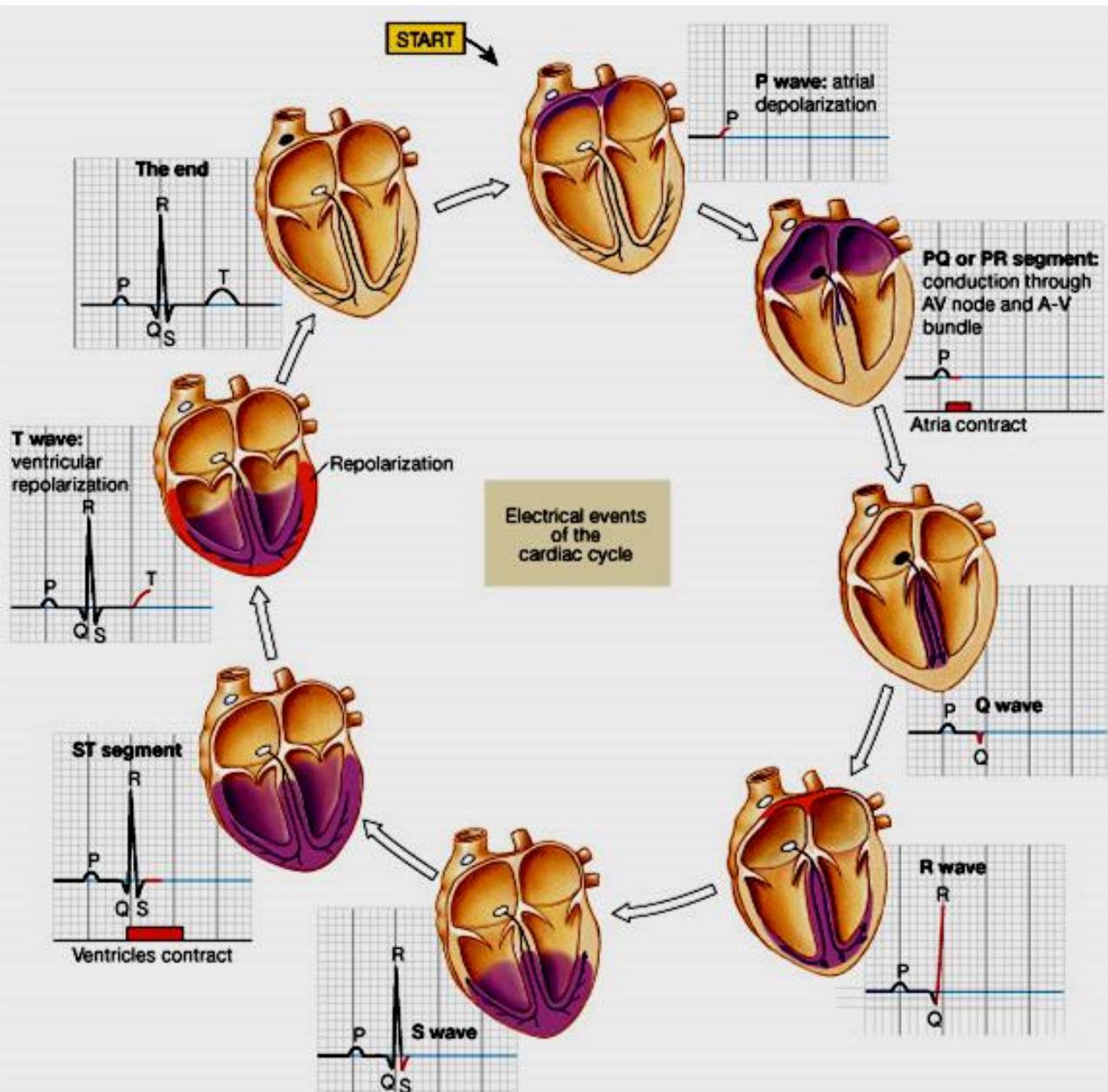
The two major components of the ECG are waves and segments.



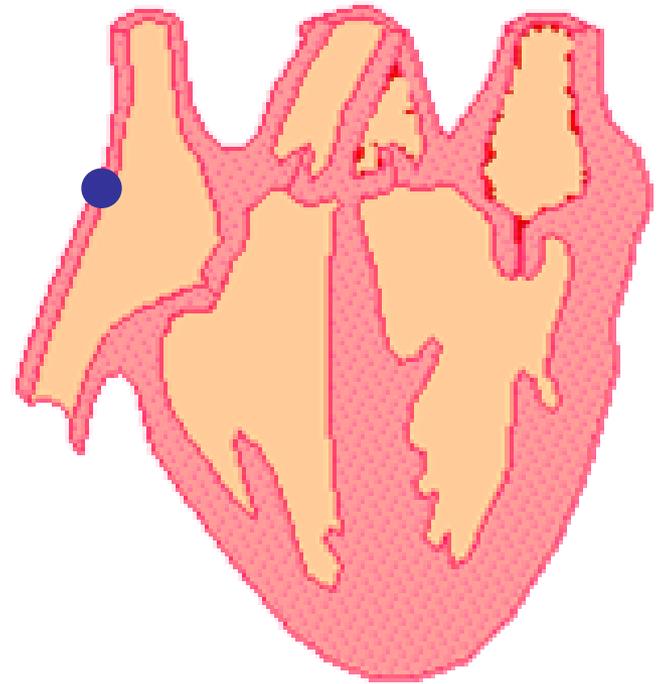
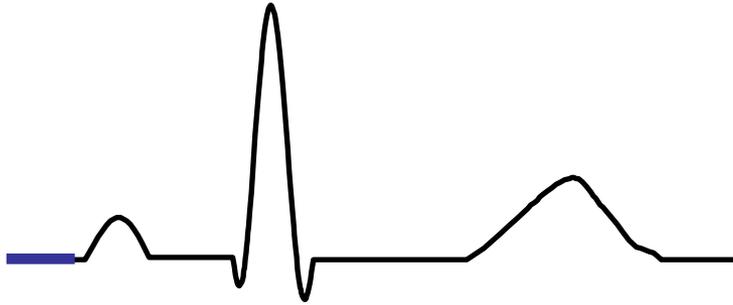




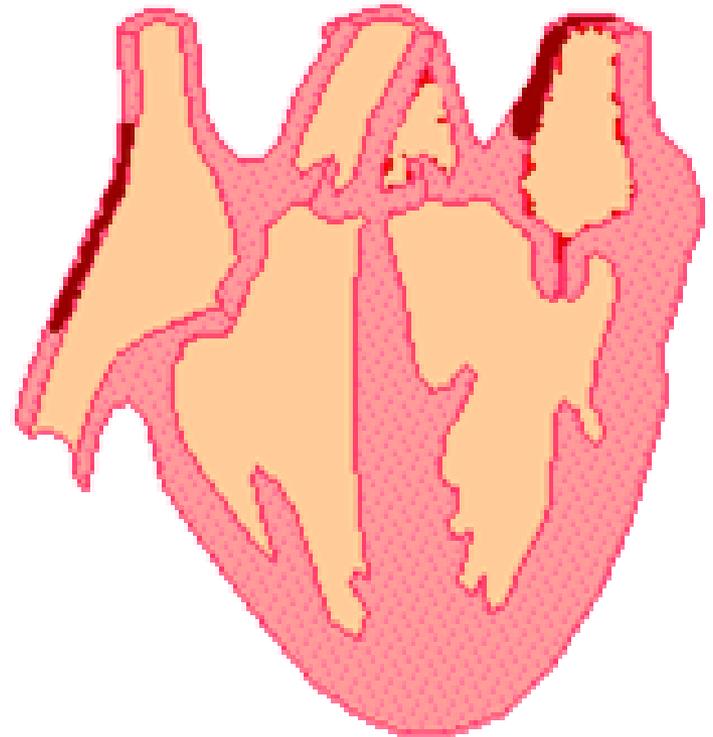
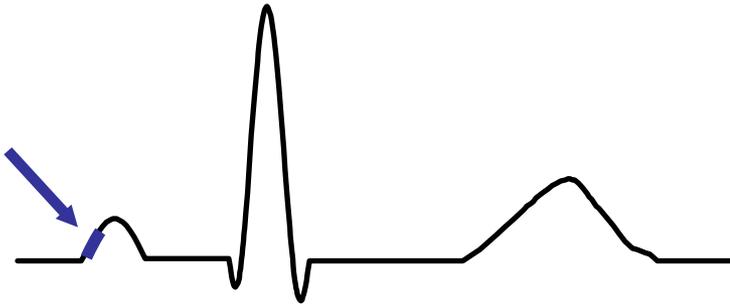
Correlation between the ECG and the electrical events in the heart



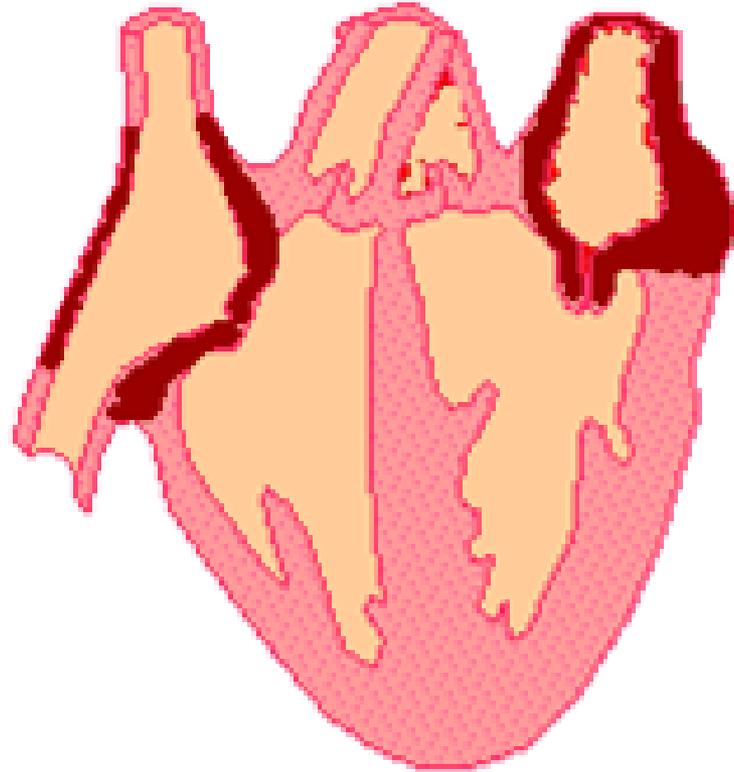
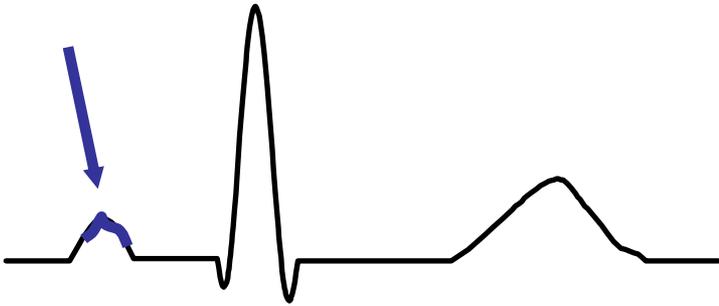
Start of ECG Cycle



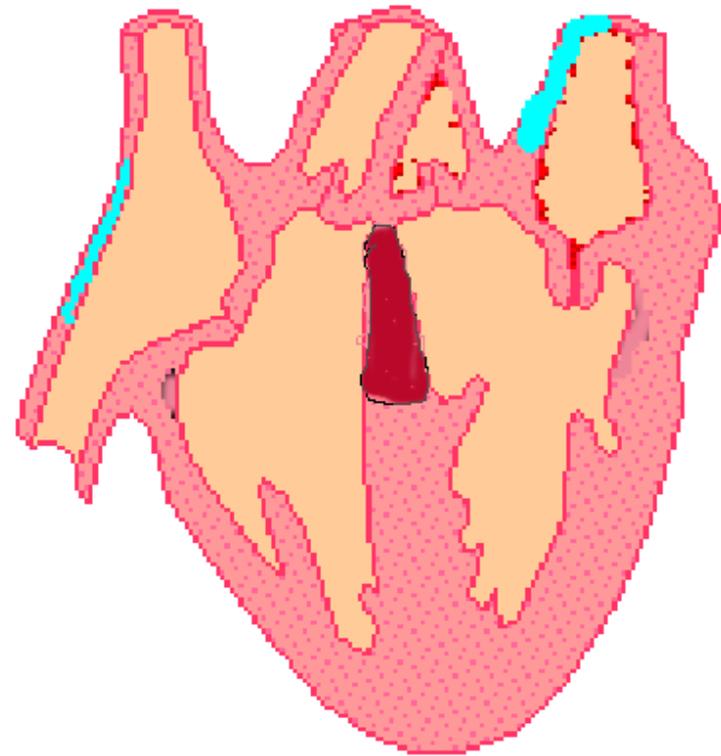
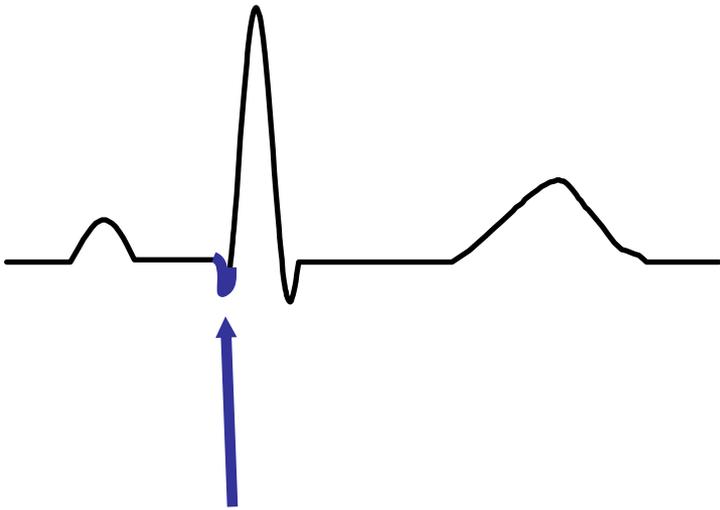
Early P Wave



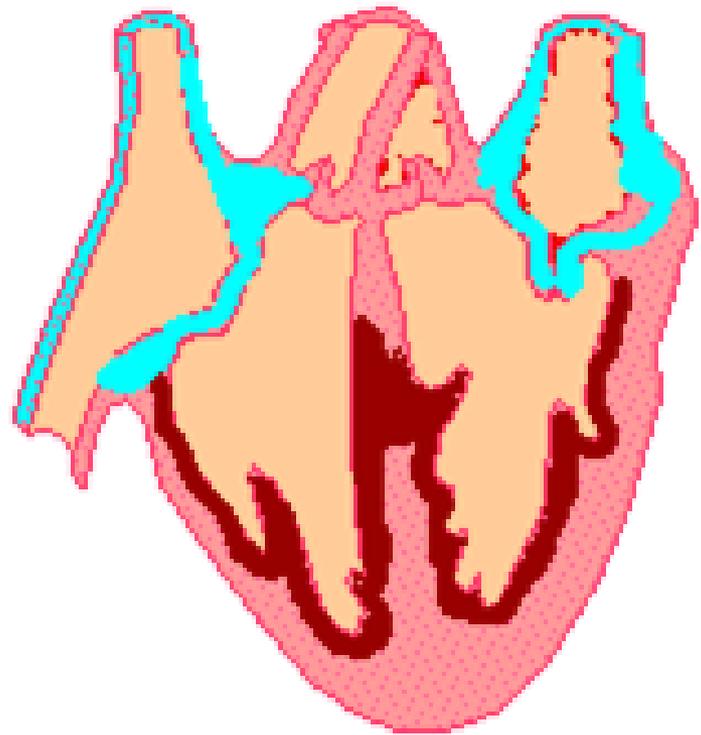
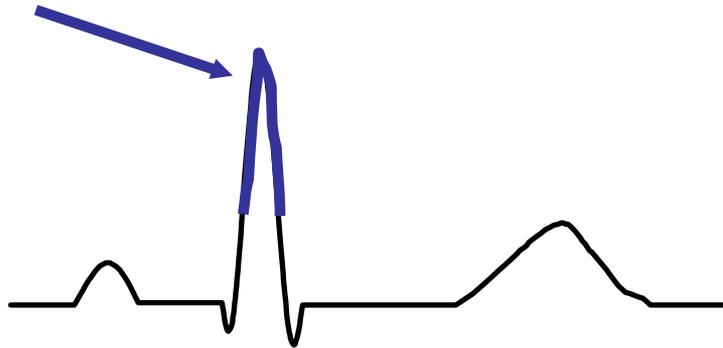
Later in P Wave



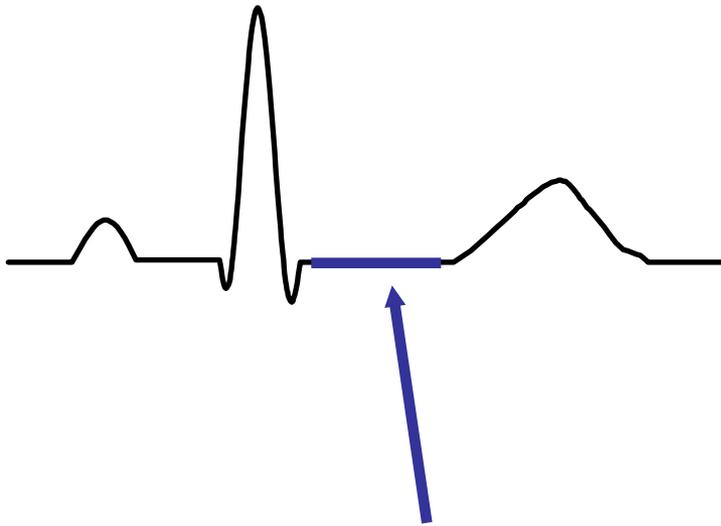
Early QRS



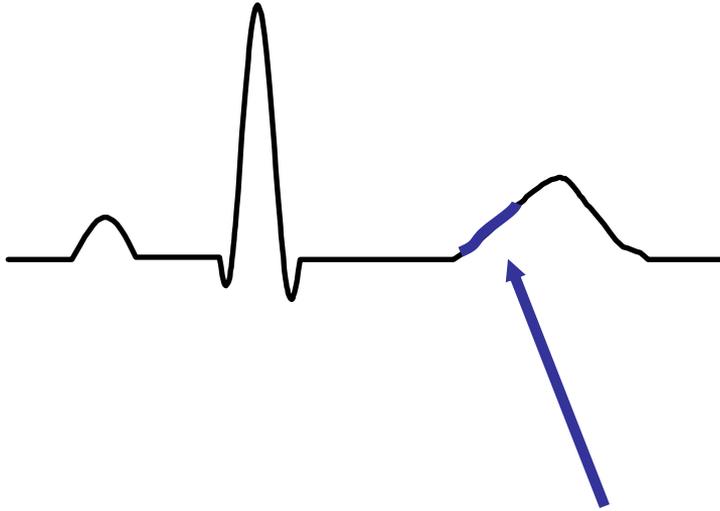
Later in QRS



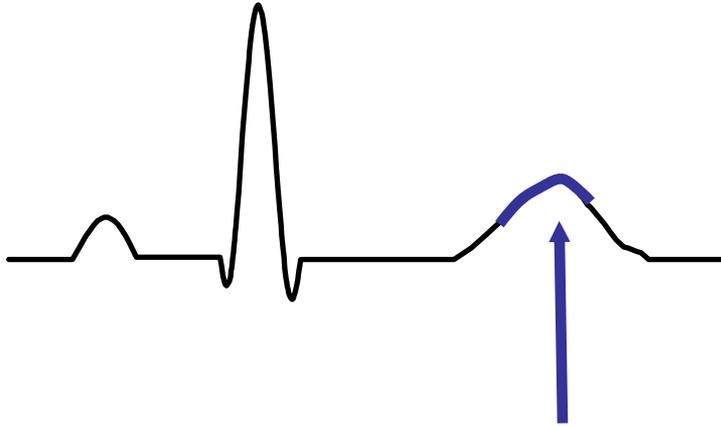
S-T Segment



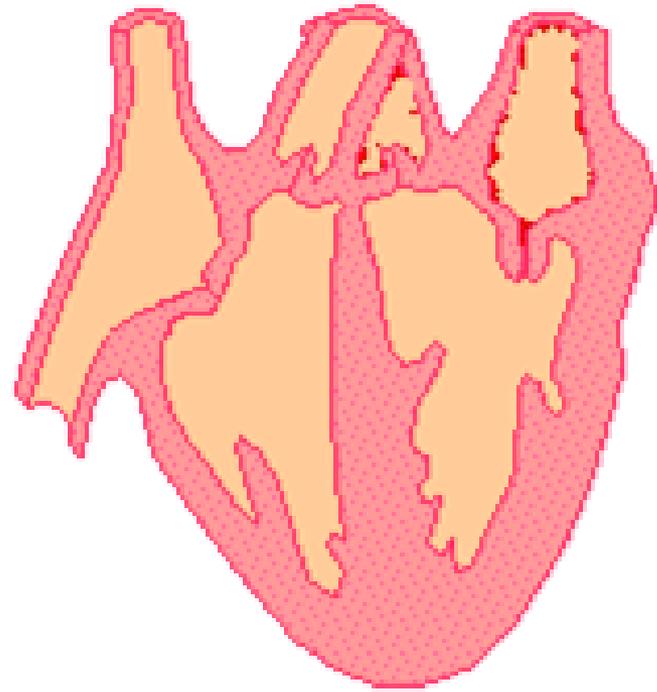
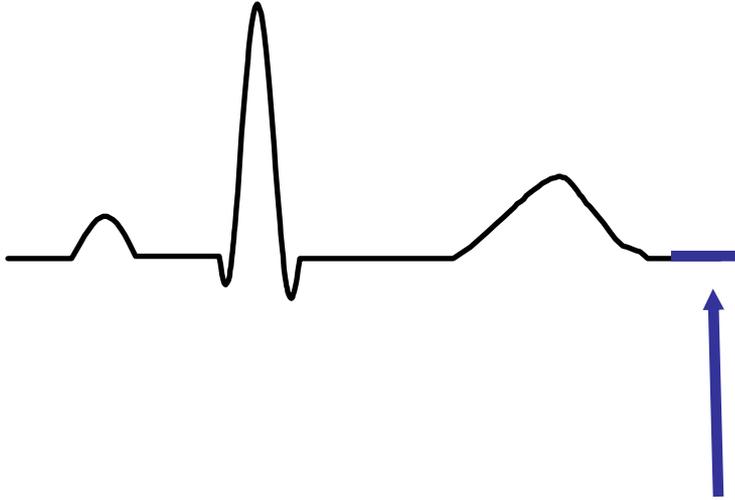
Early T Wave



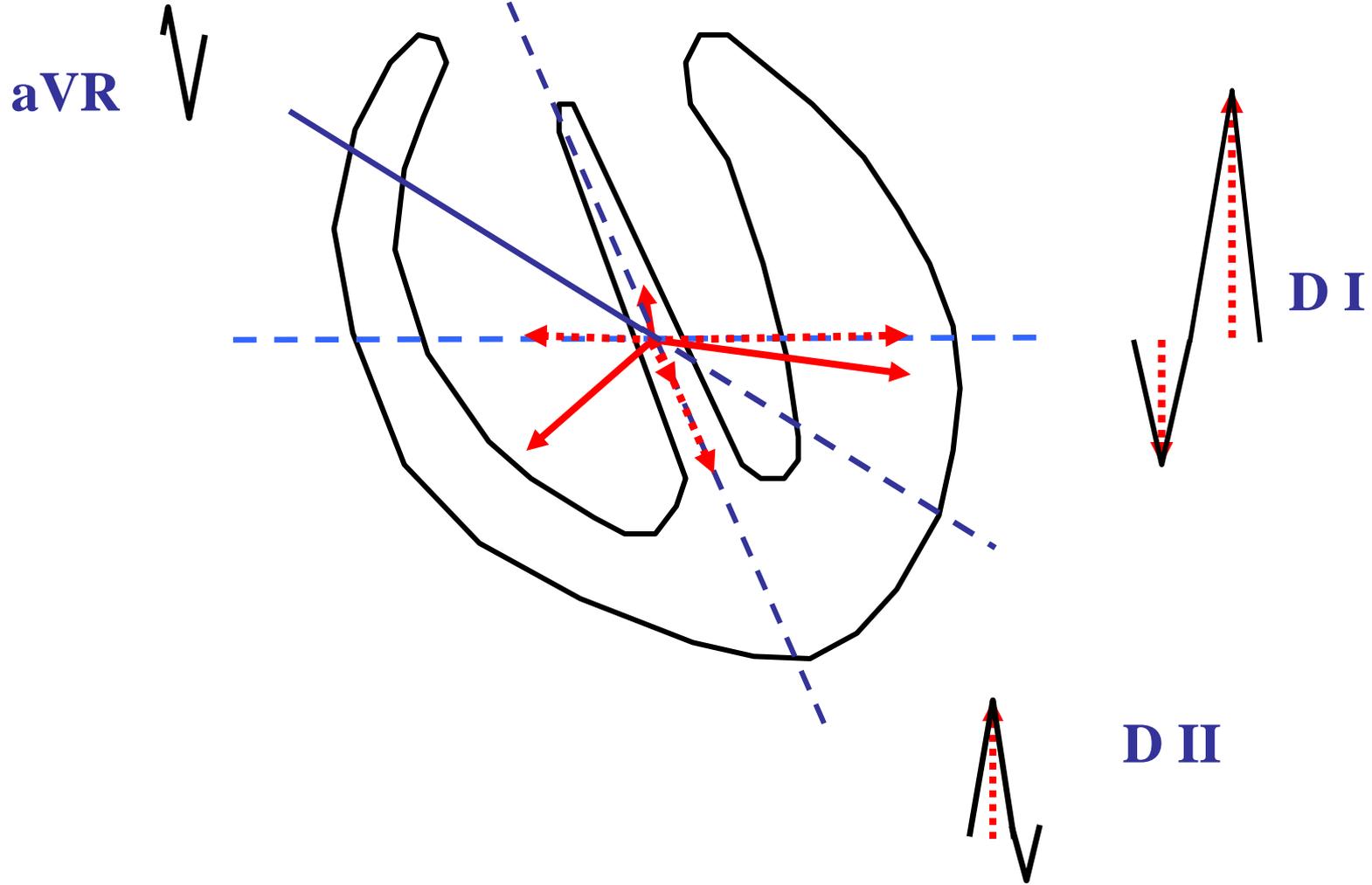
Later in T-Wave

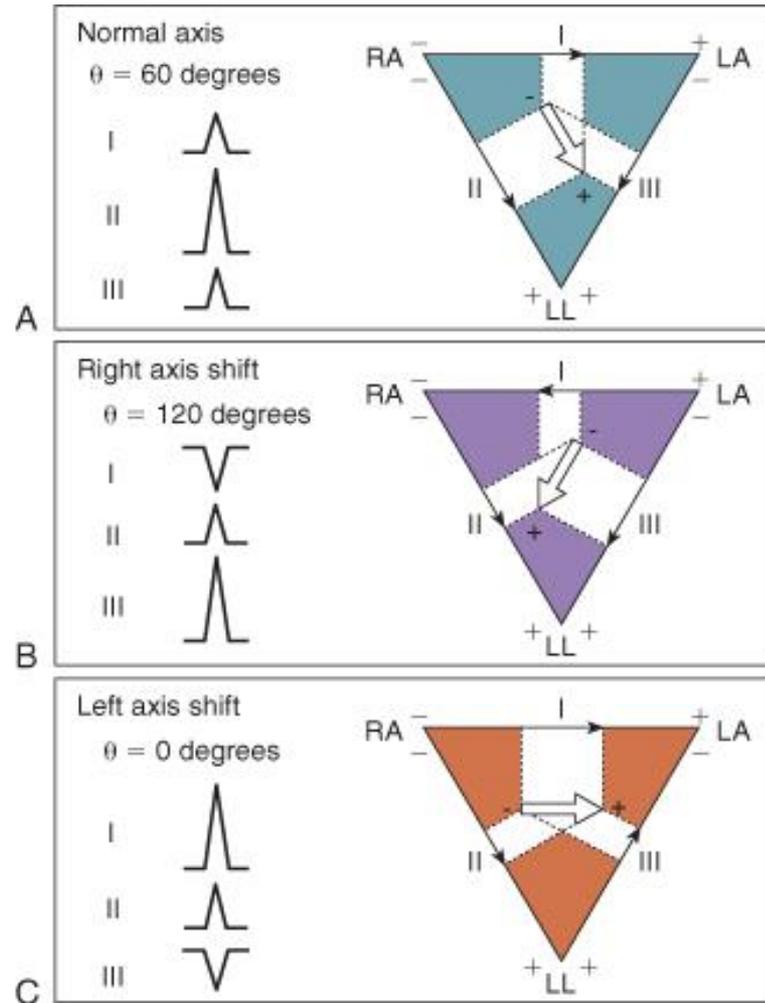
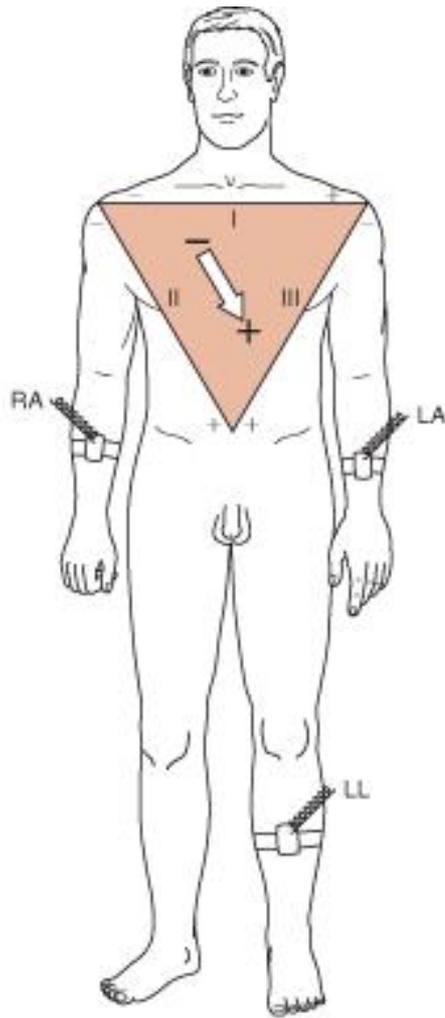


Back to where we started



ECG





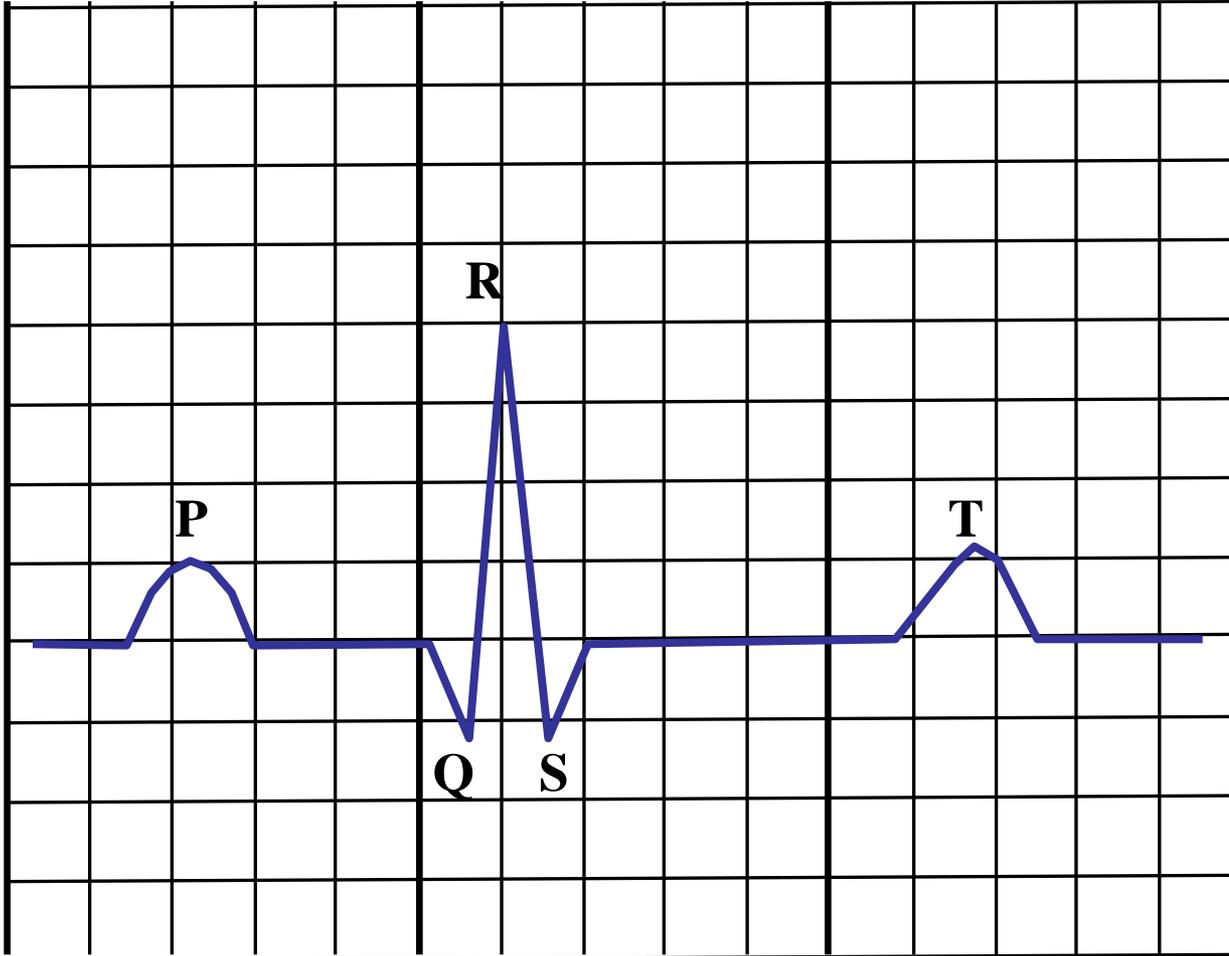
Einthoven's triangle, illustrating the galvanometer connections for standard limb leads I, II, and III.

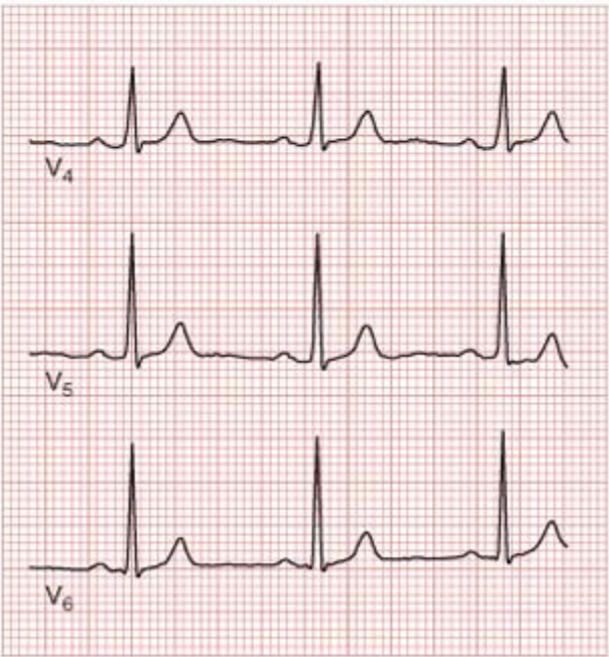
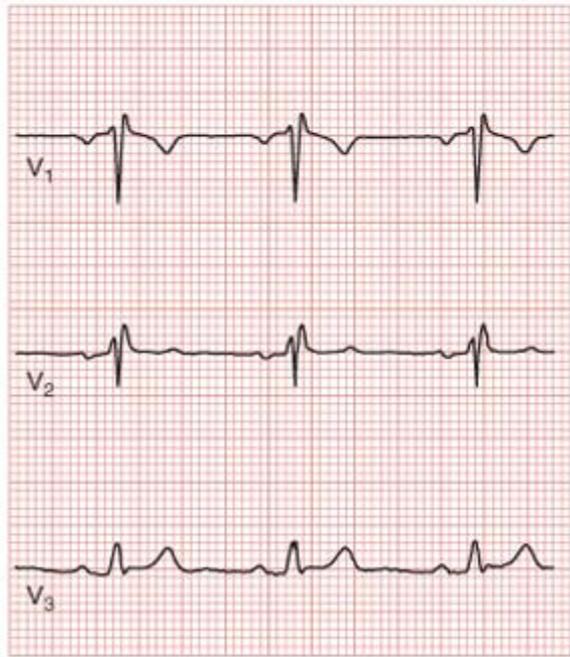
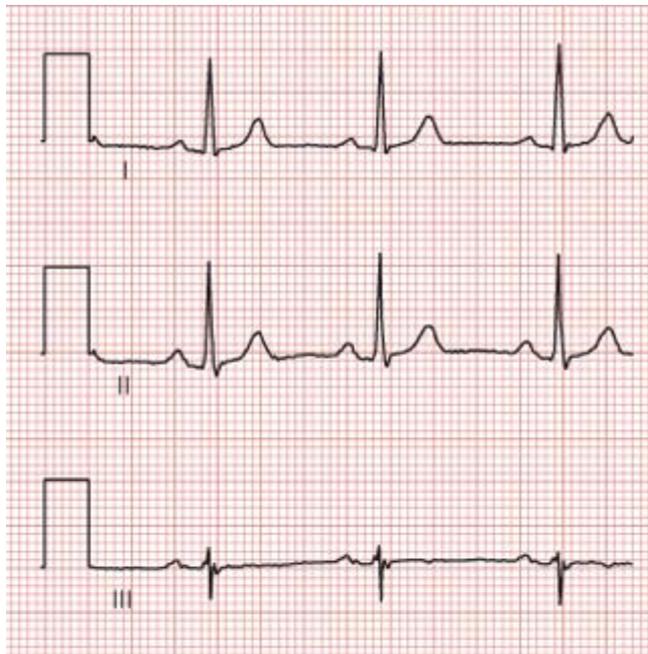
Magnitude and direction of the QRS complexes in limb leads I, II, and III when the mean electrical axis (Q) is 60 degrees (A), 120 degrees (B), and 0 degrees (C).

Leads and electrical vectors of the heart

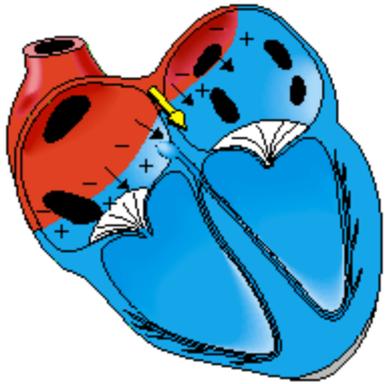
- The inferior leads (leads II, III and aVF) show the electrical activity from the *vantage point* of the inferior region (wall) of the heart
 - the apex of the left ventricle.
- The lateral leads (I, aVL, V5 and V6) look at the electrical activity from the vantage point of the lateral wall of the heart.
- The anterior leads, V1 through V6, and represent the anterior wall of the heart.
 - The lateral and anterior leads record events from the left wall and front walls of the left ventricle, respectively.
- aVR is rarely used for diagnostic information, but indicates if the ECG leads were placed correctly on the patient.
- The right ventricle has very little muscle mass → it leaves only a small imprint on the ECG, making it more difficult to diagnose changes in the right ventricle.

ECG





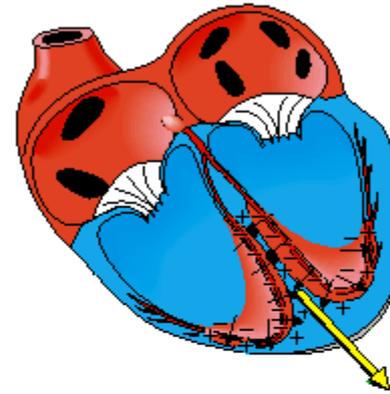
ATRIAL
DEPOLARIZATION
80 ms



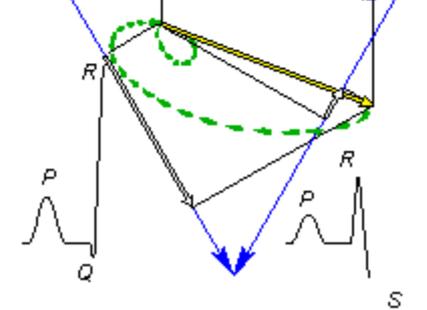
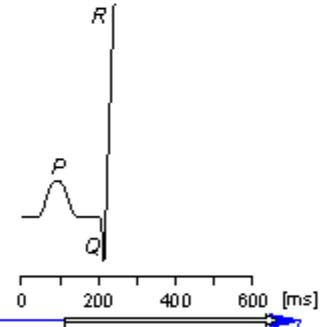
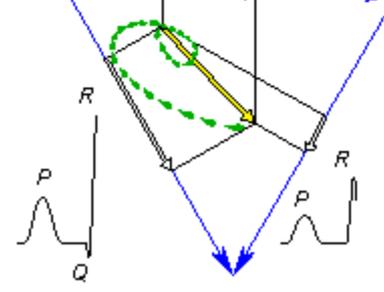
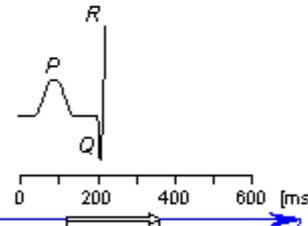
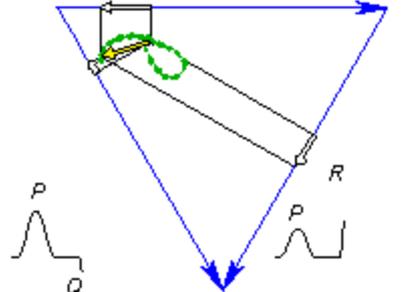
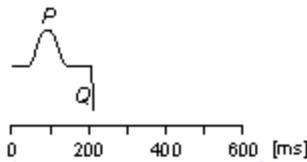
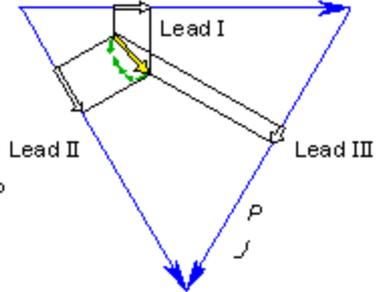
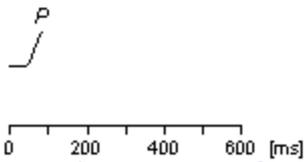
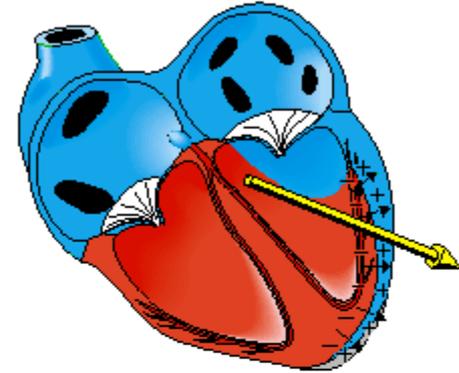
SEPTAL
DEPOLARIZATION
220 ms



APICAL
DEPOLARIZATION
230 ms

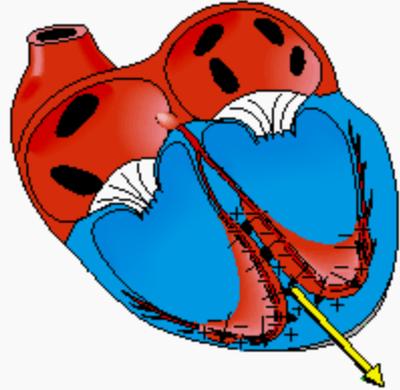


LEFT VENTRICULAR
DEPOLARIZATION
240 ms

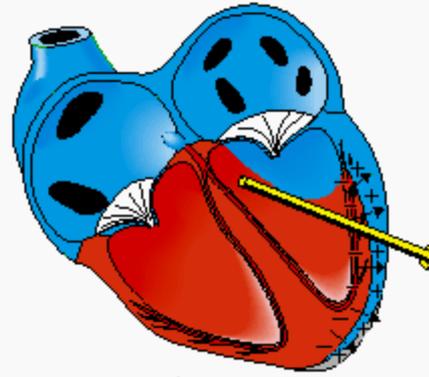


The generation of the ECG signal in the Einthoven limb leads.

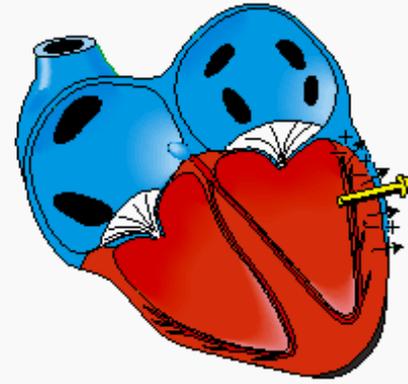
APICAL
DEPOLARIZATION
230 ms



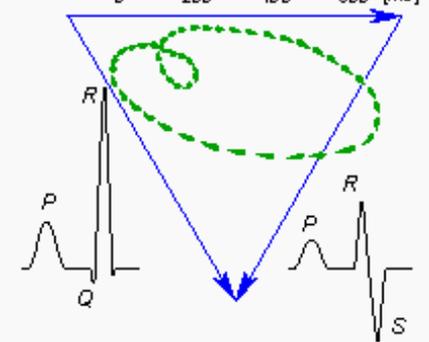
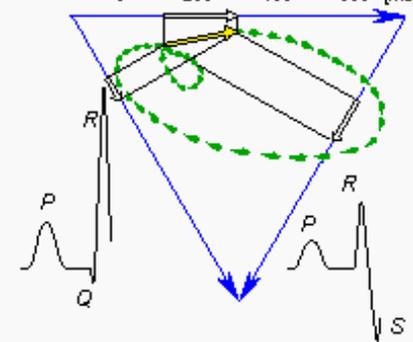
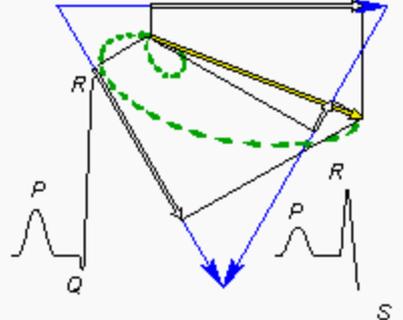
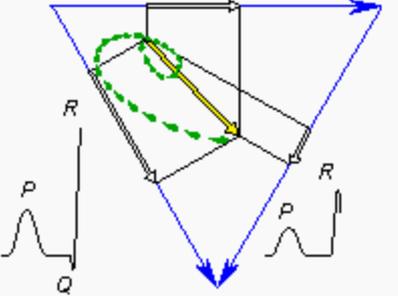
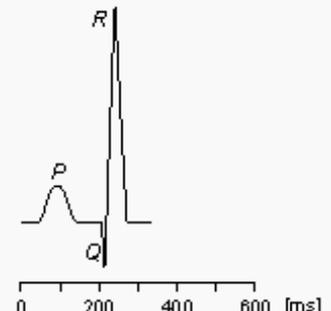
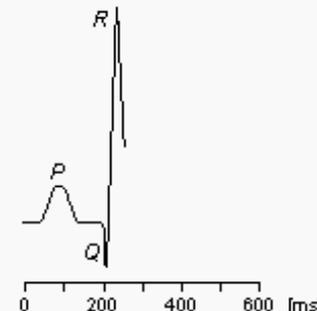
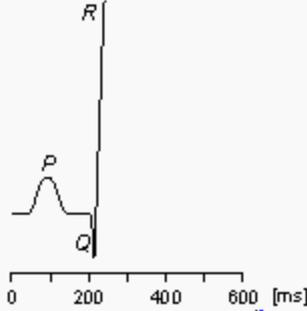
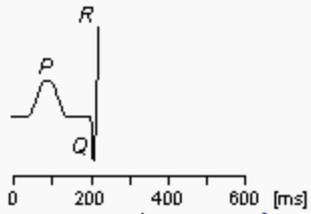
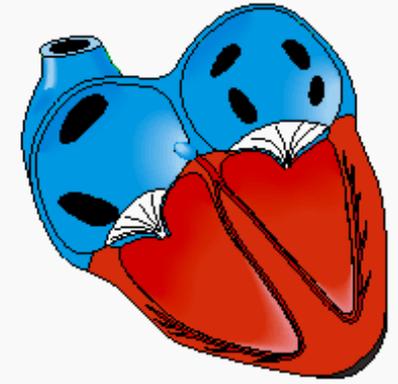
LEFT VENTRICULAR
DEPOLARIZATION
240 ms



LATE LEFT VENTRICULAR
DEPOLARIZATION
250 ms

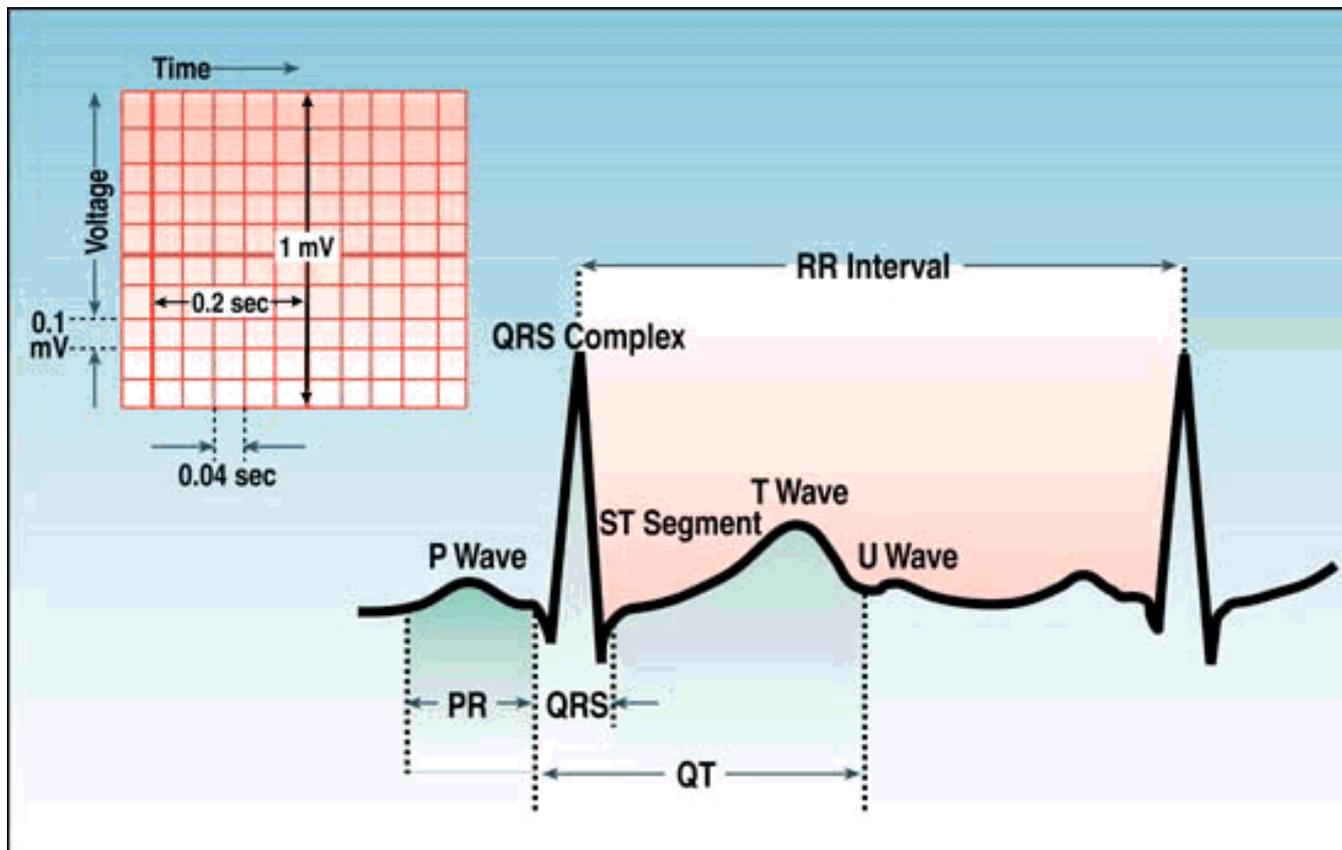


VENTRICLES
DEPOLARIZED
350 ms



The generation of the ECG signal in the Einthoven limb leads.

Analysis of Normal ECG



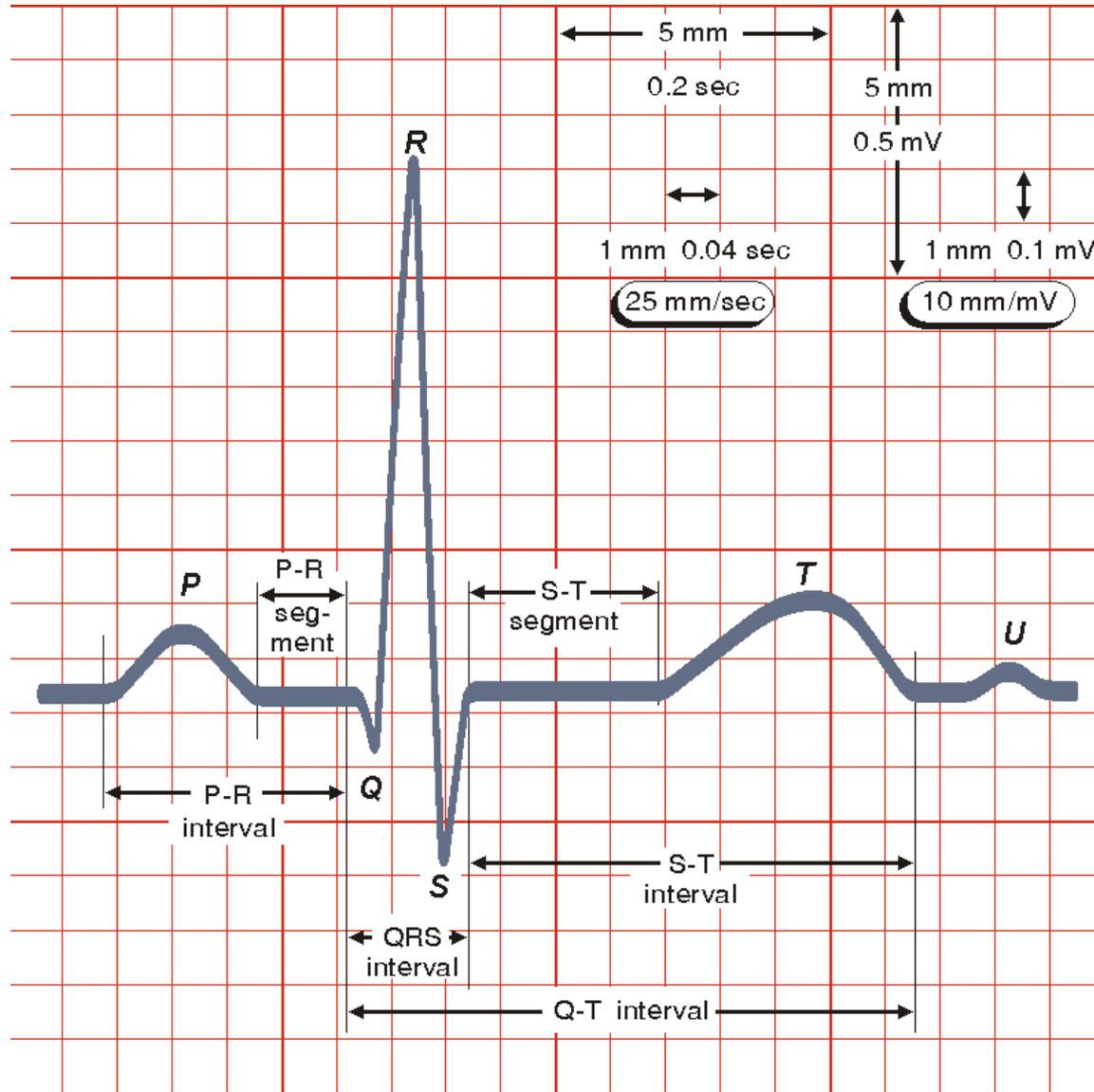
Analysis of Normal ECG

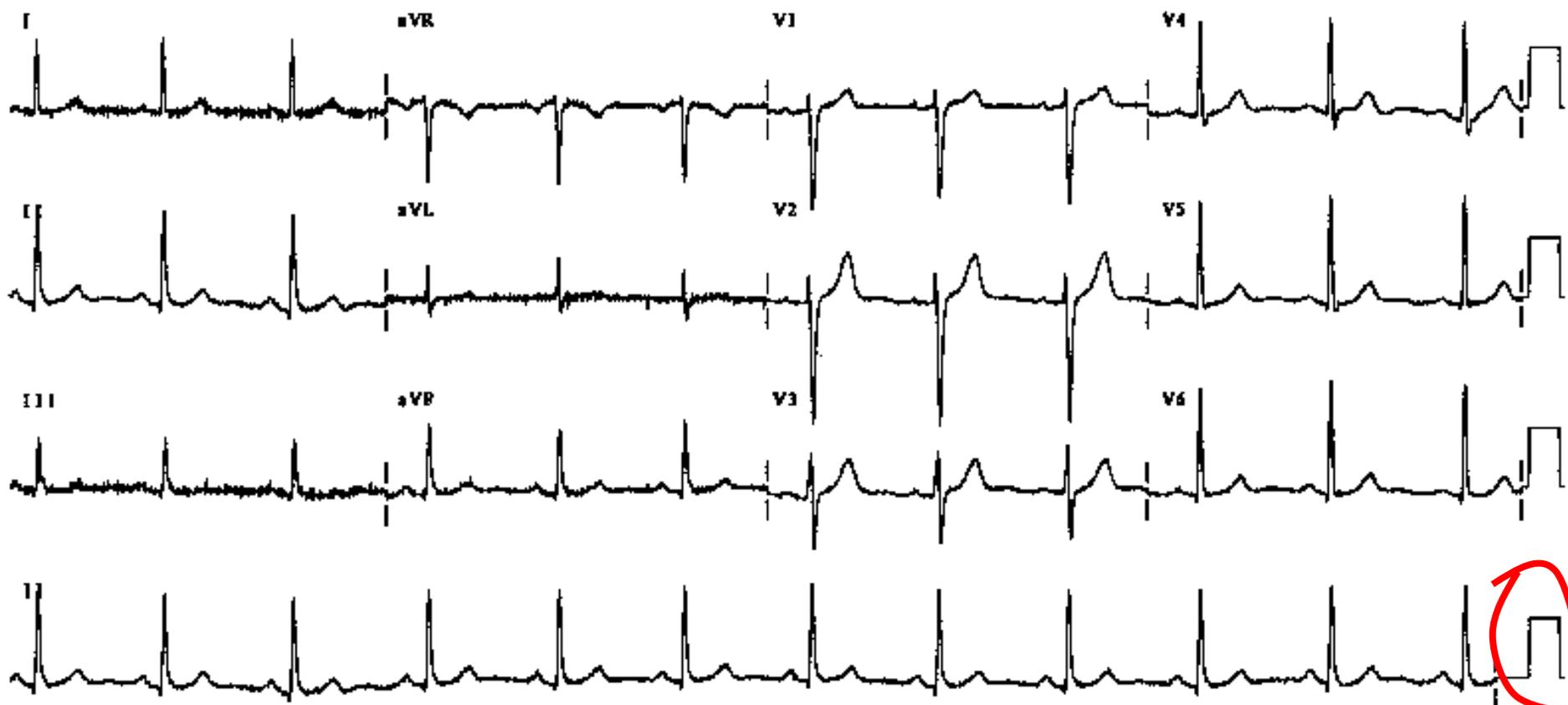
- 1. Check ECG calibration**
- 2. Rhythm of the heart: "normal sinus rhythm"**
- 3. Frequency (heart rate)**
- 4. Electrical axis of the heart**
- 5. Measurement of waves, segments, intervals**
 - the sizes of the voltage changes
 - the duration and temporal relationships of the various components
- 6. Conduction analysis (PR interval, QRS duration, QT interval)**

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1. Calibration





I.D.C 00000-0000 Speed: 25 mm/sec Limbs: 10 mV Chest: 10 mm/mV

50% 0.15-150 Hz

16405

Analysis of Normal ECG

1. **Check ECG calibration**
2. **Rhythm of the heart: "normal sinus rhythm"**
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2. Heart Rhythm

- **Normal Sinusal Rhythm (SR):**

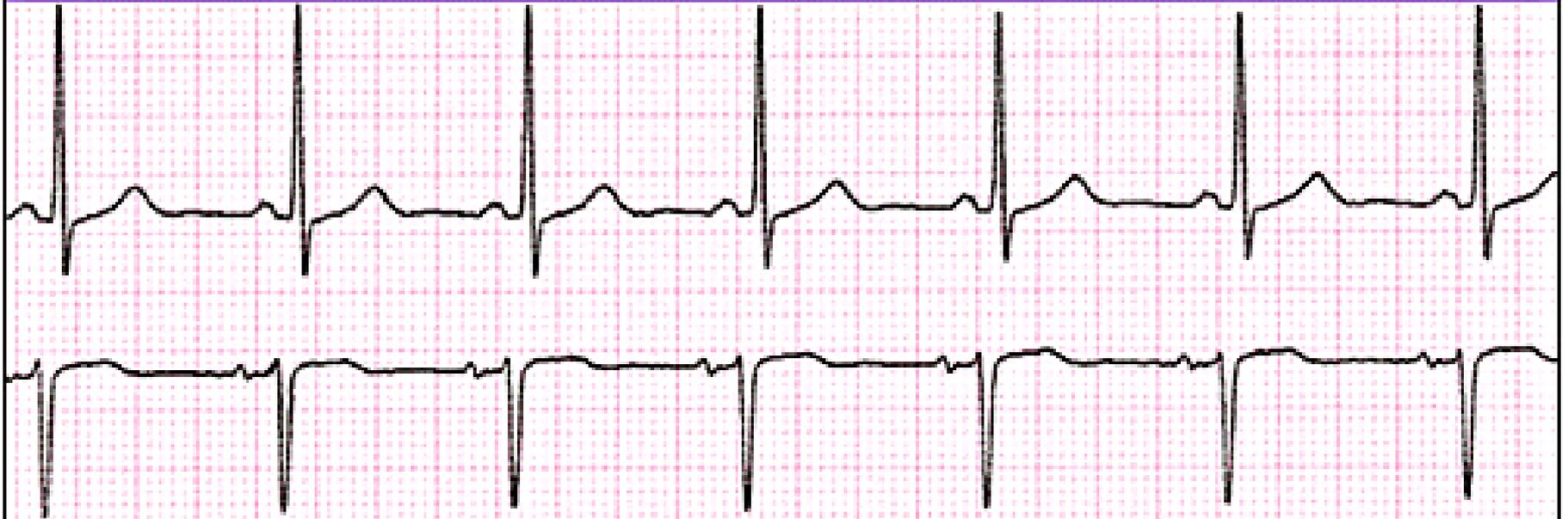
Impulses originate at S-A node at normal rate → all complexes normal, evenly spaced:

1. P wave (in Lead II: < 2.5 mm; < 0.11 sec)
2. P-R Interval $\sim 0,12-0,21$ s
3. Frequency $\sim 60-100$ beats/min, regulated (var. $<10\%$)
4. P wave electrical axis $\sim 0^\circ \div +75^\circ$ (close to $+45^\circ \div +60^\circ$)



- **Nodal rhythm** : superior/middle/inferior
- **Ventricular rhythm**: A-V dissociation

Normal Sinus Rhythm



**Heart
Rate**

Rhythm

P Wave

**PR interval
(in seconds)**

**QRS
(in seconds)**

60-100 bpm

Regular

**Before each
QRS, identical**

.12 to .20

<.12

Abnormal Sinus Rhythms

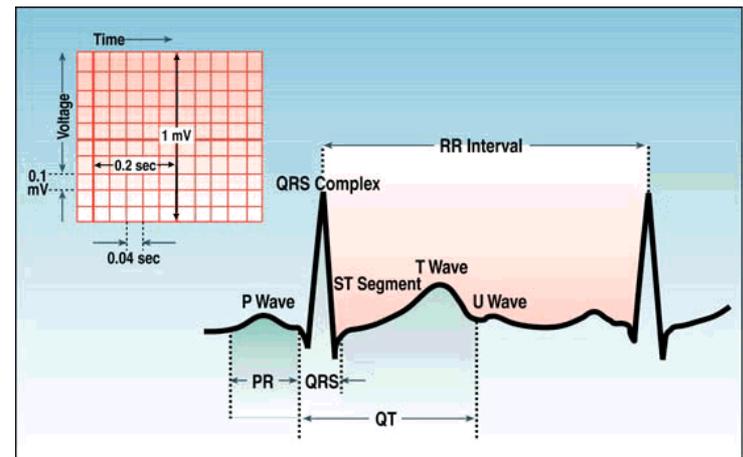
- **Tachycardia** (*fast heart rate*, in an adult person >100 beats /min) is determined by increased body temperature (18 beats/ $^{\circ}\text{C}$, up to 40.5°C), stimulation of the heart by the sympathetic nerves etc.
- **Bradycardia** (slow heart rate, def. as fewer than 60 beats/minute:
 - in athletes; after vagal stimulation – see *carotid sinus syndrome*
- **Sinus arrhythmia** with respiratory cycle results from cyclic variations in the sympathetic and parasympathetic tone, that influence the SA node
 - results mainly from "spillover" of signals from the medullary respiratory center into the adjacent vasomotor center during inspiratory and expiratory cycles of respiration
 - alternate increase and decrease in the number of impulses transmitted through the sympathetic and vagus nerves to the heart
 - increased HR during inspiration and decreased HR during expiration: 5% for normal/quiet respiration, up to 30% for deep respiration.
 - when loss, is a sign of autonomic system dysfunction...

Analysis of Normal ECG

1. **Check ECG calibration**
2. **Rhythm of the heart: "normal sinus rhythm"**
3. **Frequency (heart rate)**
4. **Electrical axis of the heart**
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 - the sizes of the voltage changes
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6. **Conduction analysis (PR interval, QRS duration, QT interval)**

3. Frequency/Heart rate (HR)

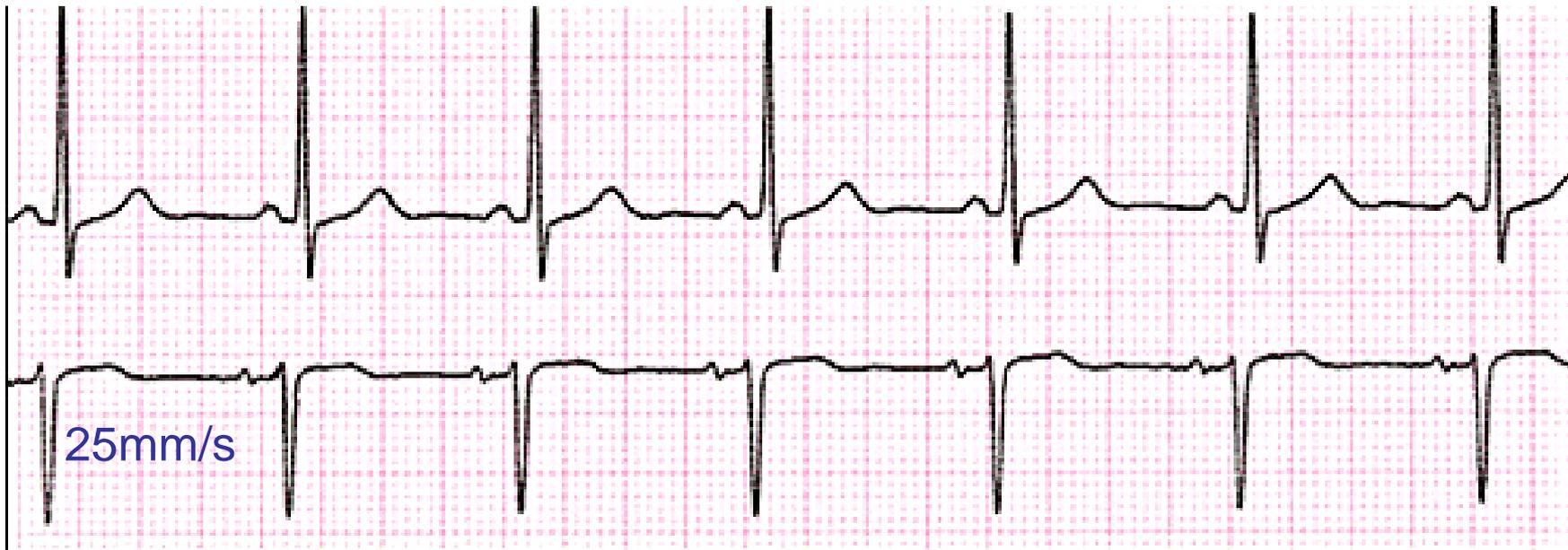
- HR – reciprocal of the time interval between 2 successive heartbeats/QRS complexes
- If the normal interval between 2 successive QRS complexes (RR interval) is 0.83 sec, then $HR = 60/0.83 = 72$ beats/min
- HR ~ 60-100 beats/min
- Method of determination...



Frequency determination – Method 1

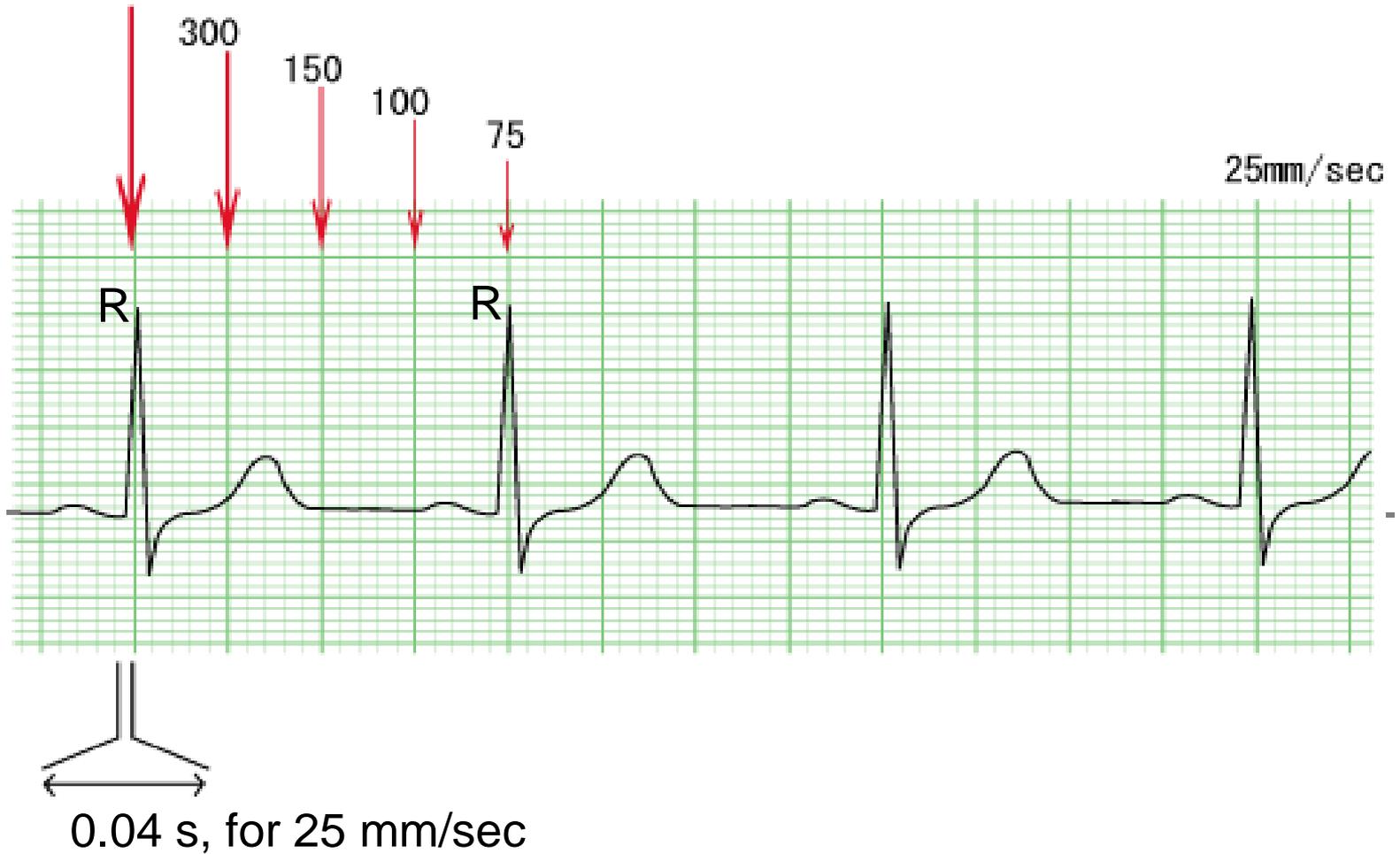
a) $60 \text{ s} = ? \text{ div. of } 0,04\text{s} \rightarrow 60\text{s} = 1500 \text{ div} \rightarrow 1500 \text{ div./ R-R div. no.}$

b) $60\,000 \text{ ms/R-R (ms)} = 60\,000/40 \times \text{no. of div. for R-R}$



75 b/m

Frequency determination – Method 2



Analysis of Normal ECG

1. **Check ECG calibration**
2. **Rhythm of the heart: "normal sinus rhythm"**
3. **Frequency (heart rate)**
4. **Electrical axis of the heart**
5. **Measurement of waves, segments, intervals**
 - the sizes of the voltage changes
 - the duration and temporal relationships of the various components
6. **Conduction analysis (PR interval, QRS duration, QT interval)**

4. Electrical axis of the heart

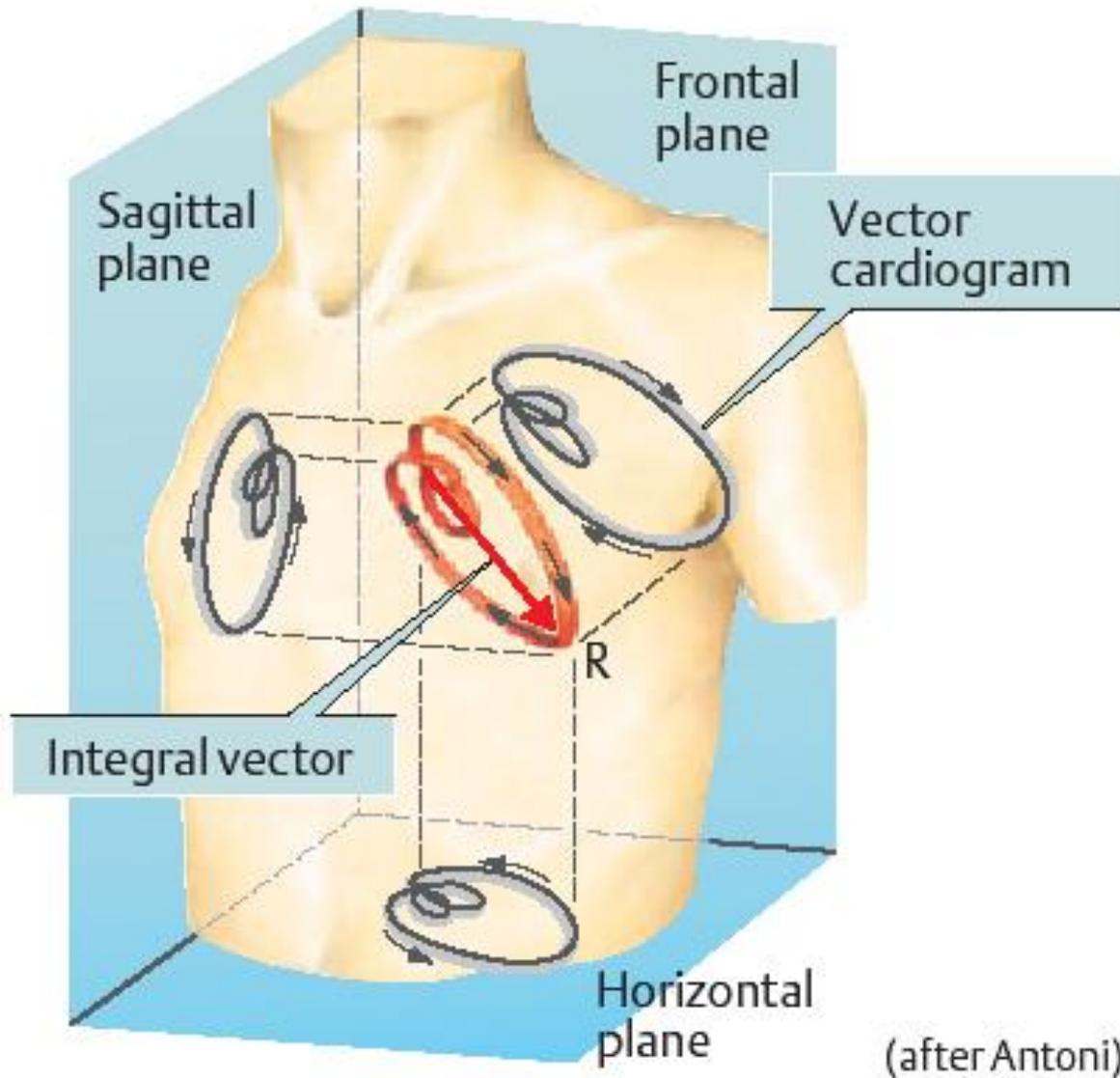
Electrical axis for a given electrical potential is represented as a vector:

- vector def: an arrow that points in the direction of the electrical potential generated by the current flow, *with the arrowhead in the positive direction.*
- by convention, the length of the arrow is drawn *proportional to the voltage of the potential*
- the summated vector of the generated potential at any particular instant is called *instantaneous mean vector*

4. QRS axis

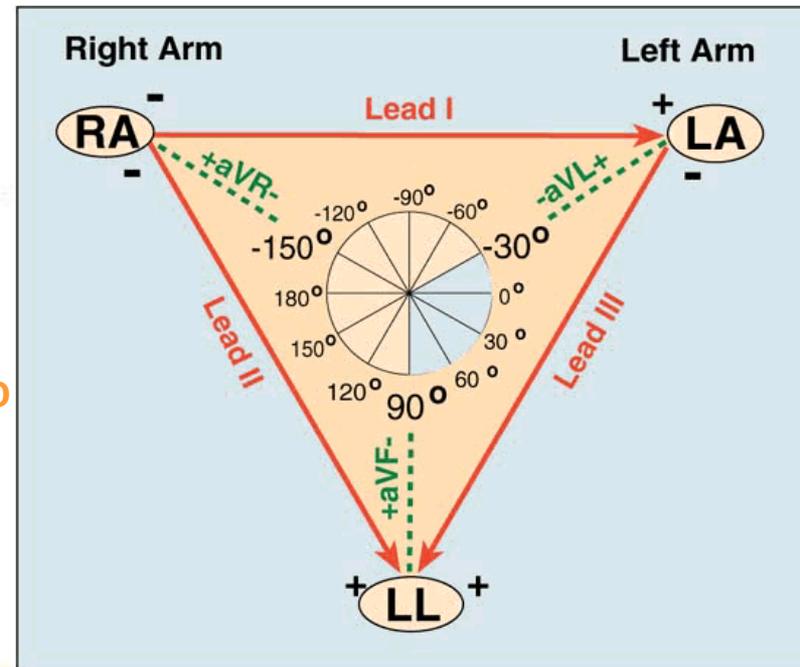
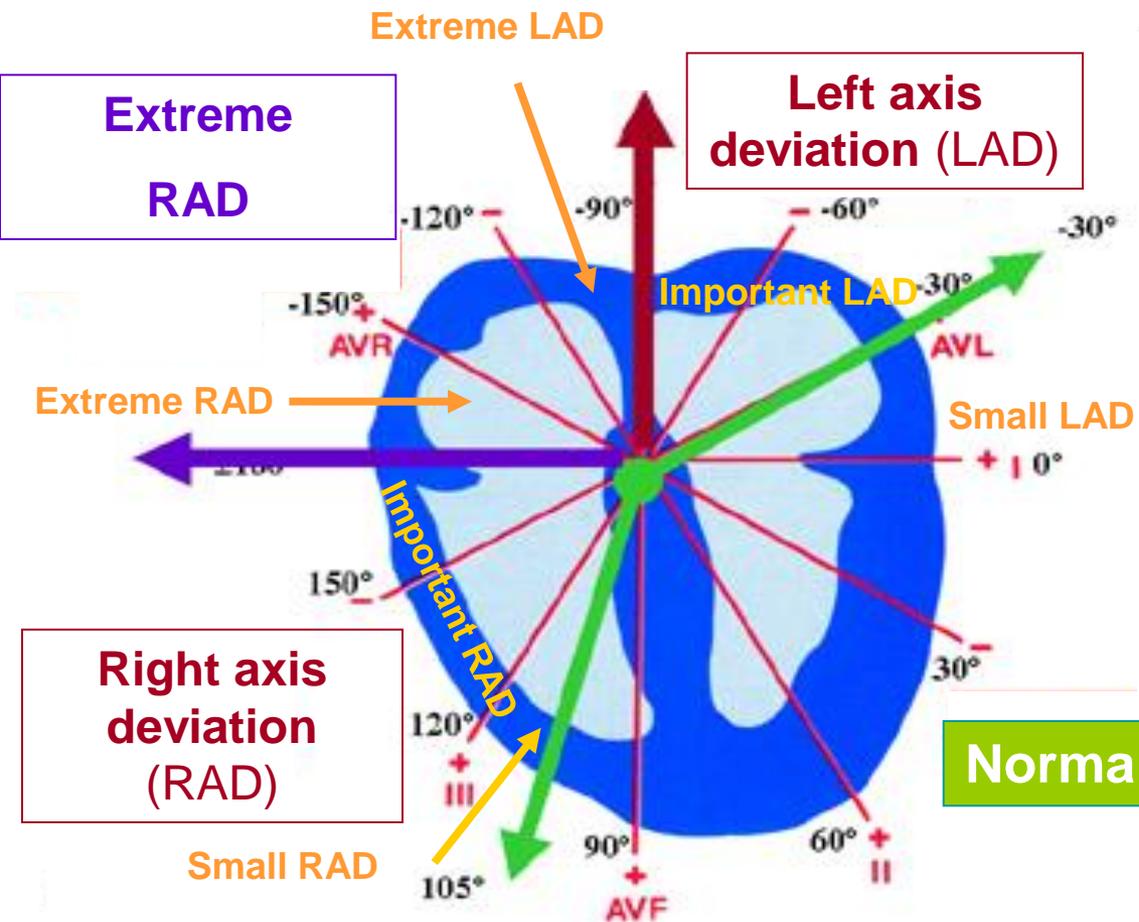
- QRS electric axis (mean vector) denotes the average direction of the electric activity throughout ventricular activation:
 - the direction of the electric axis denote the instantaneous direction of the electric heart vector.
- The normal range of the electric axis lies between **-30° and +110° in the frontal plane and between +30° and -30° in the transverse plane.**

QRS axis



Electrical axis in the frontal plane

- Definition, relation with anatomical axis, deviations



QRS Axis

The direction of the electric axis may be **approximated** from the 12-lead ECG by finding the lead in the frontal plane, where the QRS-complex has largest positive deflection. The direction of the electric axis is in the direction of this lead vector.

QRS Axis

- qualitative inspection method -

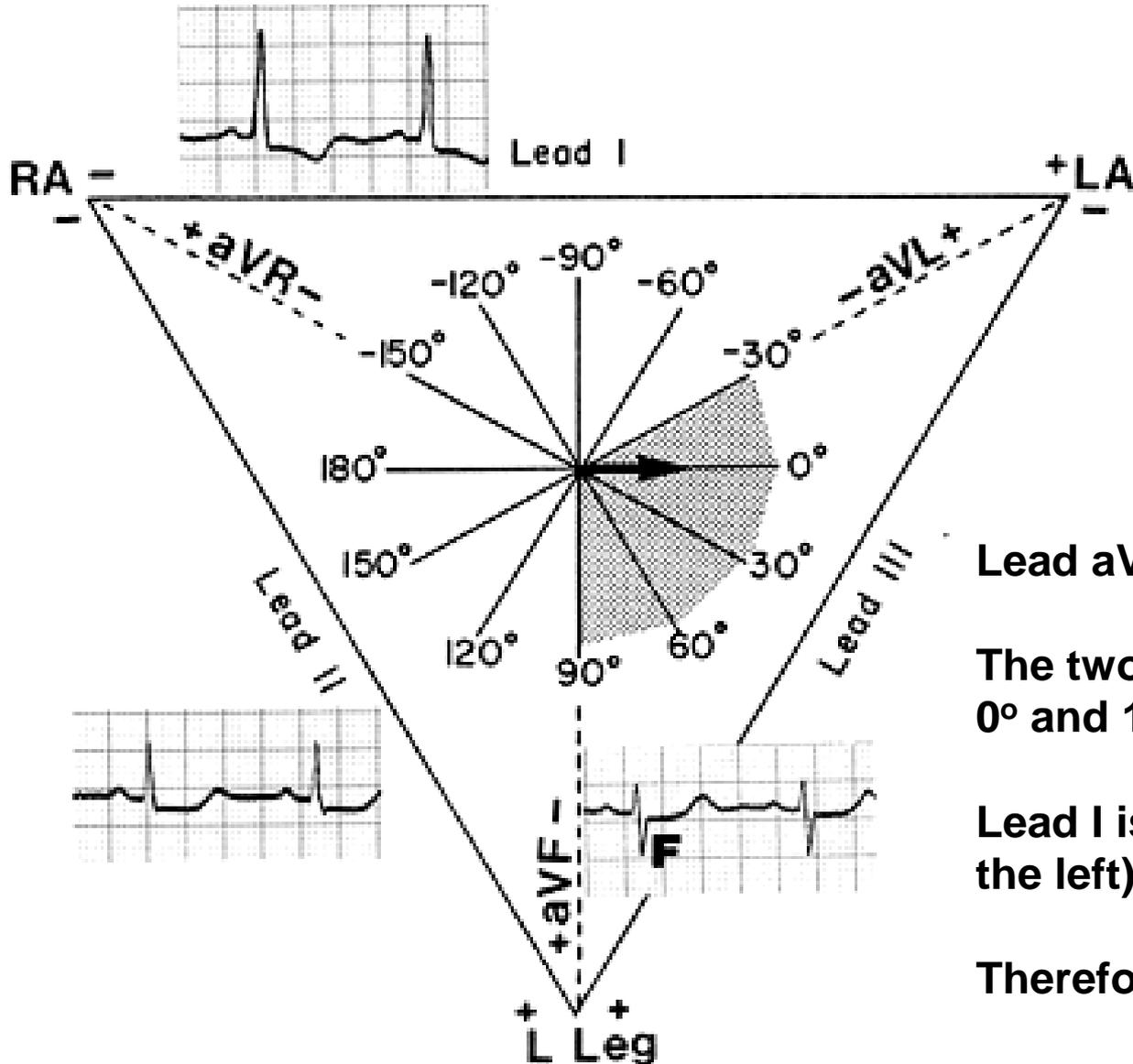
First find the *isoelectric* lead if there is one; i.e., the lead with equal forces in the positive and negative direction. Often this is the lead with the smallest QRS.

The QRS axis is *perpendicular* to that lead's orientation.

Since there are two perpendiculars to each isoelectric lead, choose the perpendicular that best fits the direction of the other ECG leads.

Occasionally each of the 6 frontal plane leads is small and/or isoelectric. The axis cannot be determined and is called *indeterminate*. This is a normal variant.

Axis in the normal range



Lead aVF is the isoelectric lead.

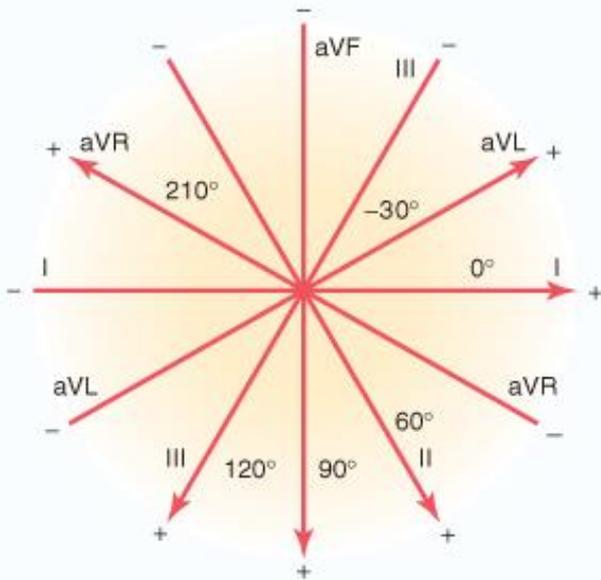
The two perpendiculars to aVF are 0° and 180°.

Lead I is positive (i.e., oriented to the left).

Therefore, the axis has to be 0°.

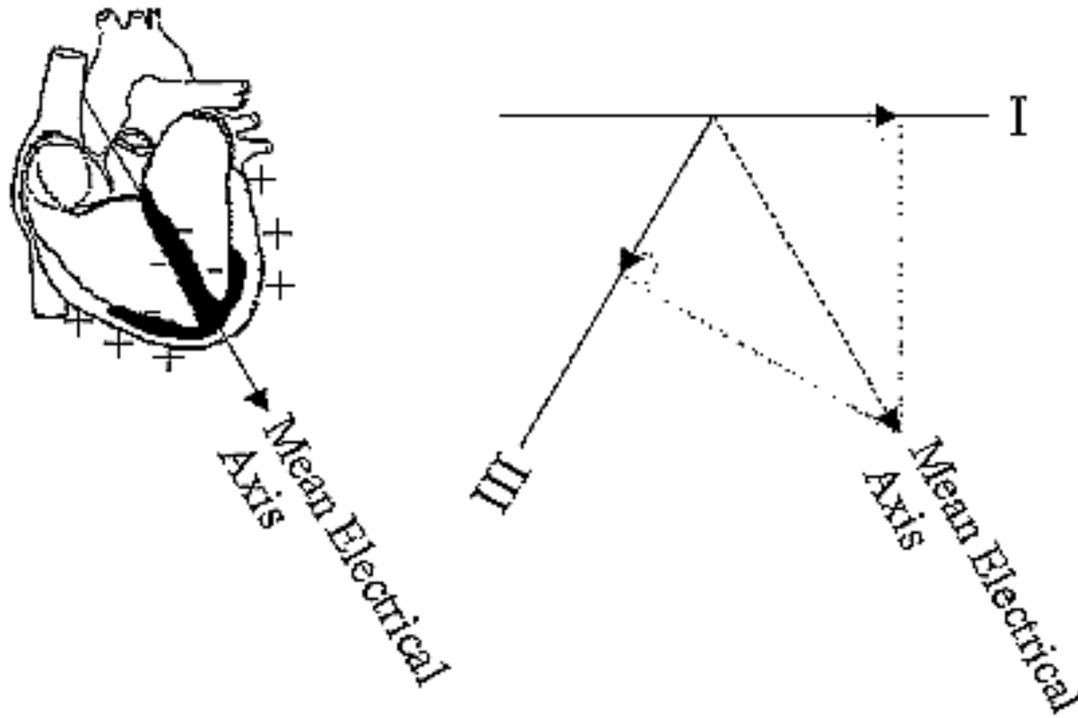
QRS axis – Geometric methods :

1. Einthoven triangle (for the standard leads: I, II, III)
2. Bayley (three axis): parallels to the Einthoven triangle, through the triangle's center, considered the electrical center of the heart
3. Hexagonal reference system: standard and augmented frontal leads

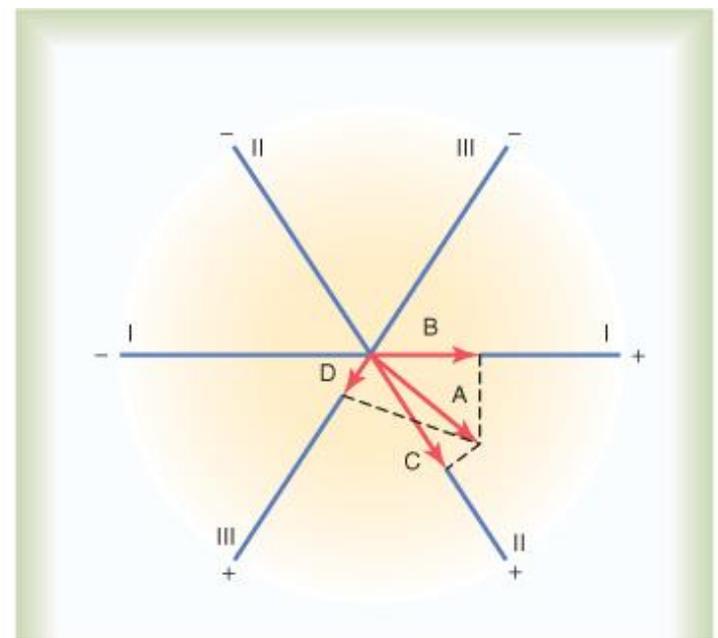
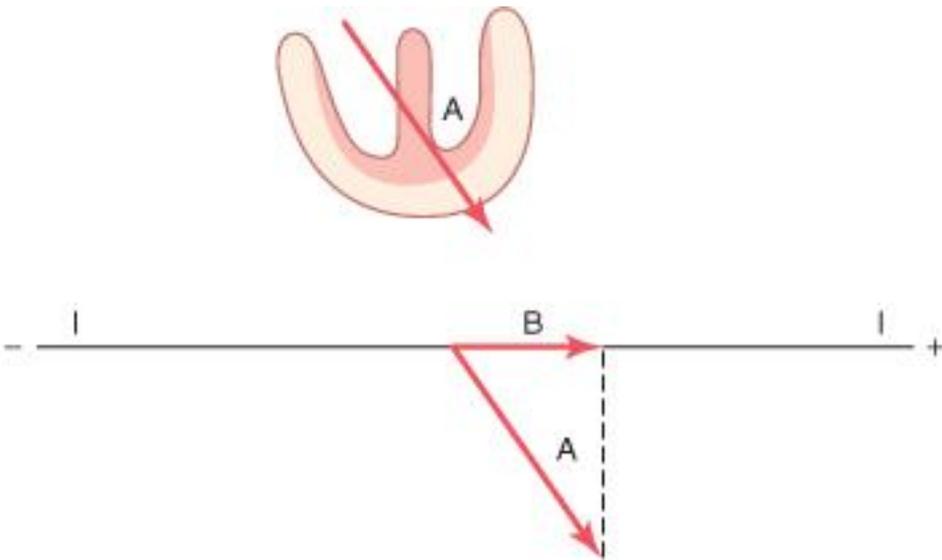


Circle of axis: from zero reference point, the scale of vectors rotates clockwise; when the vector extends from above and straight downward → +90 degrees; when it extends from the person's left to right, it has a direction of +180 degrees; when it extends straight upward, it has a direction of -90 (or +270) degrees.

Axis of lead I is 0 degrees, lead II is +60 degrees, lead III is +120 degrees, lead aVR is +210 (-150) degrees, lead aVL is -30 degrees.



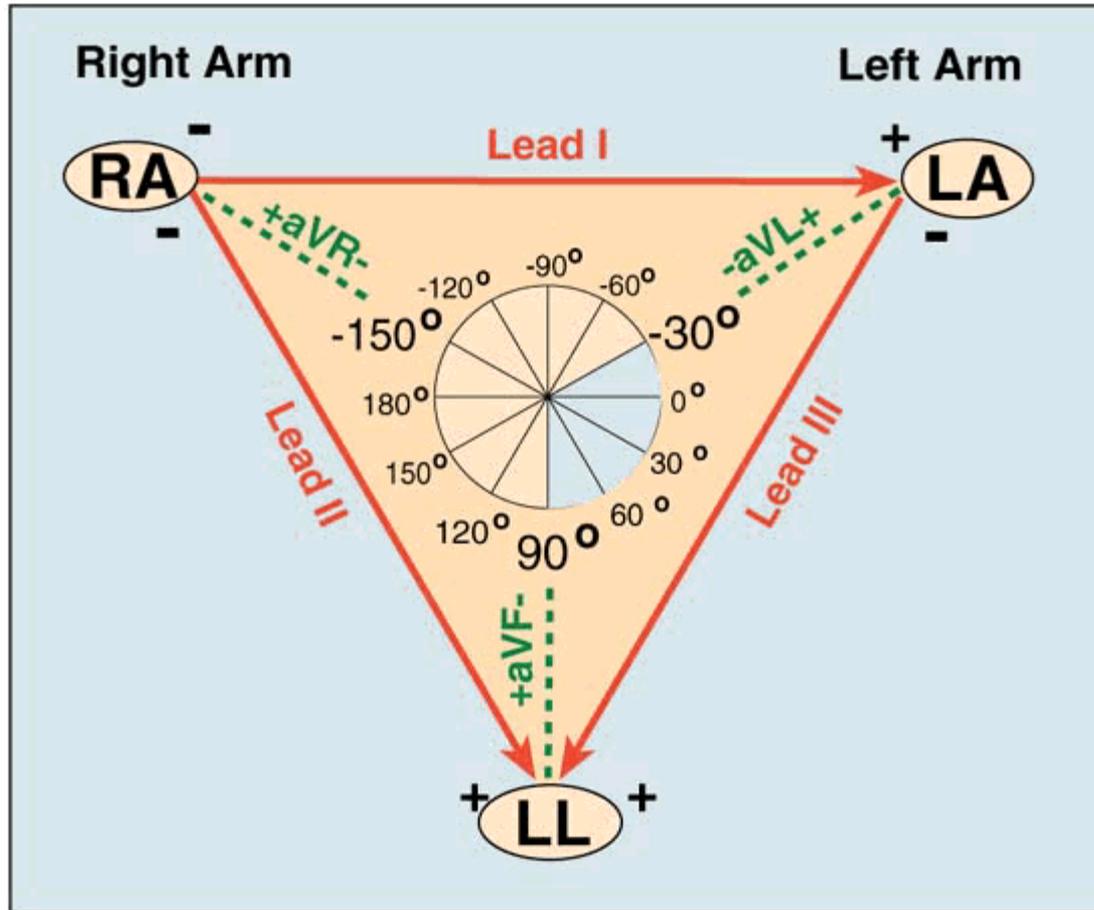
In a normal heart, the average direction of the vector during spread of the depolarization wave through the ventricles (*mean QRS vector*) is about +59 degrees.



To determine how much of the voltage in **vector A** will be recorded in lead I, a line perpendicular to the axis of lead I is drawn from the tip of vector *A* to the lead I axis → **projected vector (B)** along the lead I axis, with the arrow toward the positive end of the lead I axis, which means that the record momentarily being recorded in the electrocardiogram of lead I is positive.

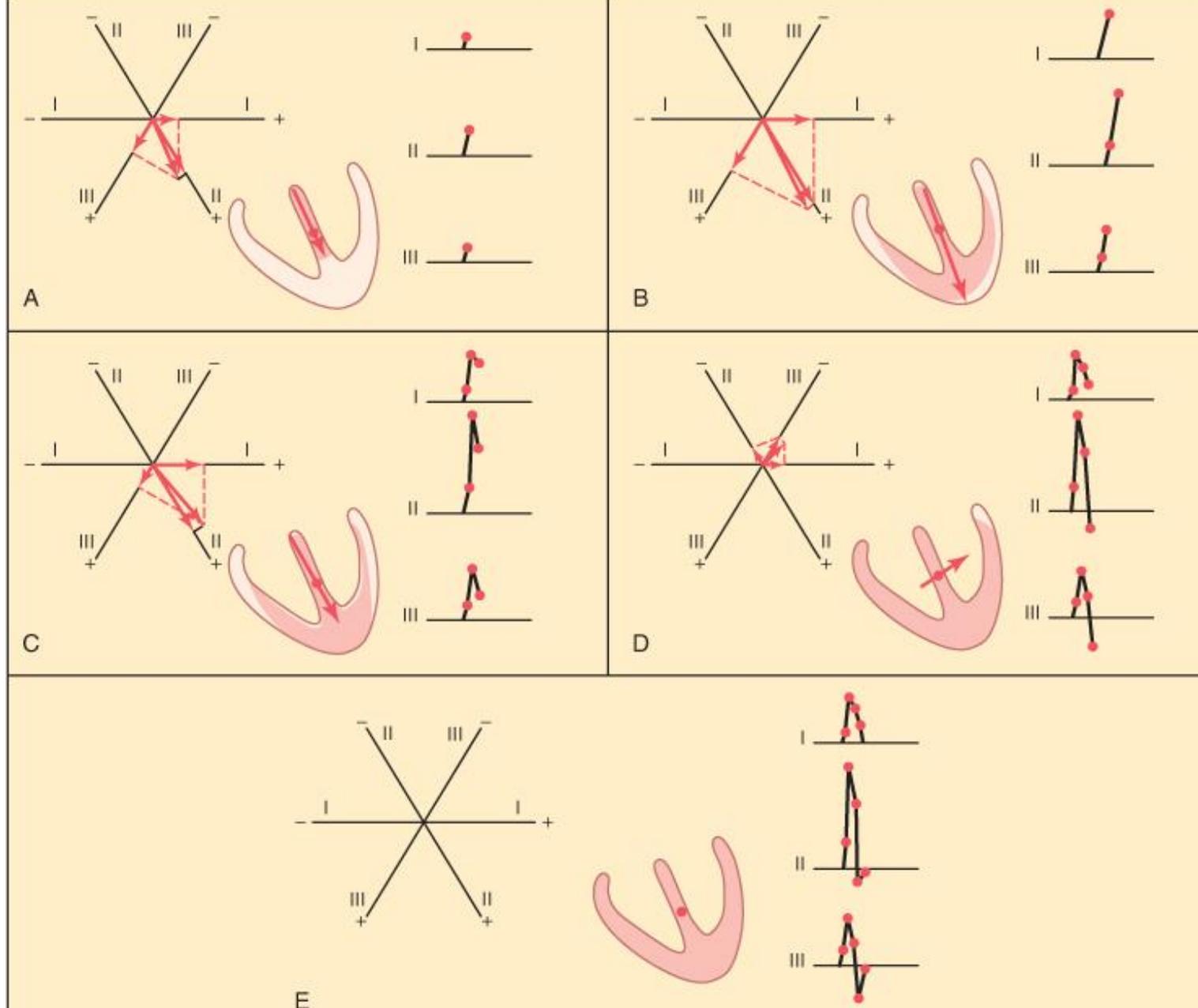
C – projected vector along the L II axis

D – projected vector along the L III axis



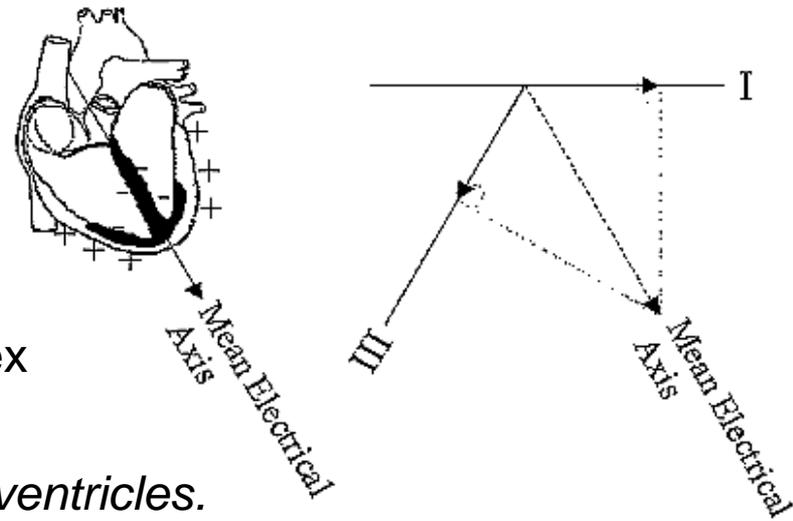
Einthoven's law:

If the three standard limb leads (I,II,III) are placed correctly, the sum of the voltages in leads I and III equals the voltage in lead II



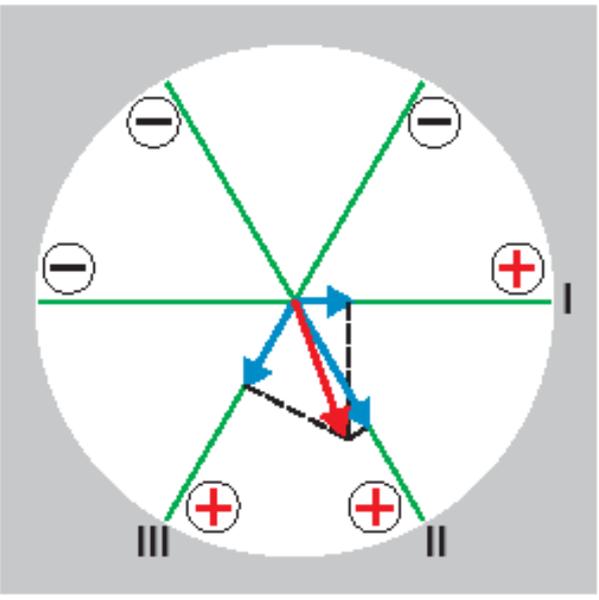
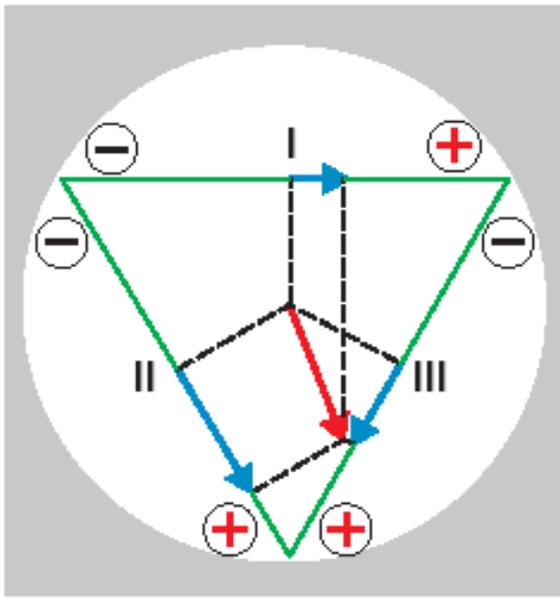
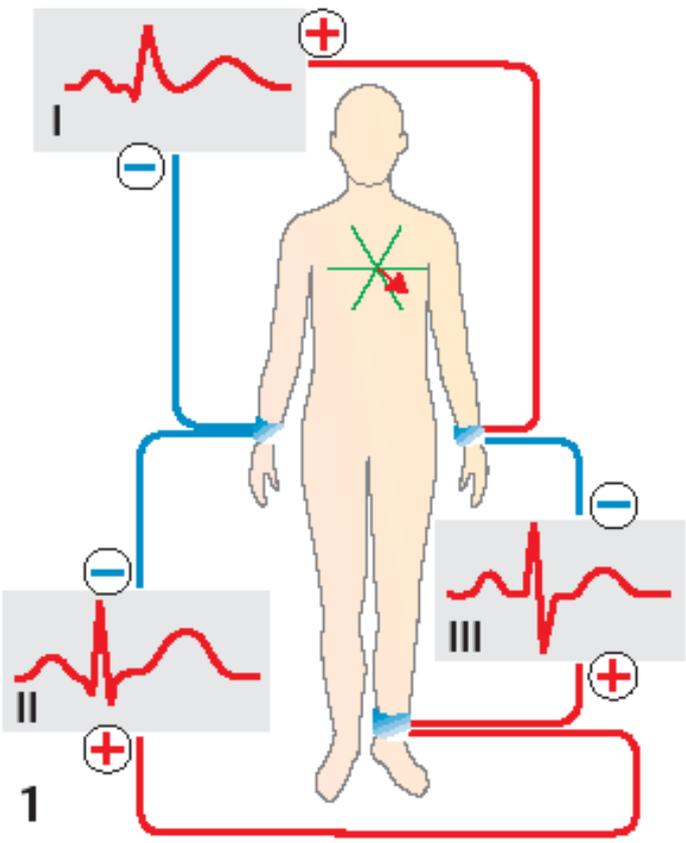
The ventricular vectors and QRS complexes: 0.01 second after onset of ventricular depolarization (A); 0.02 second after onset of depolarization (B); 0.035 second after onset of depolarization (C); 0.05 second after onset of depolarization (D); and after depolarization of the ventricles is complete, 0.06 second after onset (E).

Determining the Electrical Axis from Standard Lead ECG



- During most of the depolarization wave, the apex of the heart remains positive with respect to the base of the heart → *mean electrical axis of the ventricles*.
- In standard leads: determine the net potential and polarity of the recordings.
Net potential for a lead obtained after subtracting the negative potential from the positive part of the potential.
Then each net potential is plotted on the axes of the respective lead, with the base of the potential at the point of intersection of the axes.
- To determine the vector of the total QRS ventricular mean electrical potential, one draws perpendicular lines from the apices of two standard leads.
The point of intersection of these two perpendicular lines represents, by vectorial analysis, the apex of the **mean QRS vector** in the ventricles, and the point of intersection of the leads axes represents the negative end of the mean vector → *mean QRS vector* is drawn between these two points.
The average potential generated by the ventricles during depolarization is represented by the length of the mean QRS vector, and the mean electrical axis is represented by the direction of the mean vector.

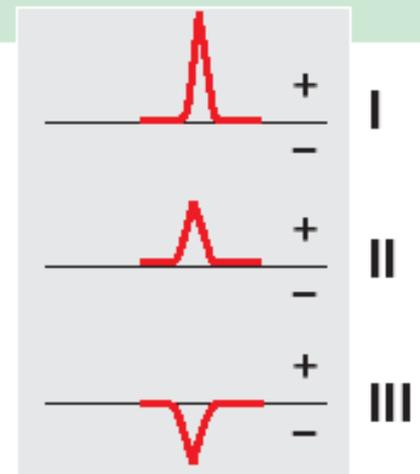
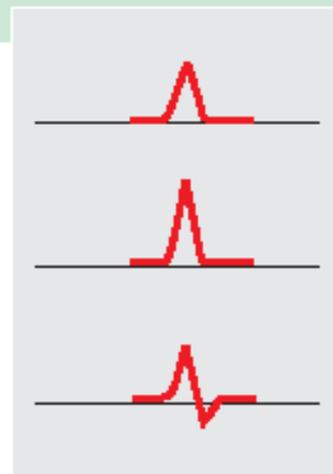
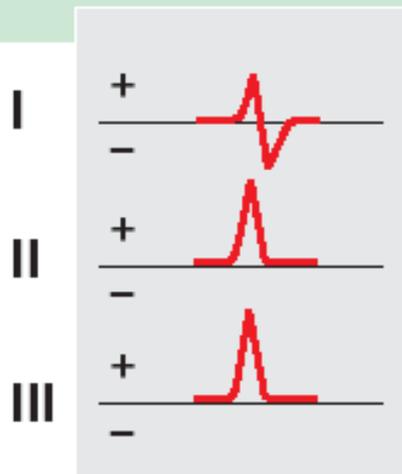
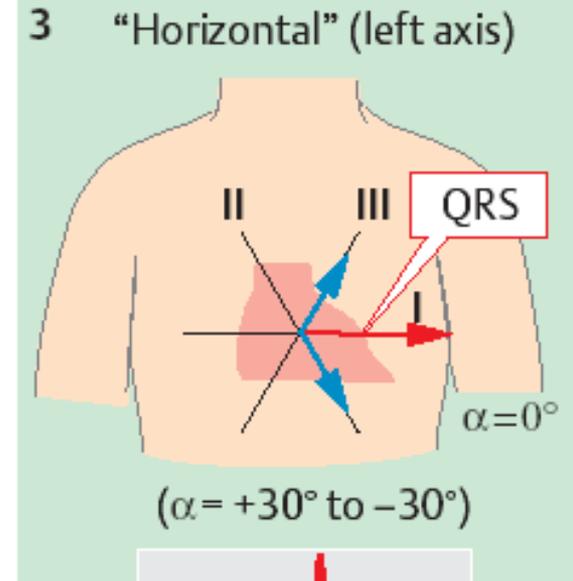
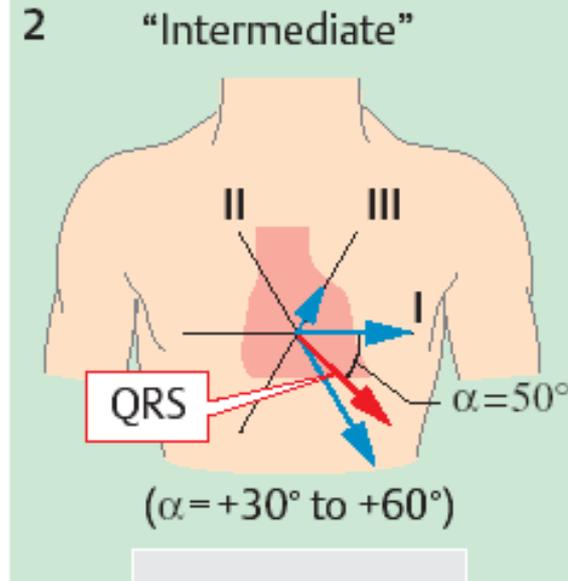
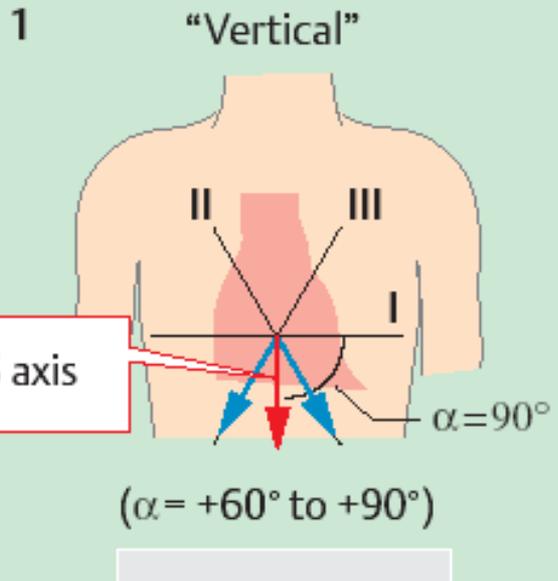
Einthoven leads I, II and III (bipolar)



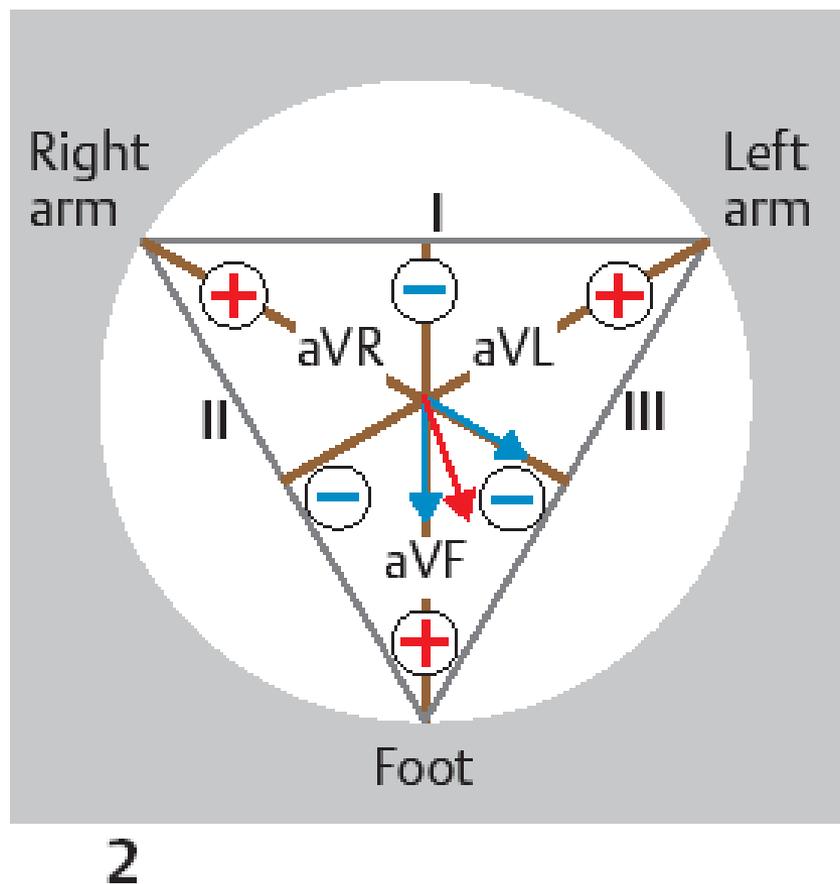
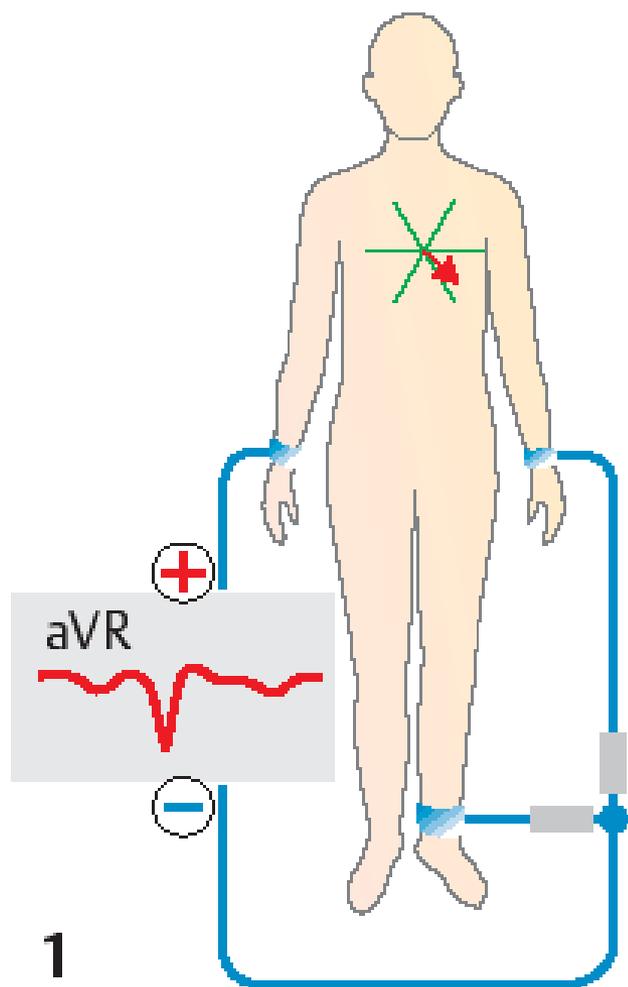
2

3

Determination of largest mean QRS vector (QRS axis) using ECG leads I–III

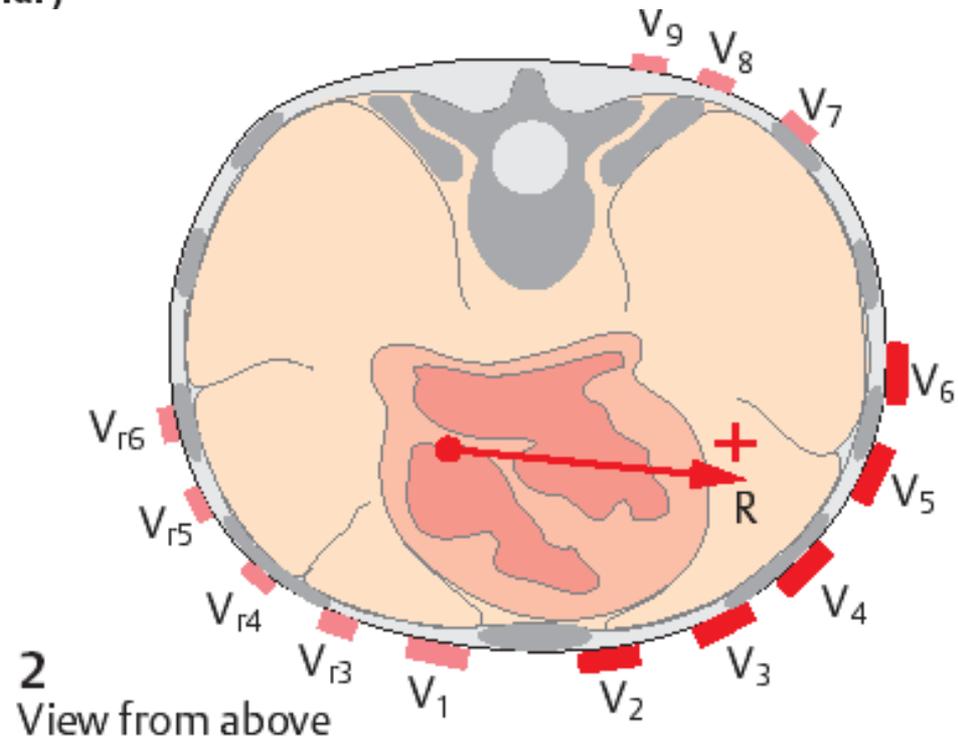
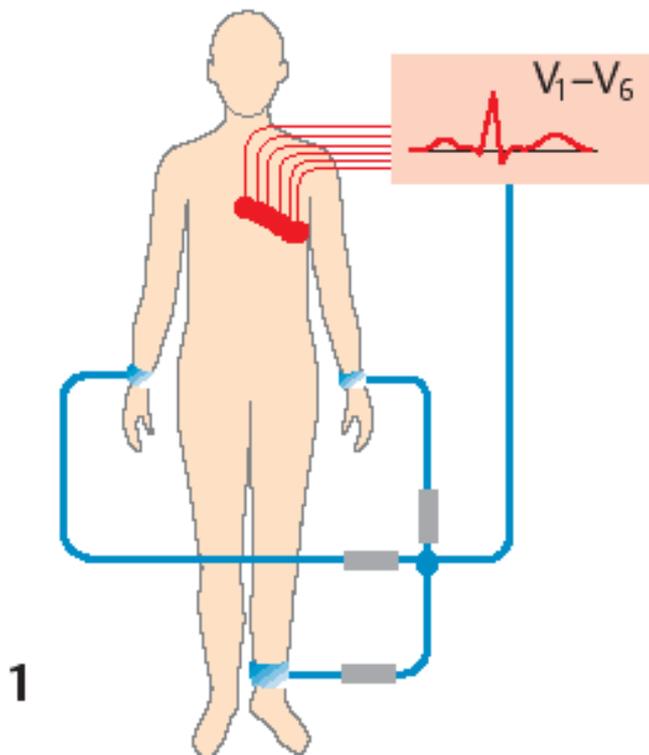


Goldberger limb leads (unipolar)

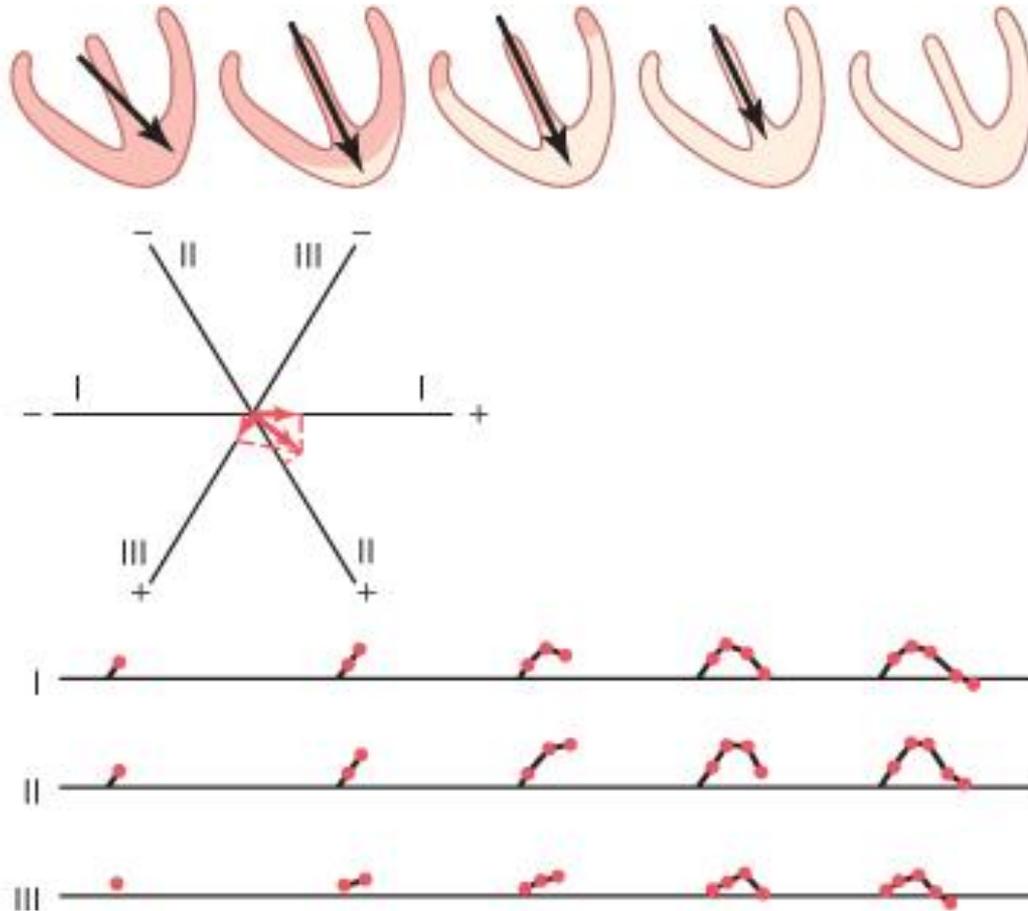


QRS axis in the horizontal plane

Wilson chest leads (unipolar)

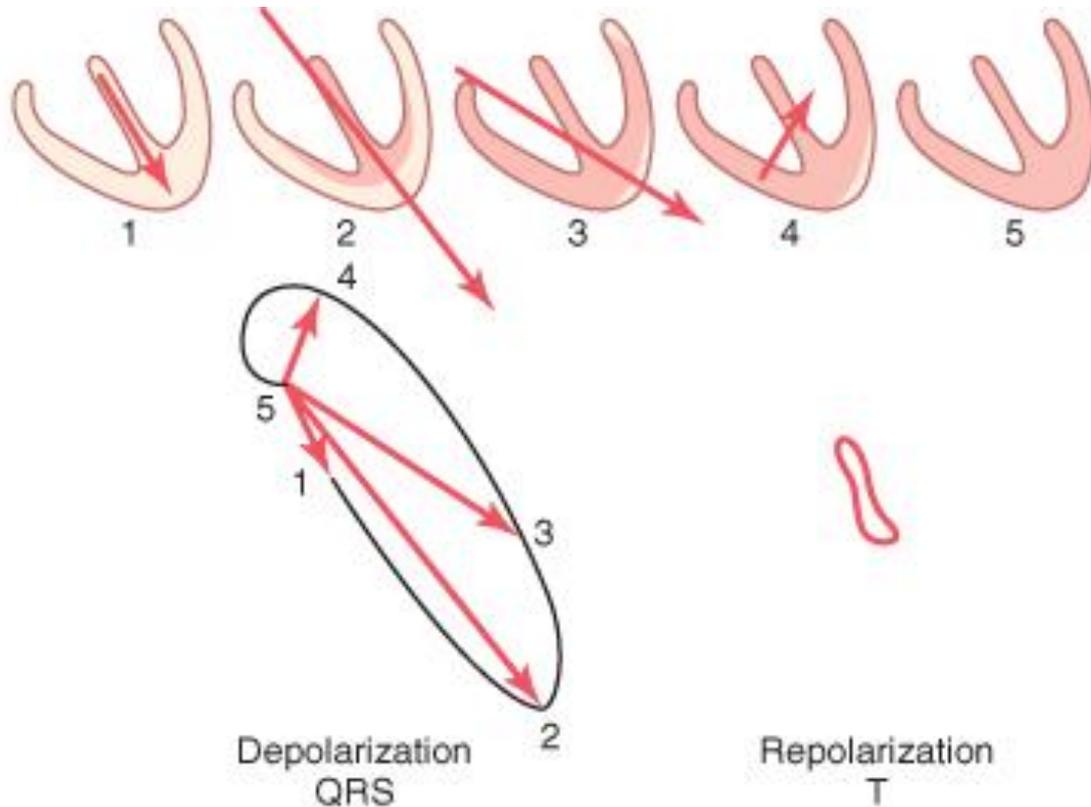


T wave axis



T wave – ventricles repolarization

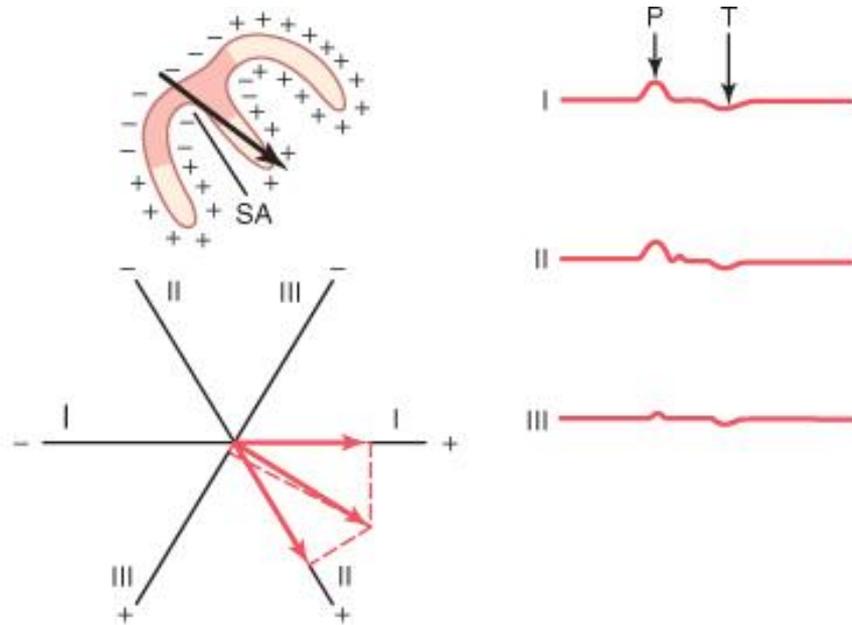
T wave duration ~ 0.15 sec.; axis: +30 , +60 degrees)



QRS and T vectorcardiograms:

- vector increases and decreases in length because of increasing and decreasing voltage of the vector.
- vector changes direction because of changes in the average direction of the electrical potential from the heart.

P wave axis



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P wave - depolarization of the atria

Spread of depolarization through the atrial muscle is *much slower than in the ventricles* (atria have no Purkinje system for fast conduction of the depolarization signal).

Repolarization begins in SA node → atrial repolarization vector is *backward to the vector of depolarization*, and it is almost always totally obscured by the large *ventricular* QRS complex.

Analysis of Normal ECG

1. **Check ECG calibration**
2. **Rhythm of the heart: "normal sinus rhythm"**
3. **Frequency (heart rate)**
4. **Electrical axis of the heart**
5. **Measurement of waves, segments, intervals**
 - the sizes of the voltage changes
 - the duration and temporal relationships of the various components
6. **Conduction analysis (PR interval, QRS duration, QT interval)**

Waves: P, QRS, T, U

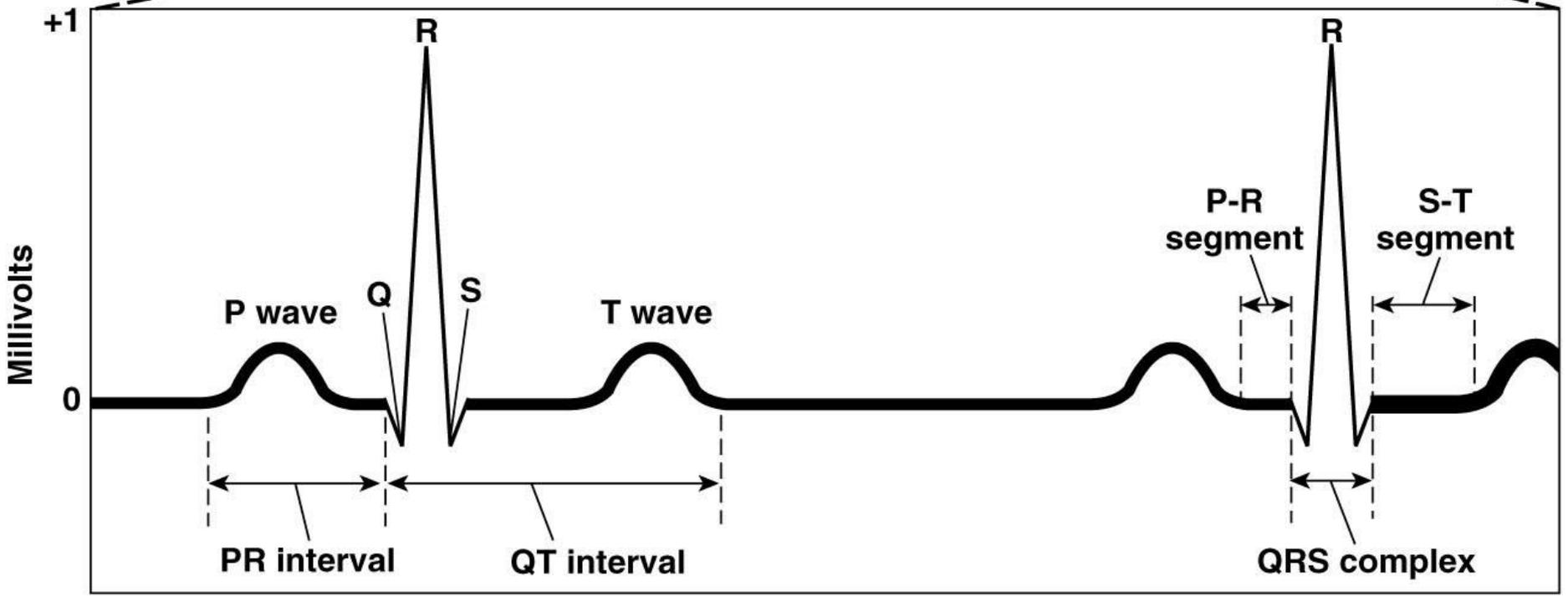
Segments – isoelectric lines on ECG:
no potentials are recorded when the
ventricular muscle is either completely
polarized or completely depolarized.

PQ(R), ST, TP

Intervals – segments + waves

PQ(R), ST, QT

5. ECG Measurement of waves, segments, intervals

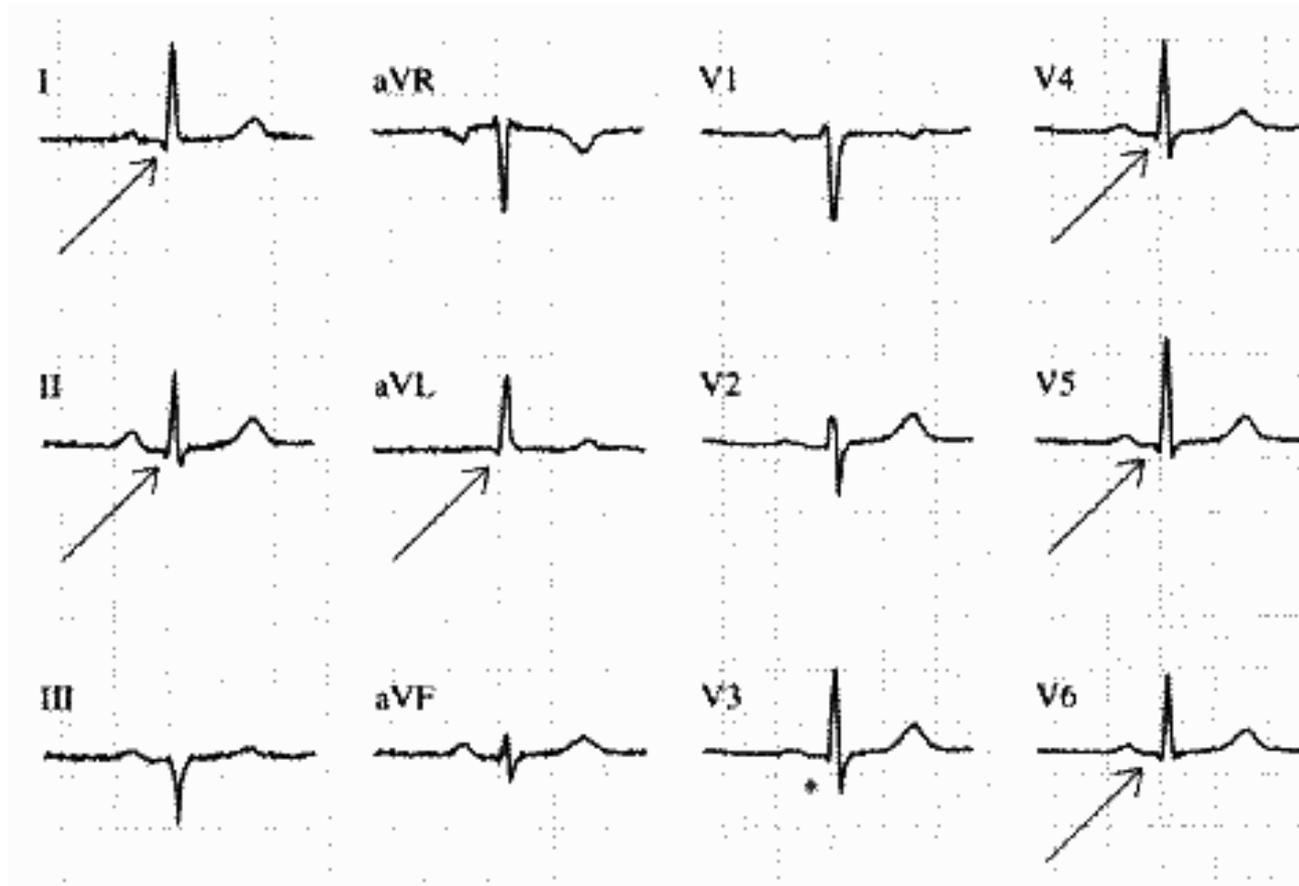


P wave: atrial depolarization wave

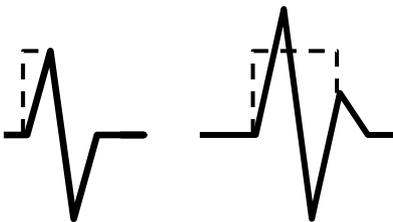
- amplitude < 2.5 mm in lead II
- duration < 0.11 s in lead II
- axis: between 0 – +75 (+45 and +60) degrees
- morphology: rounded, symmetrical, usually positive wave, except aVR
- abnormal P waves: right atrial hypertrophy, left atrial hypertrophy...

QRS

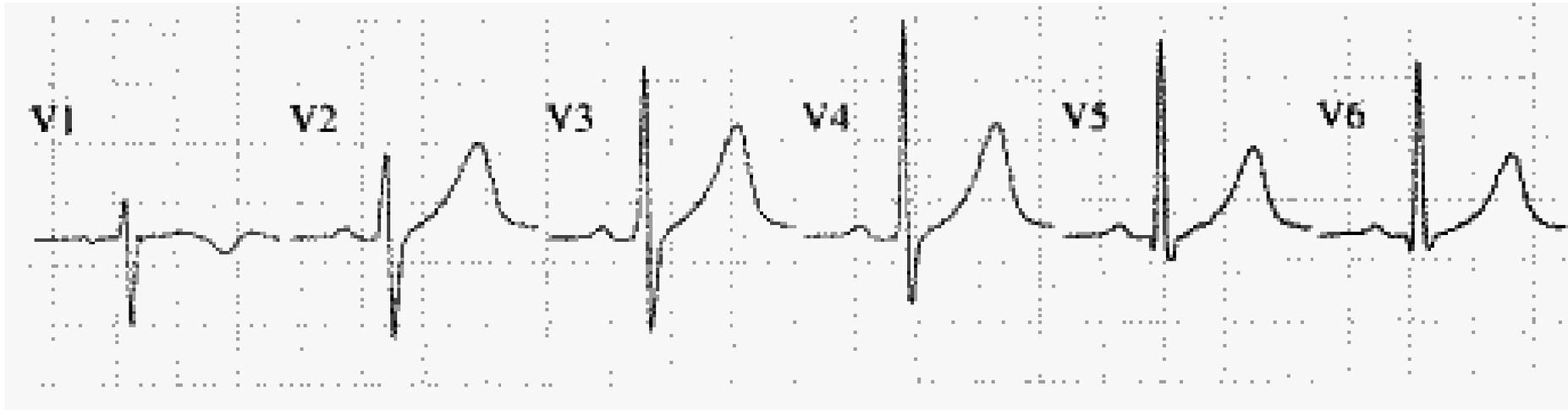
- Ventricular depolarization wave
- QRS ~ 0.06 - 0.10 s
- q < 0.04s, < 25% R, reflects normal septal activation in the lateral leads (I, aVL, V5, V6).



Intrinscoid Deflection in precordial leads

- definition: 

- up to 0,02 sec for V1,2
- up to 0,05 sec for V4-6



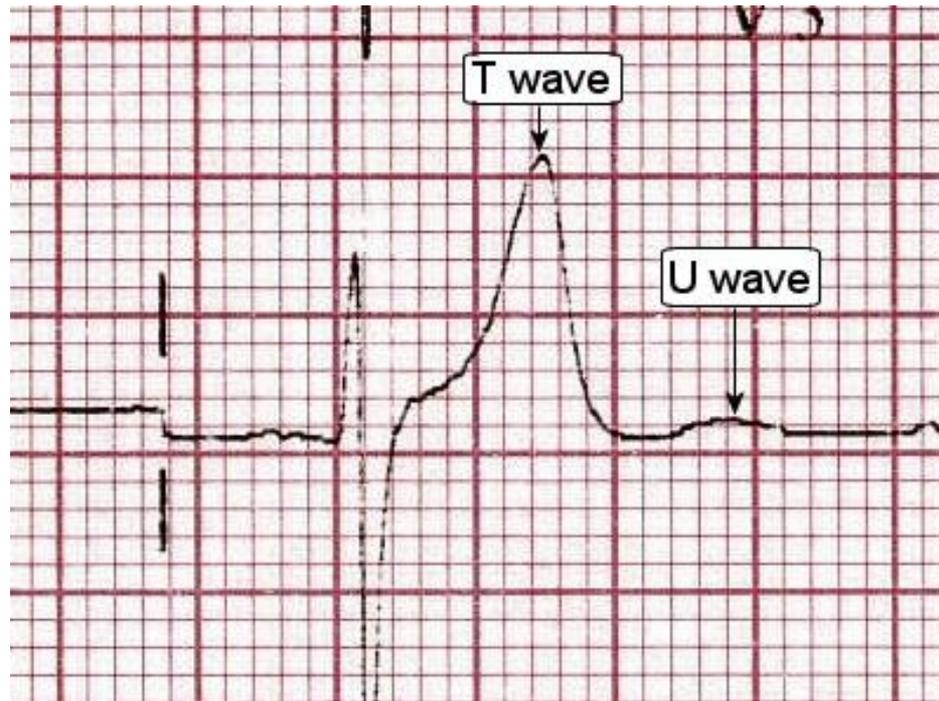
T wave: ventricular repolarization

- amplitude:
 - ~ $\frac{1}{3}$ R, but it is considered normal within the $\frac{1}{4}$ R – $\frac{1}{2}$ R interval
- duration ~ 0.15 s
- axis: +30 - +60 degrees
- morphology: rounded, asymmetrical wave.



Wave U

- Amplitude usually $< 1/3$ T wave amplitude in same lead
- direction - the same as T wave direction in the same lead
- more prominent at slow HR, best seen in the right precordial leads.
- origin of the U wave
 - related to afterdepolarizations which interrupt or follow repolarization
 - also possible due to delayed repolarization of papillary muscles



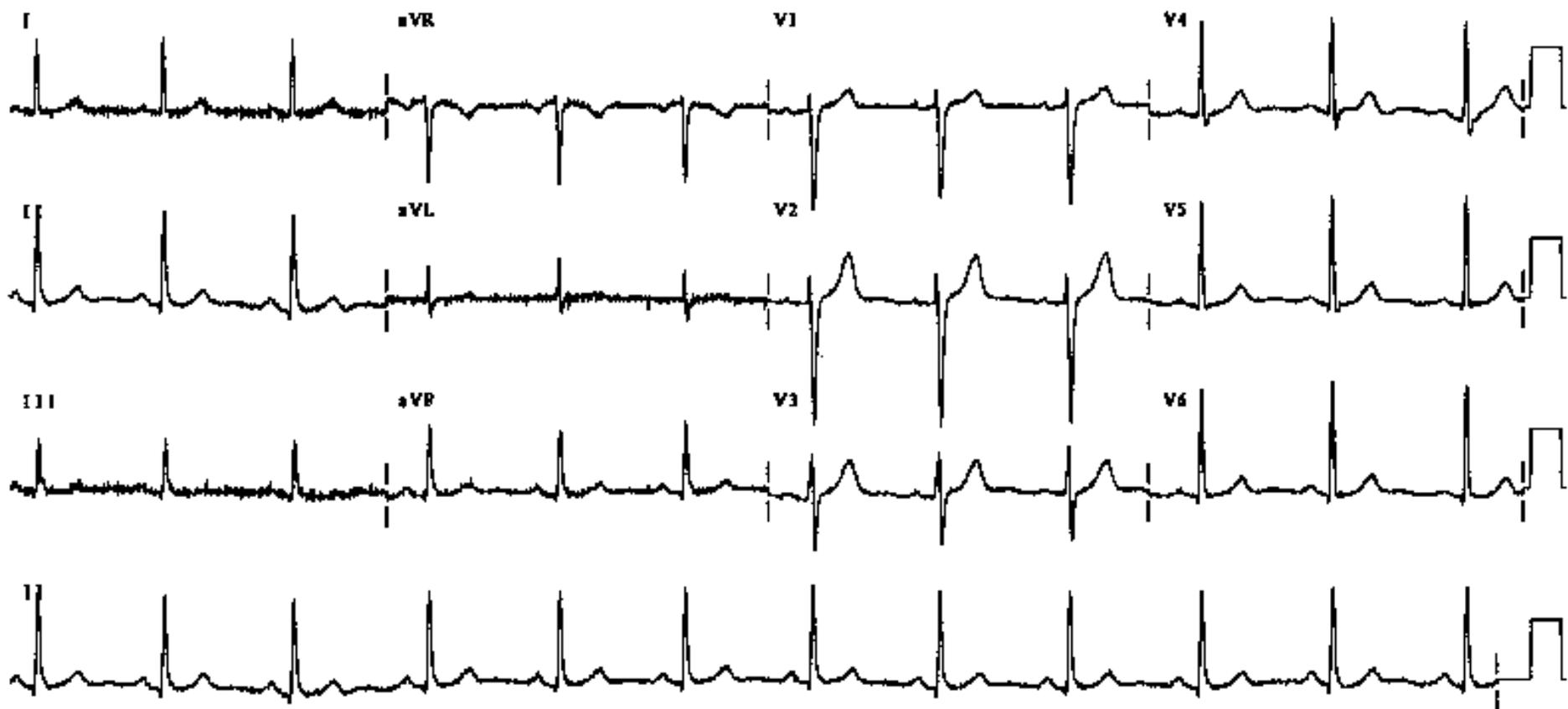
Analysis of Normal ECG

1. **Check ECG calibration**
2. **Rhythm of the heart: "normal sinus rhythm"**
3. **Frequency (heart rate)**
4. **Electrical axis of the heart**
5. **Measurement of waves, segments, intervals**
 - the sizes of the voltage changes
 - the duration and temporal relationships of the various components
6. **Conduction analysis (PR interval, QRS duration, QT interval)**

Conduction Analysis

"Normal" conduction implies normal sino-atrial (SA), atrio-ventricular (AV), and intraventricular (IV) conduction:

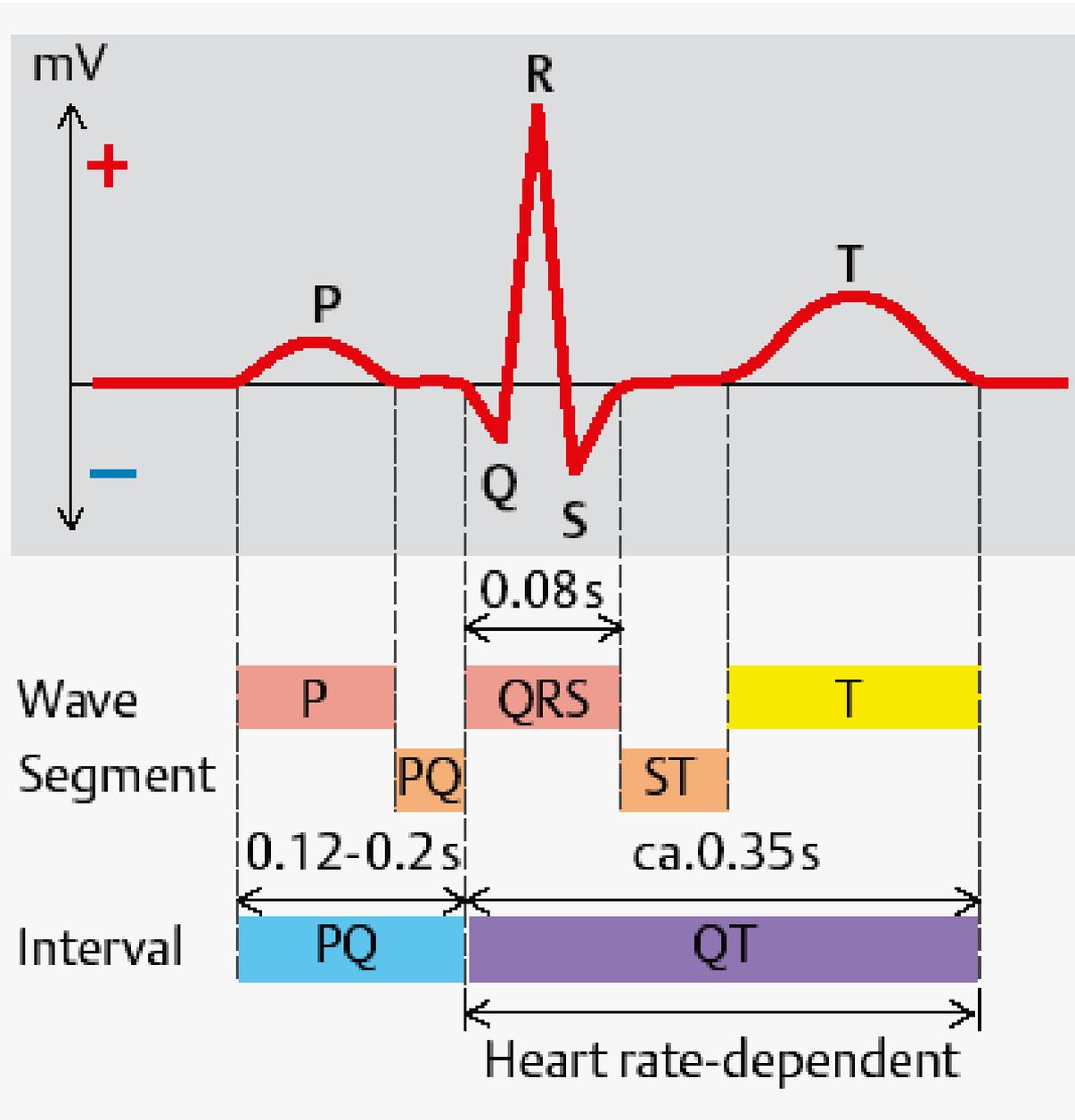
- PR interval = 0.12 - 0.20 s
- QRS complex \sim 0.06 – 0.1 s
- QT interval \sim 45% RR
0.33 s – 0.46 s
depends on HR

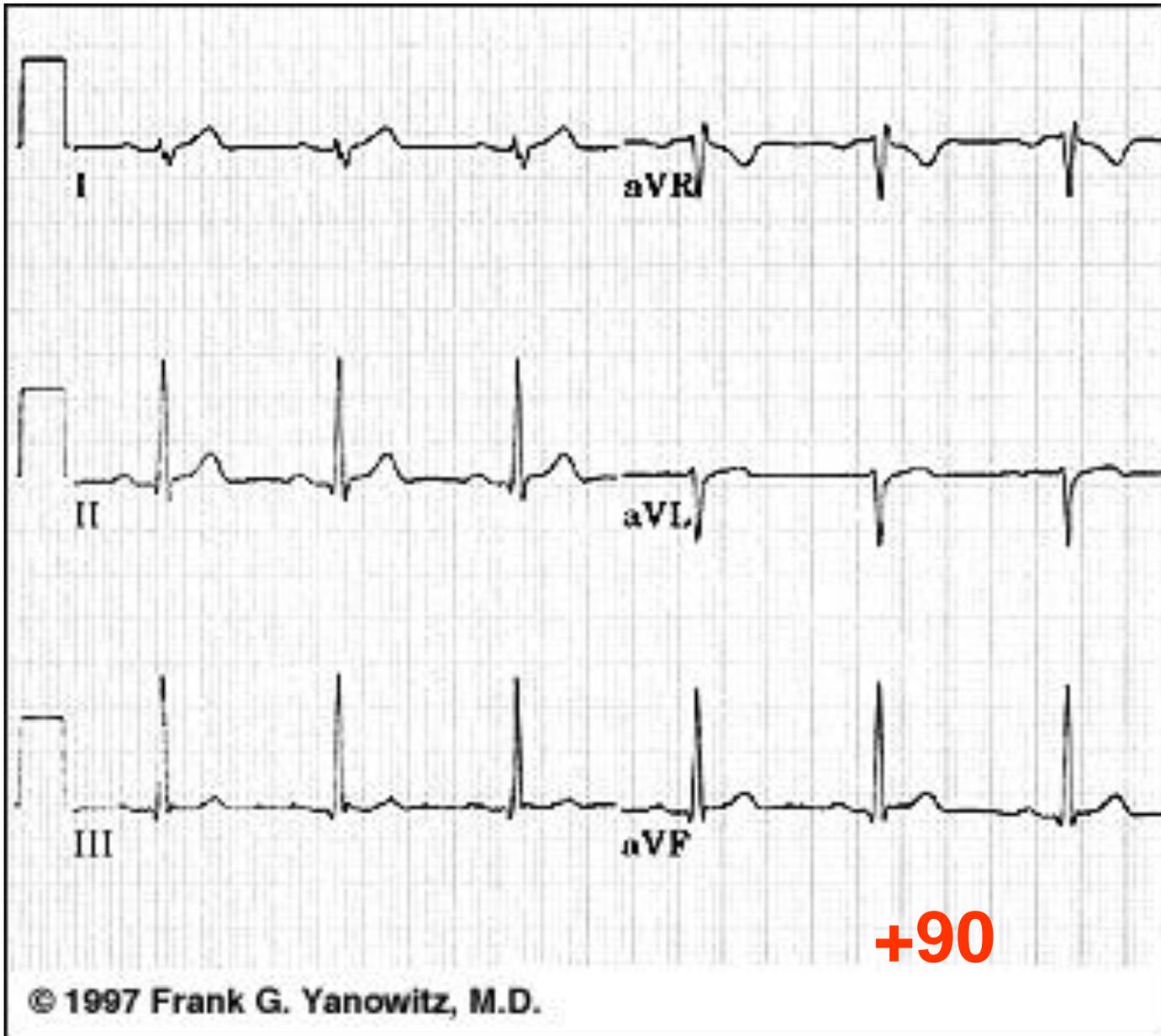


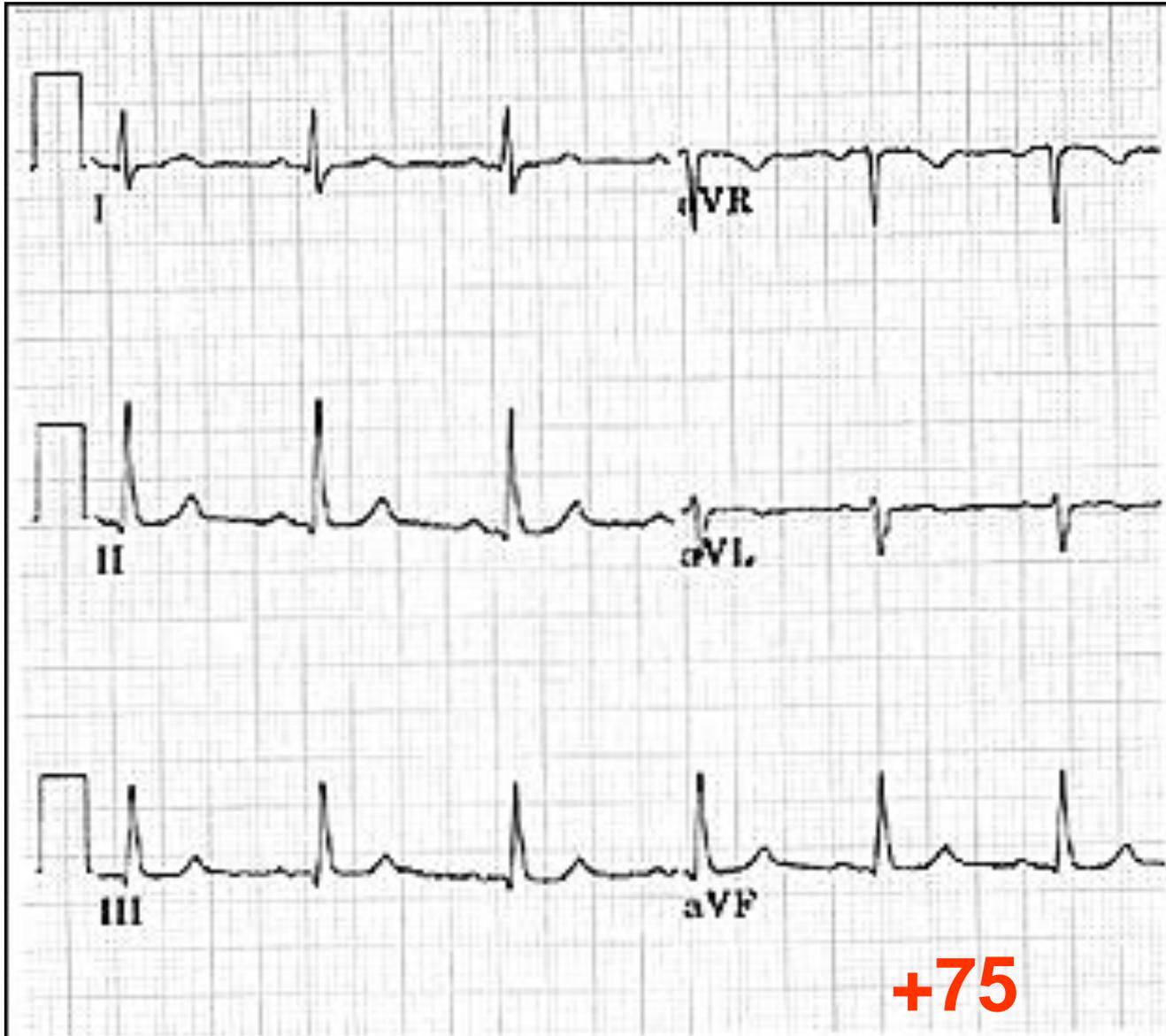
LOC 0000-0000 Speed: 25 mm/sec Limb: 10 mV Chest: 10 mm/mV

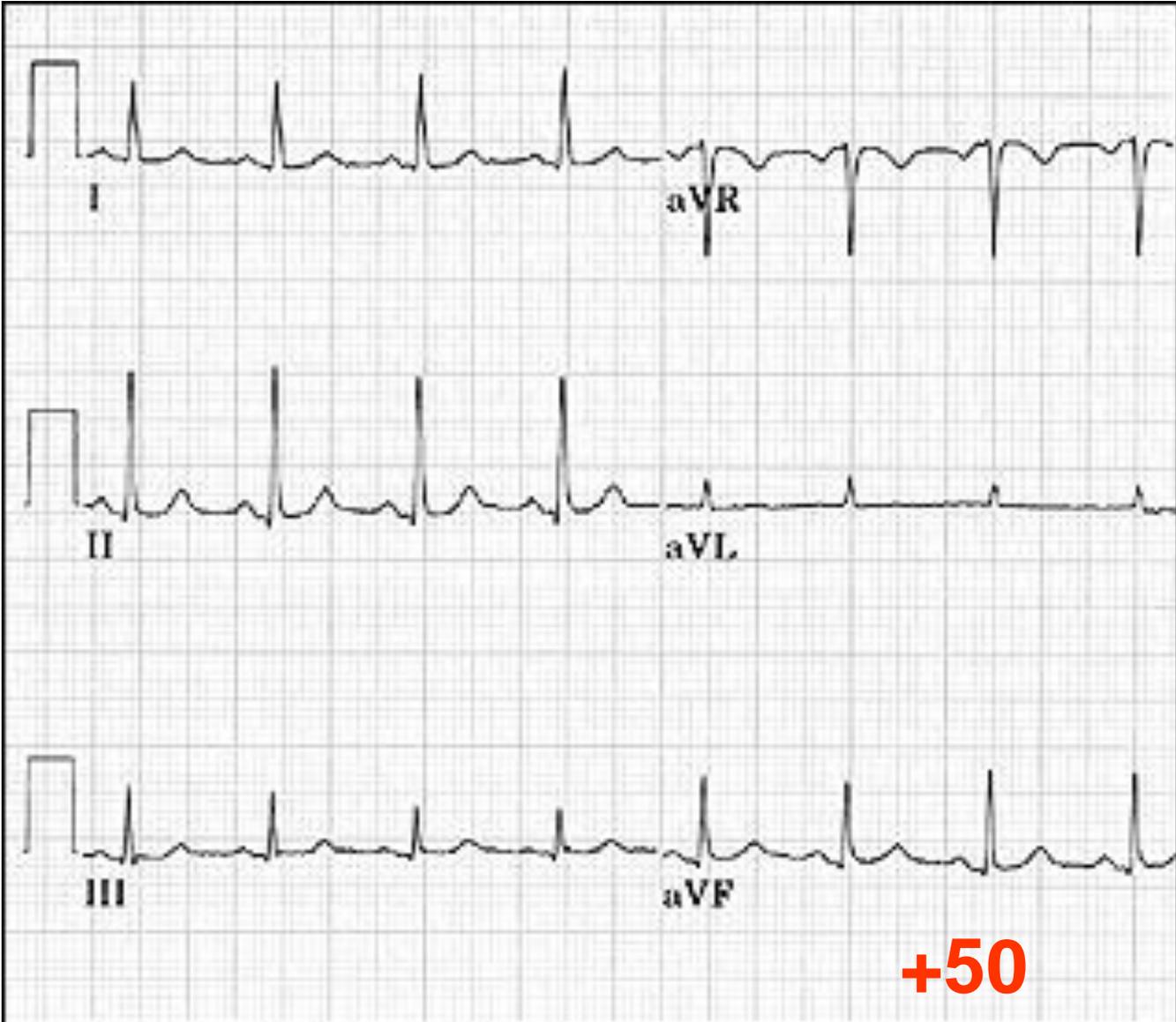
50% 0.15-150 Hz

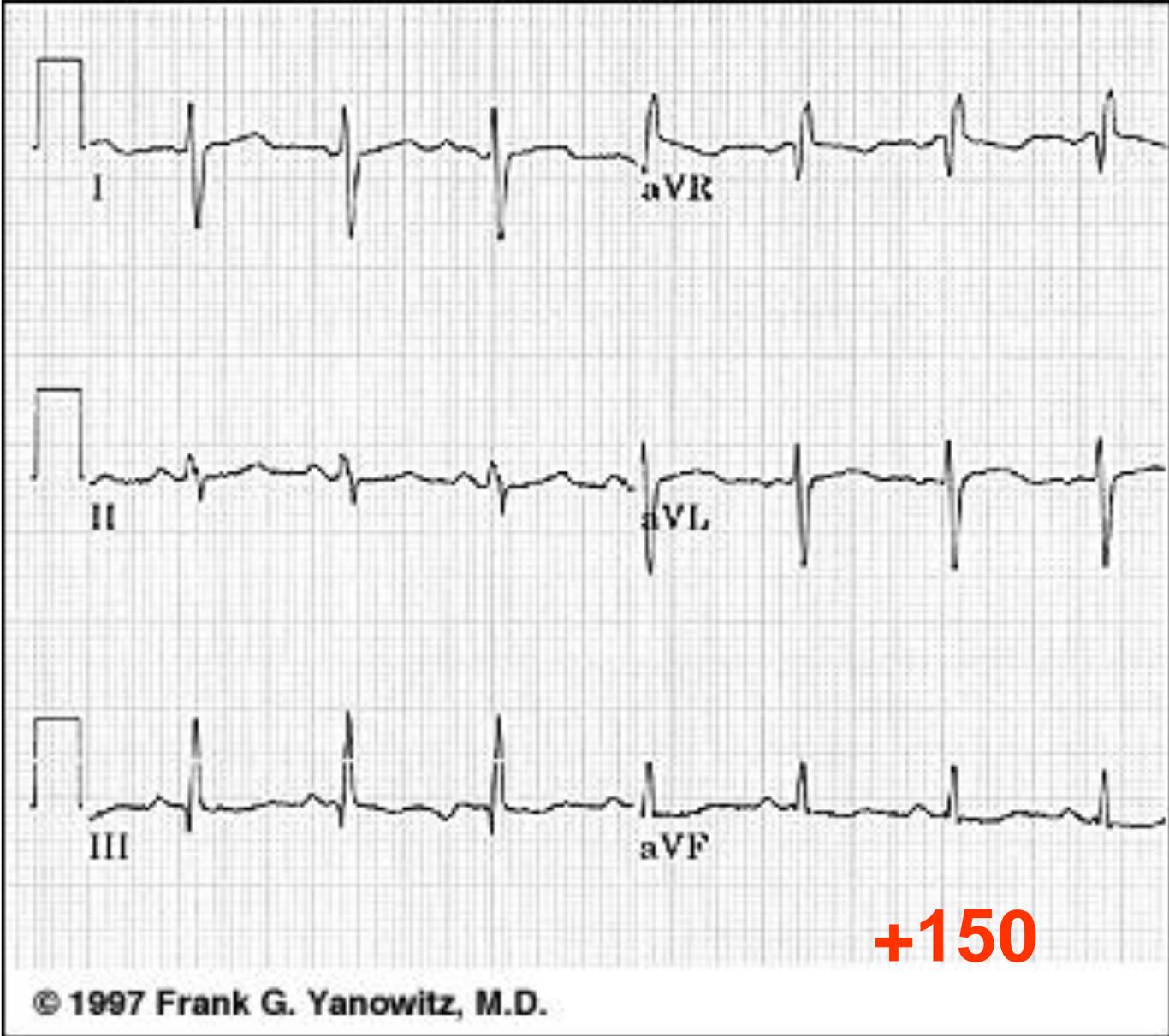
16405



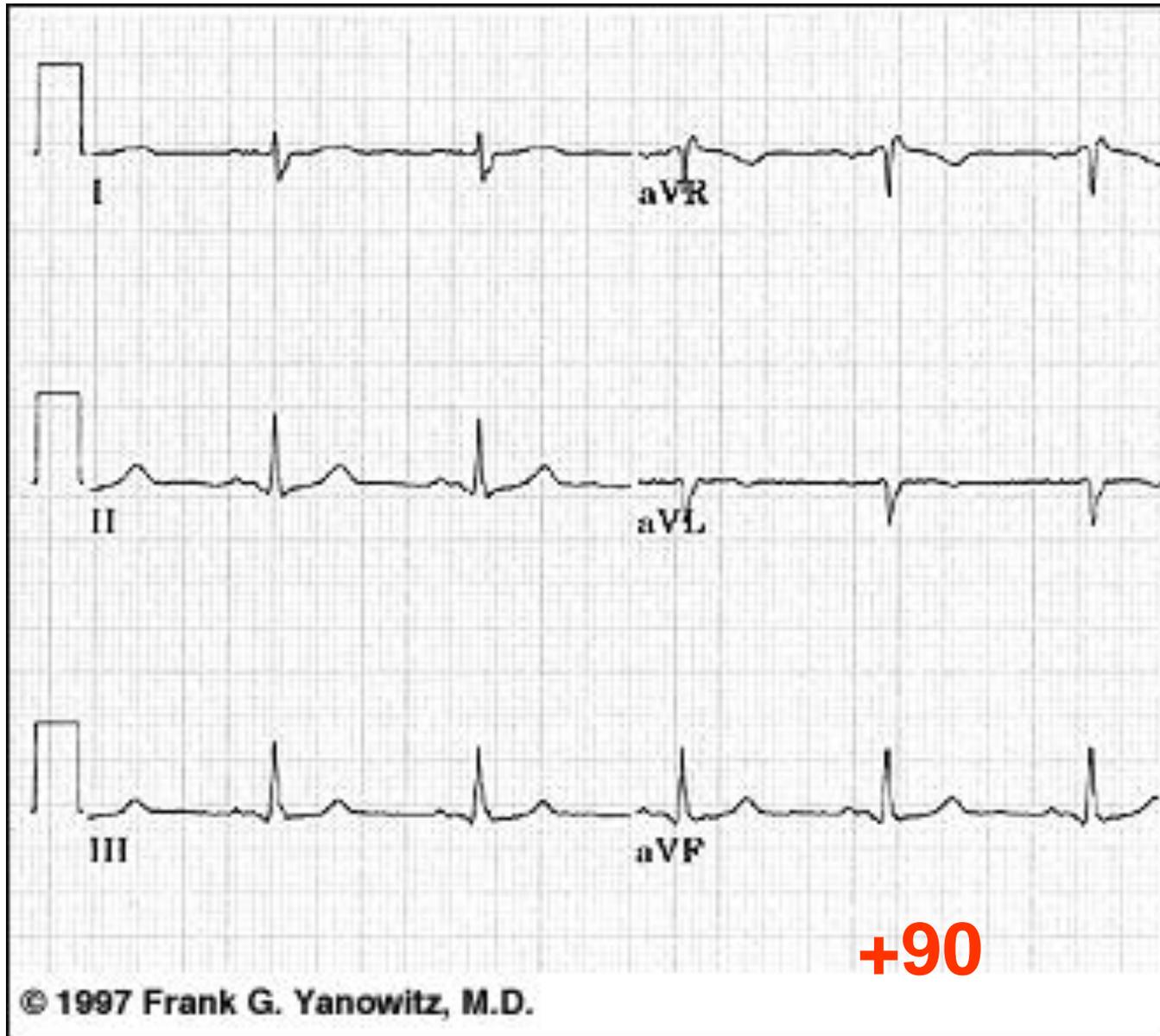


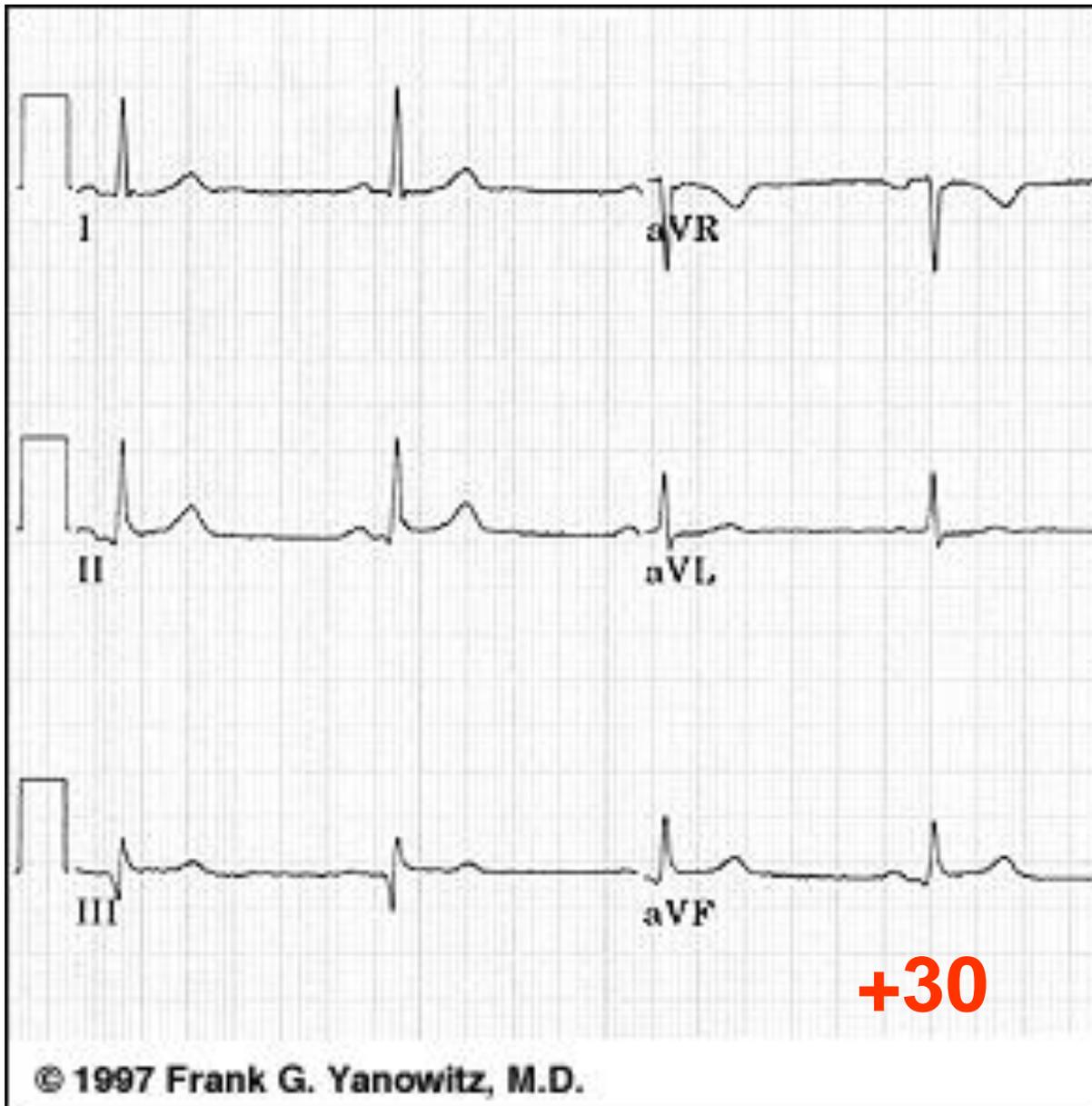


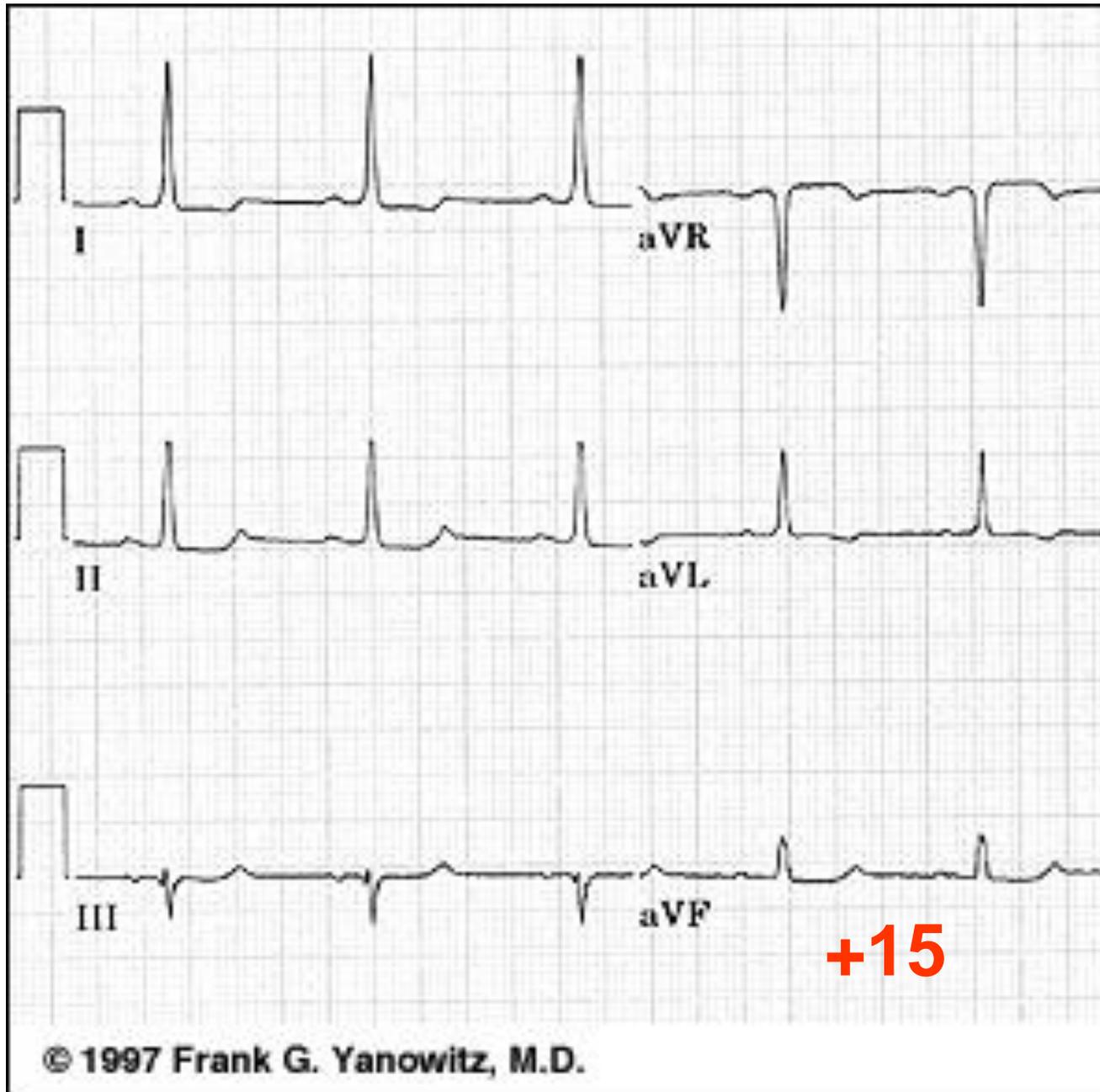


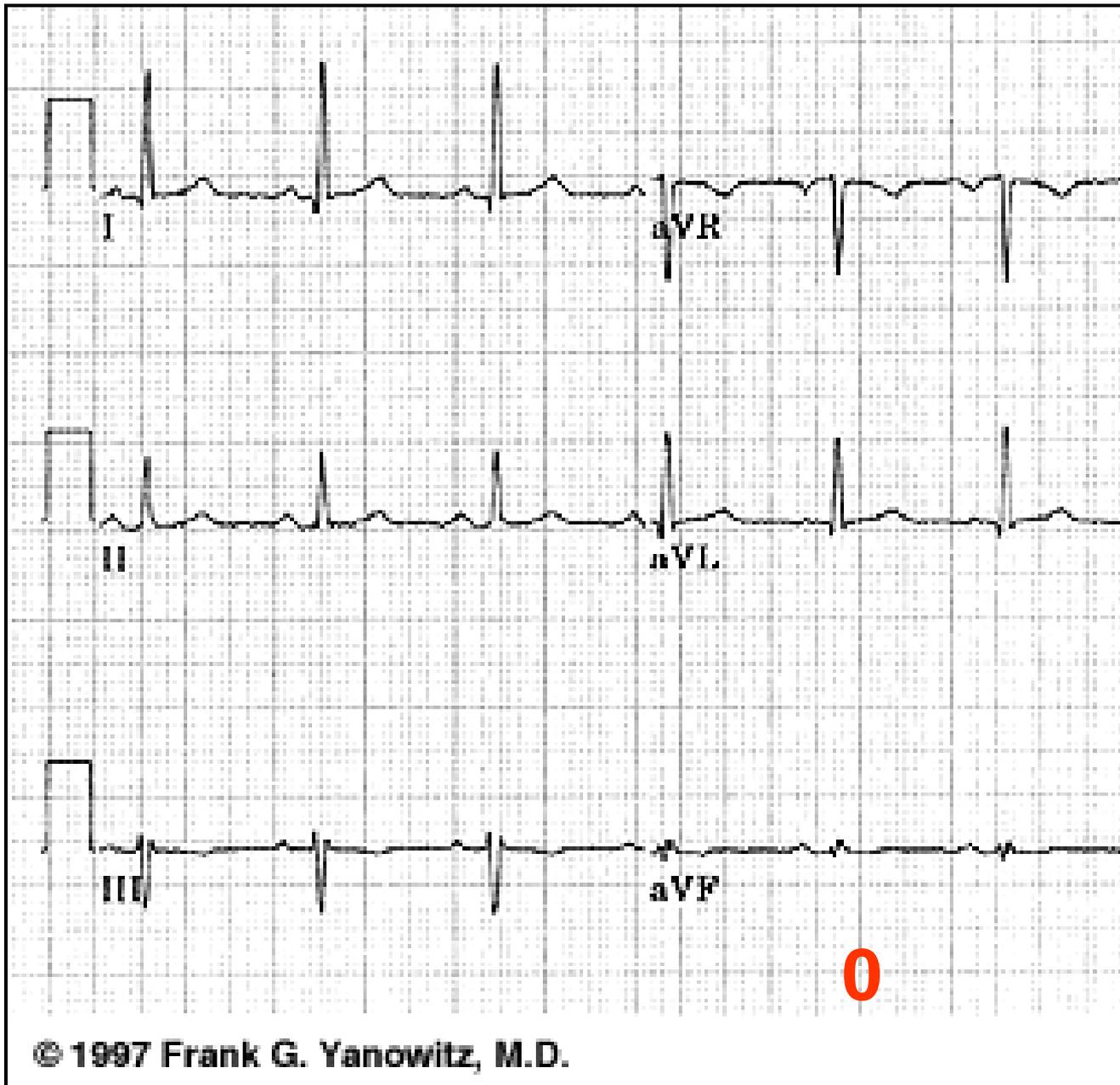


+150

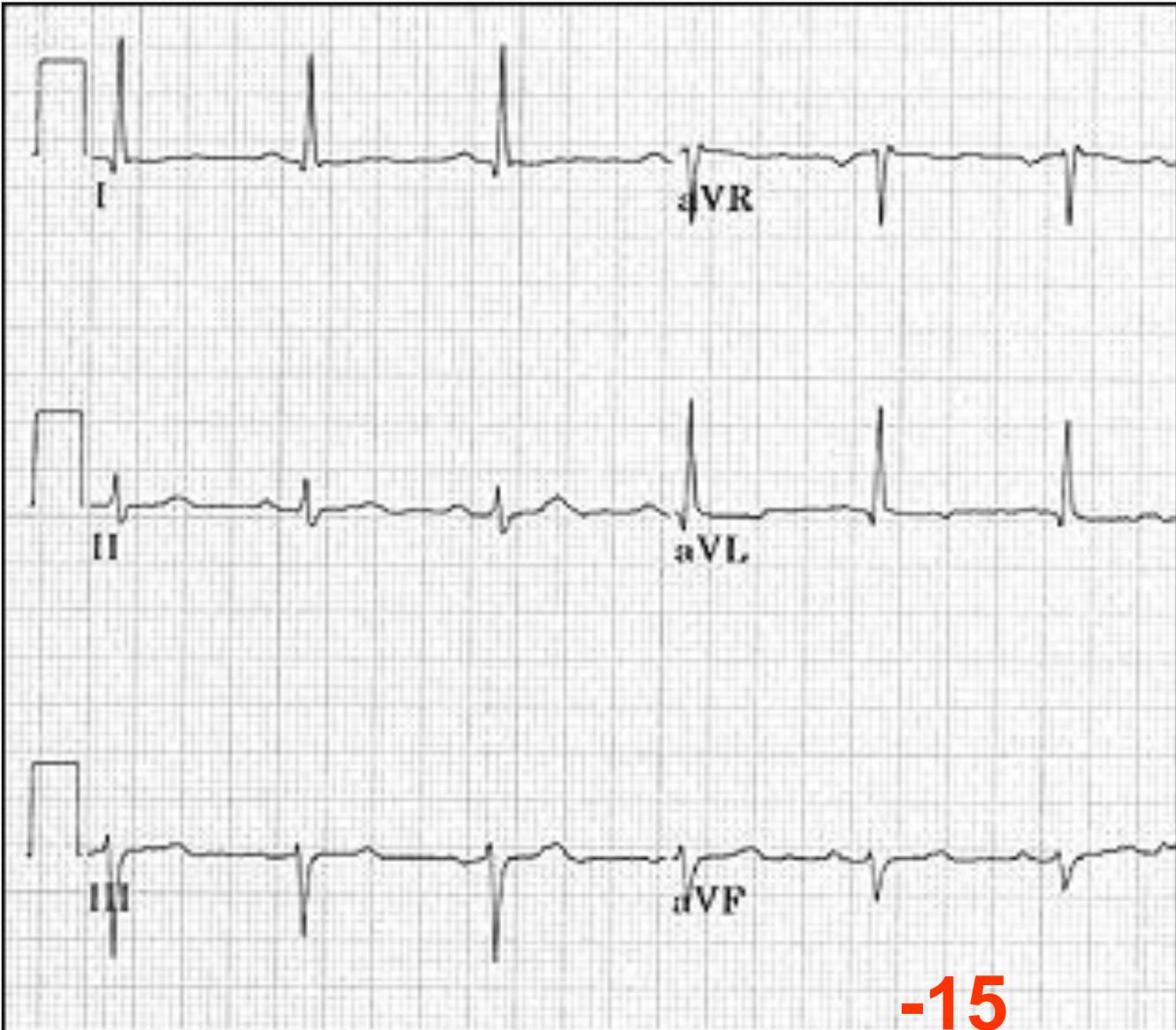




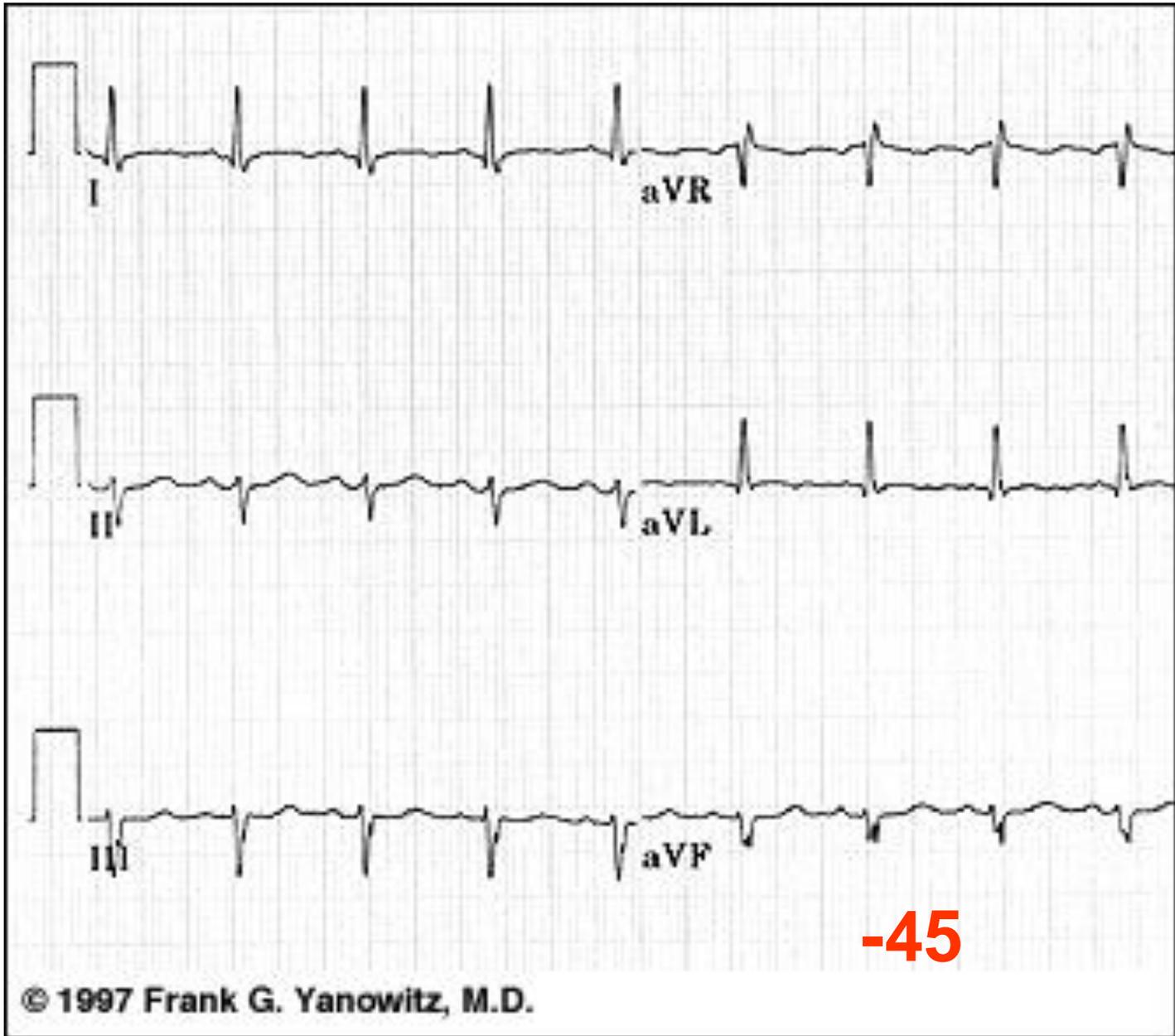


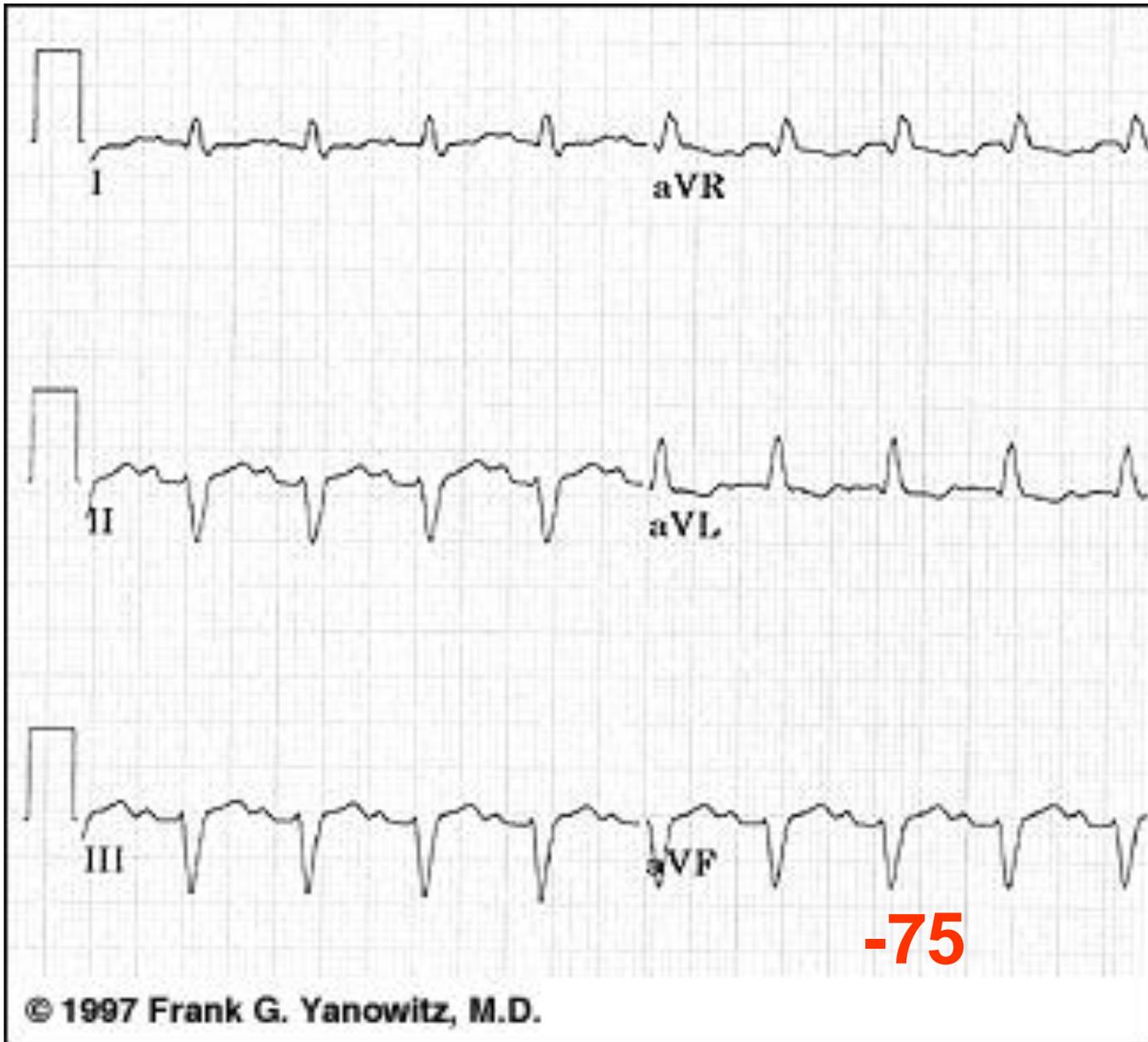


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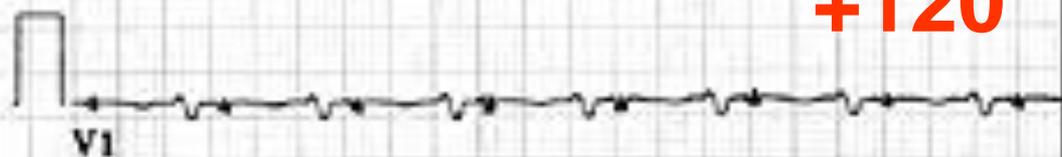
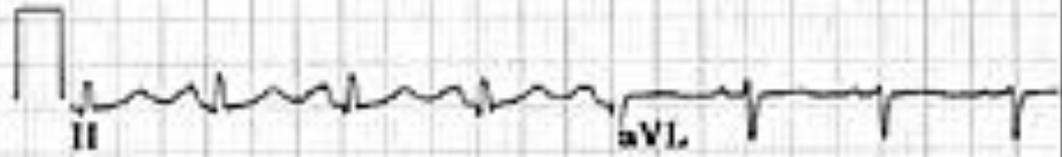
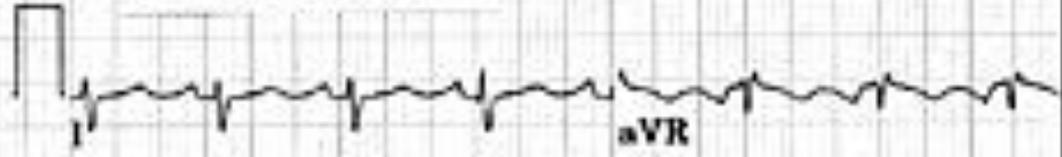


-15

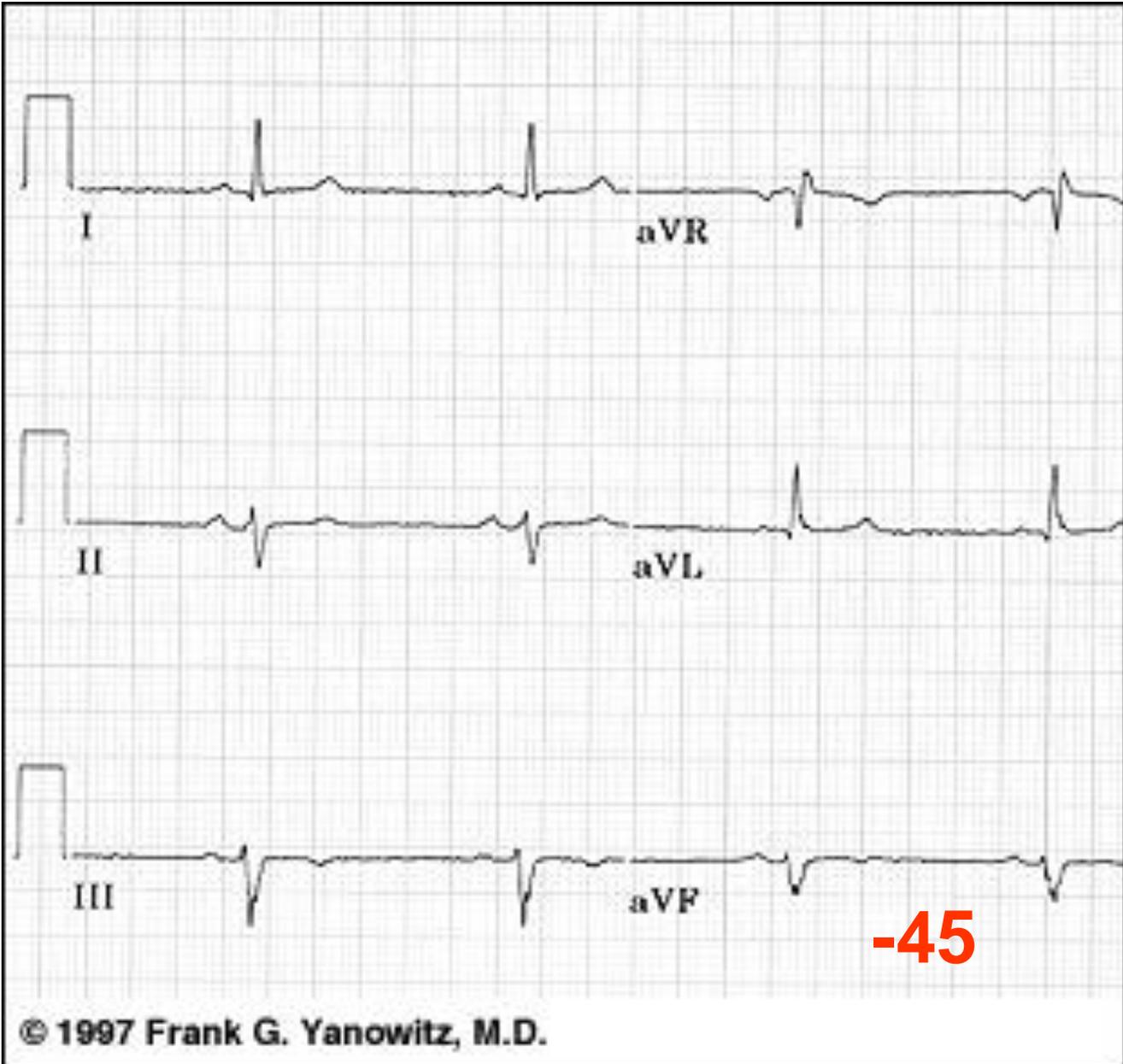


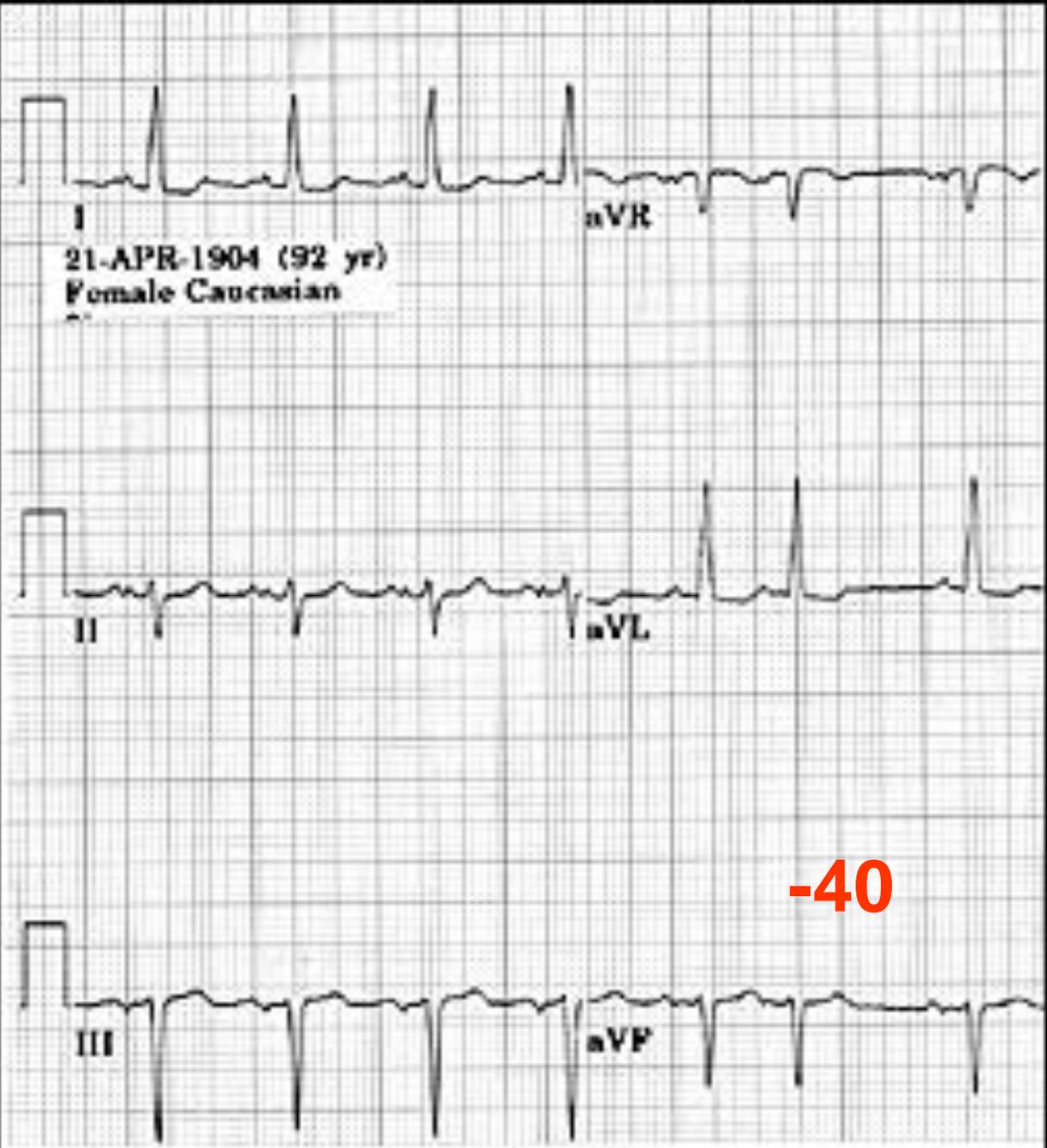


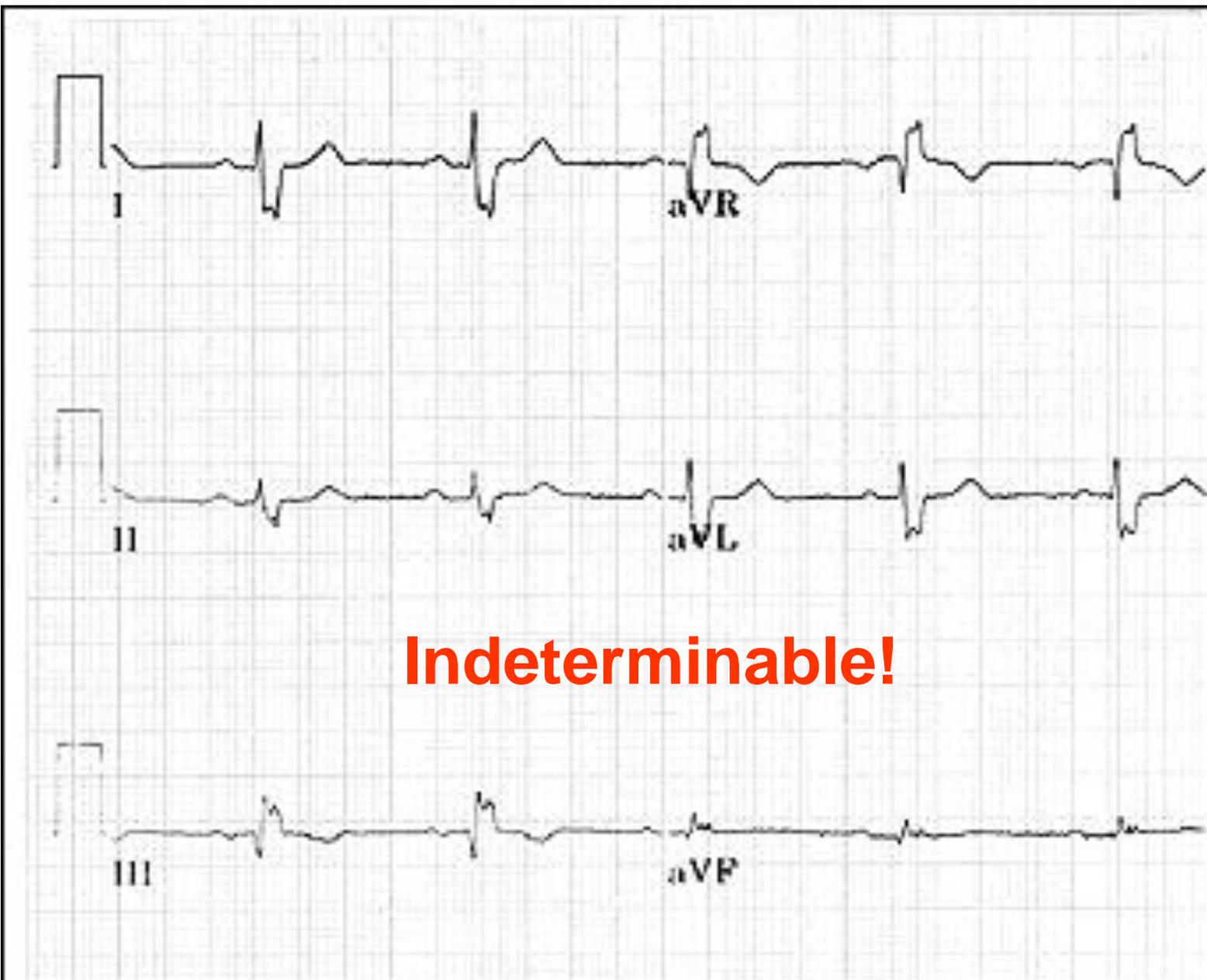
10-NOV-1919 (78 yr)
Female Caucasian



+120







Indeterminable!

Pathologic ECG

Vector analysis - Axis determination

- Normal axis

- Left axis deviation

- Right axis deviation

Abnormal Voltages of the QRS complex

- Increased voltage (att to electrode location)

- Decreased voltage

- Prolonged QRS

Cardiac rhythms

- Tachycardia

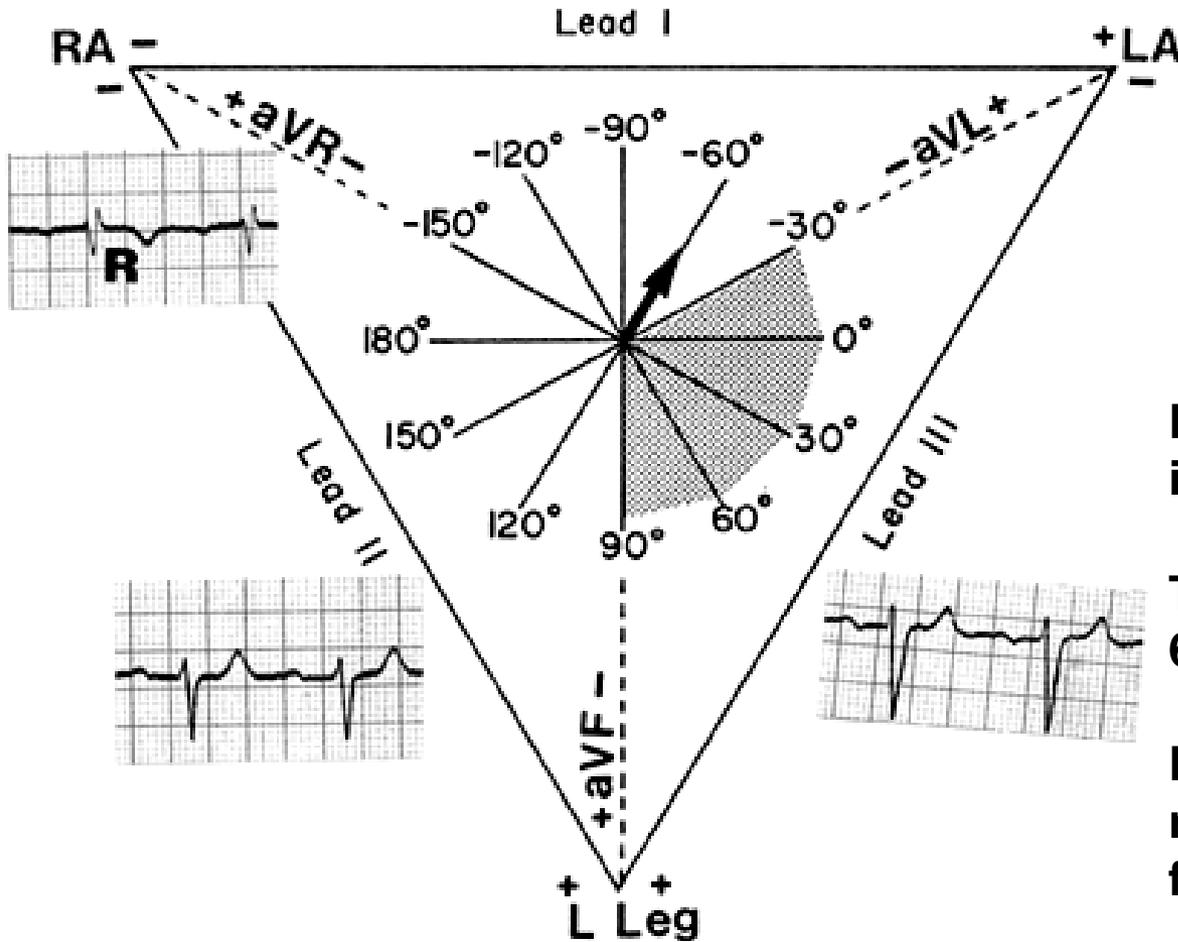
- Bradycardia

- Sinus arrhythmia

Deviation of the electric axis

- to the **right** = increased electric activity in the RV due to increased RV mass (e.g. severe pulmonary hypertension).
- to the **left** = increased electric activity in the LV due to increased LV mass (e.g. hypertension, aortic stenosis, etc.).

Axis in the left axis deviation (LAD) range



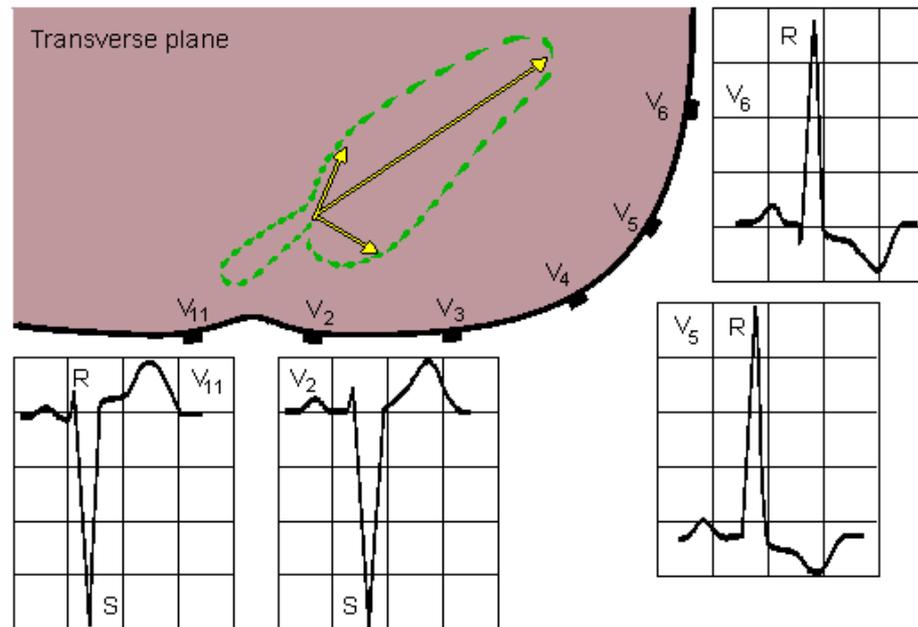
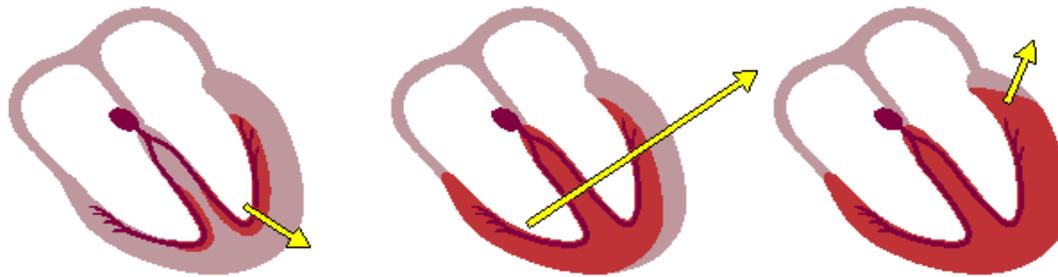
Lead aVR is the smallest and isoelectric lead.

The two perpendiculars are -60° and +120°.

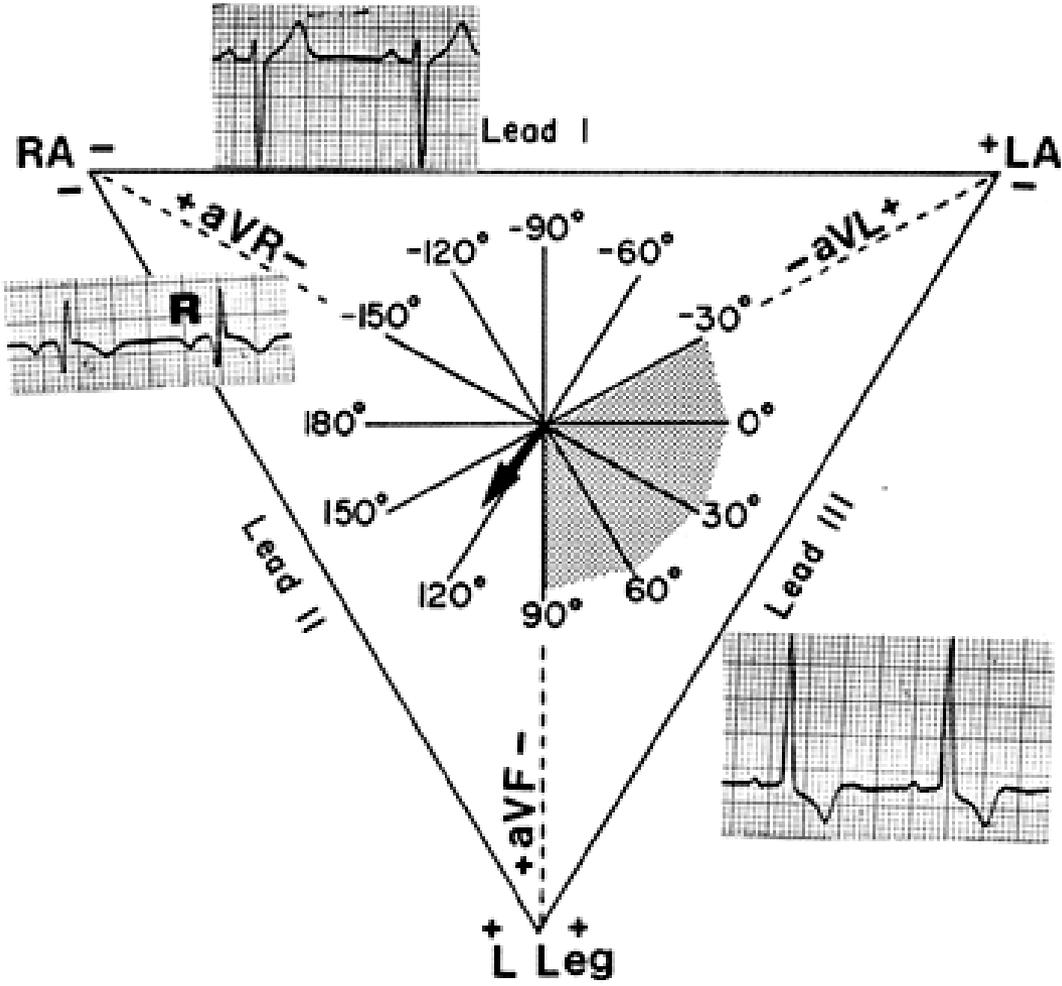
Leads II and III are mostly negative (i.e., moving away from the + left leg)

The axis, therefore, is -60°.

Axis deviation - LVH



Axis in the right axis deviation (RAD) range



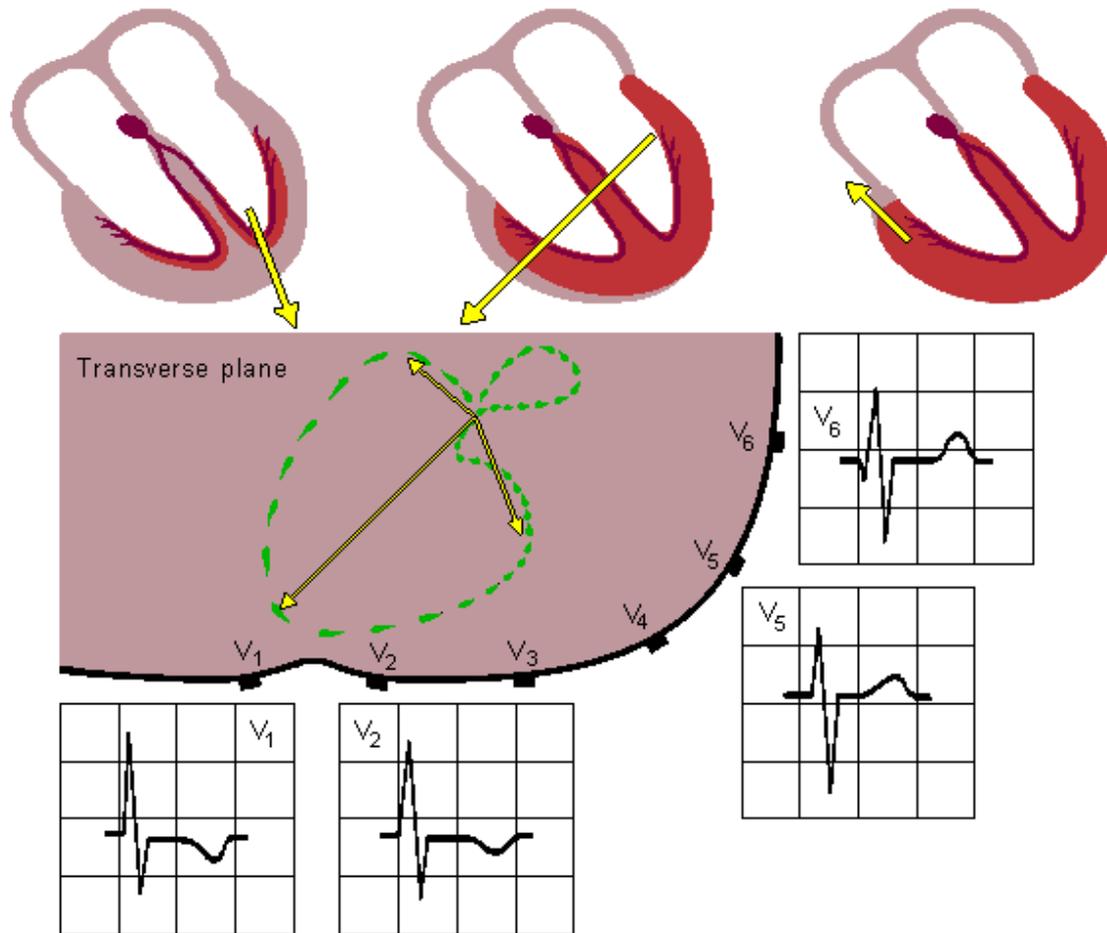
Lead aVR is closest to being isoelectric (slightly more positive than negative)

The two perpendiculars are -60° and +120°.

Lead I is mostly negative; lead III is mostly positive.

Therefore the axis is close to +120°. Because aVR is slightly more positive, the axis is slightly beyond +120° (i.e., closer to the positive right arm for aVR).

Axis deviation - RVH



Pathologic ECG

Vector analysis - Axis determination

Normal axis

Left axis deviation

Right axis deviation

Abnormal Voltages of the QRS complex

Increased voltage (att to electrode location)

Decreased voltage

Prolonged QRS

Cardiac rhythms

Tachycardia

Bradycardia

Sinus arrhythmia

Abnormal Voltages of QRS

- Increases:
 - Sum of the voltages of QRS [S-R] of the 3 standard leads > 4 mV \rightarrow high voltage ECG
 - ex. muscle hypertrophy
- Decreases:
 - cardiac myopathies
 - diminished muscle mass – ex. after myocardial infarctions (delay of impulse conduction and reduced voltages)
 - ‘short-circuits’ of the heart electrical potentials through pericardial fluid, pleural effusions
 - pulmonary emphysema

Pathologic ECG

Vector analysis - Axis determination

Normal axis

Left axis deviation

Right axis deviation

Abnormal Voltages of the QRS complex

Increased voltage (att to electrode location)

Decreased voltage

Prolonged QRS

Cardiac rhythms

Tachycardia

Bradycardia

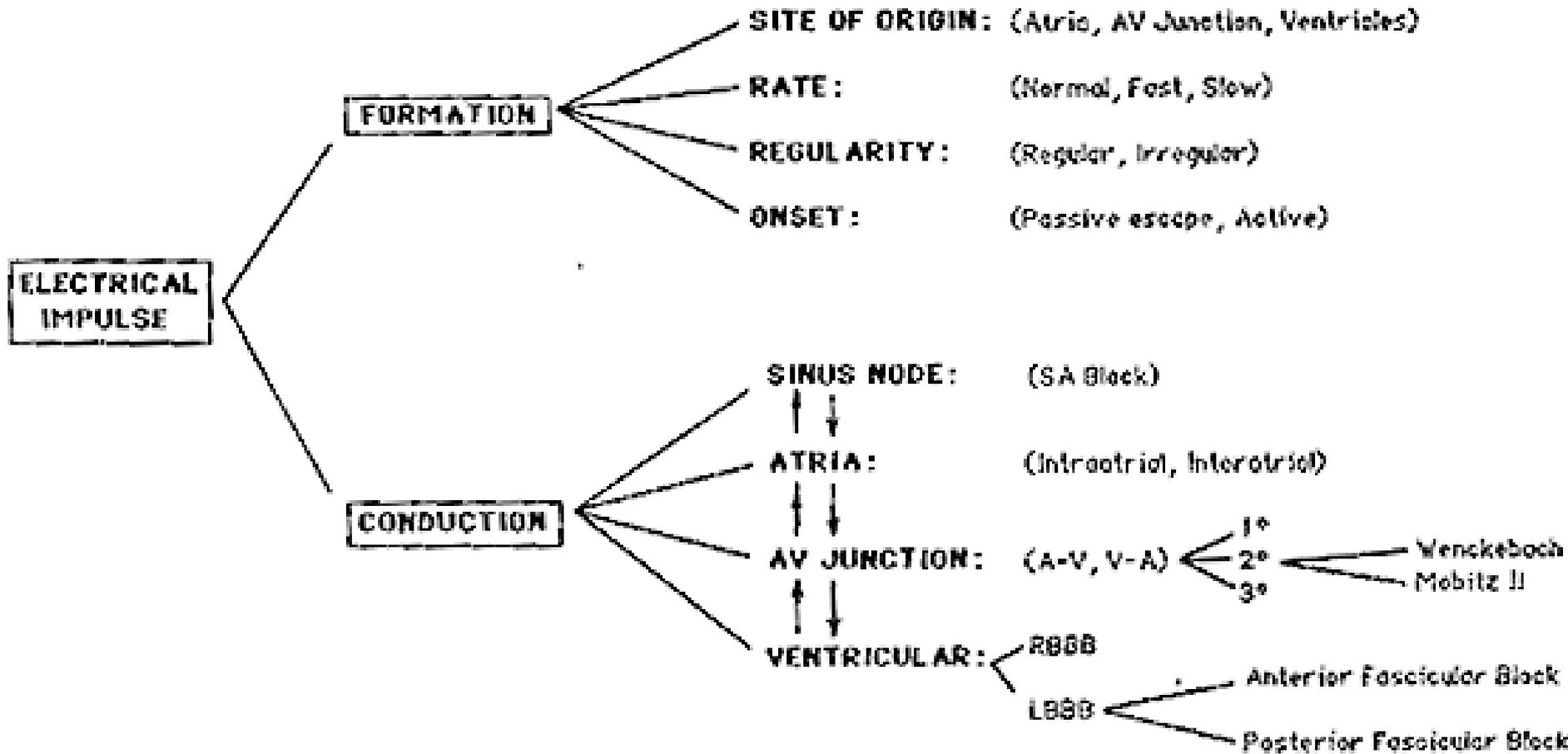
Sinus arrhythmia

Pathologic ECG - Arrhythmias

Causes of the cardiac arrhythmias

1. Abnormal rhythmicity of the pacemaker
2. Shift of the pacemaker from the sinus node to another place in the heart
3. Blocks at different points in the spread of the impulse through the heart
4. Abnormal pathways of impulse transmission through the heart
5. Spontaneous generation of impulses in almost any part of the heart

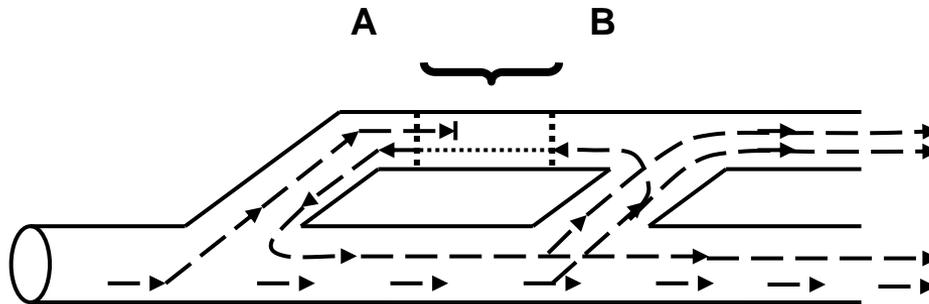
HOW TO THINK ABOUT ARRHYTHMIAS AND CONDUCTION DISTURBANCES



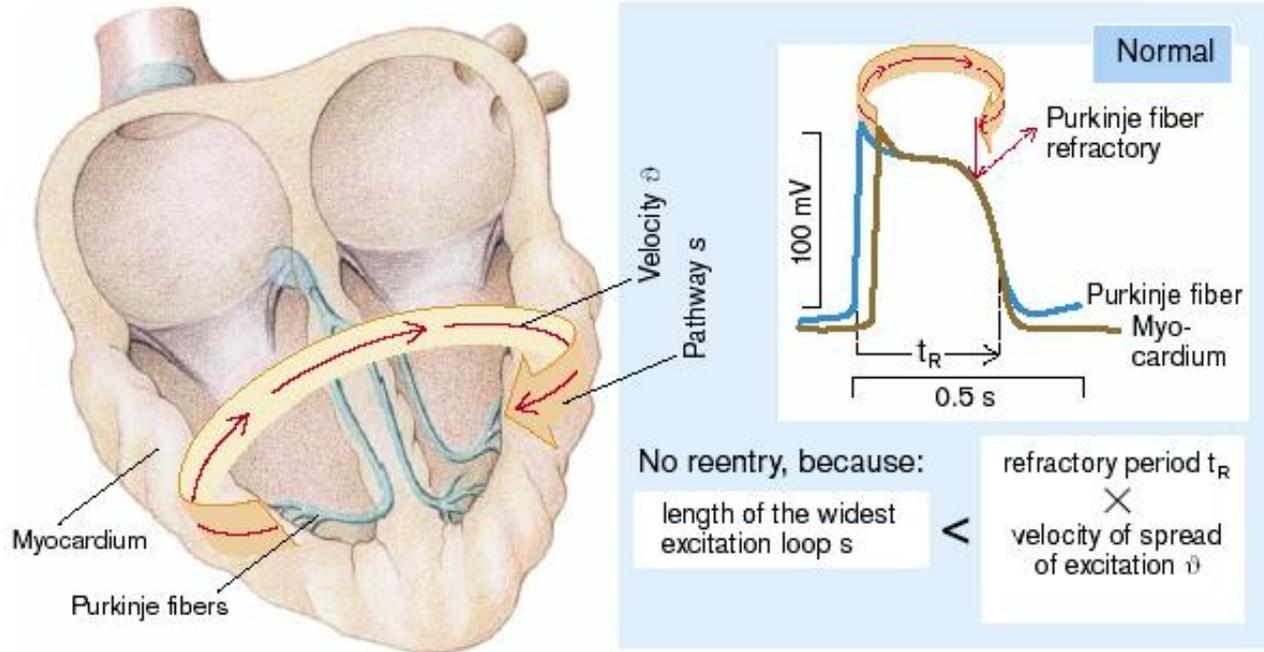
Cardiac Arrhythmia

Re-entry mechanism

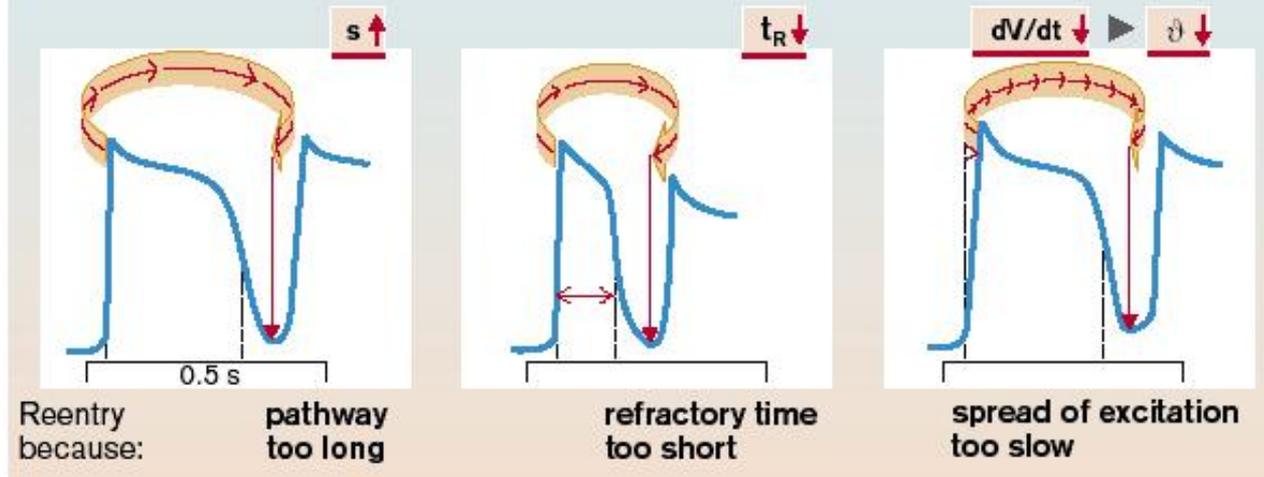
Deficient conduction area
with unidirectional block



1 Rapid spread of excitation and long refractory period: protection against reentry



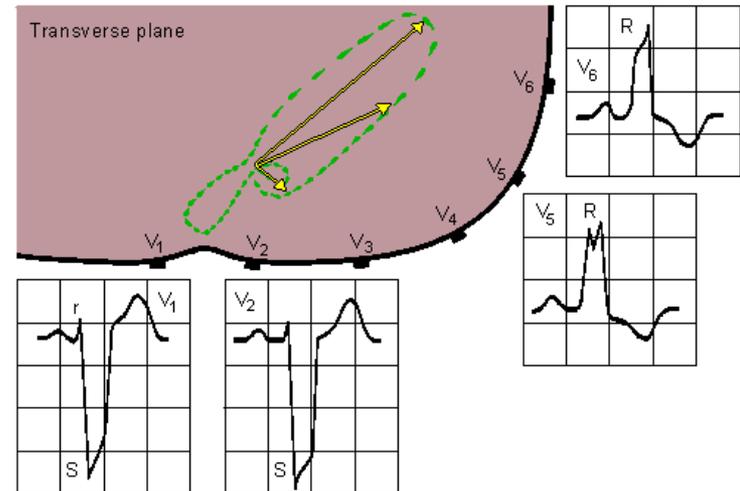
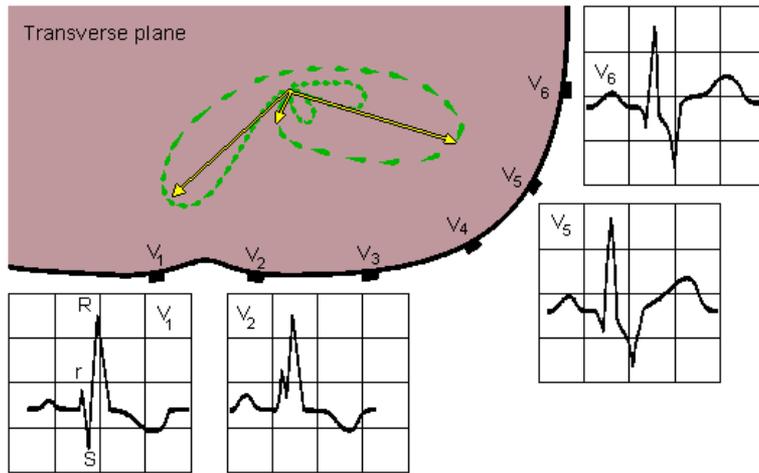
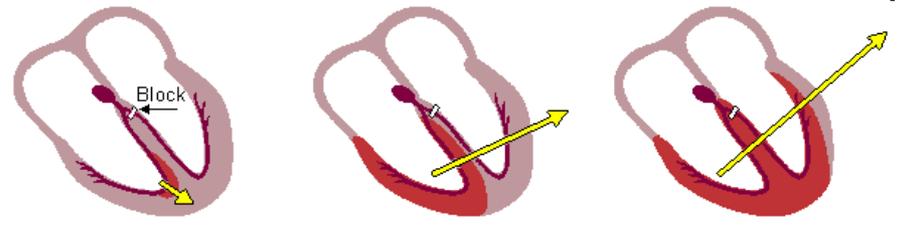
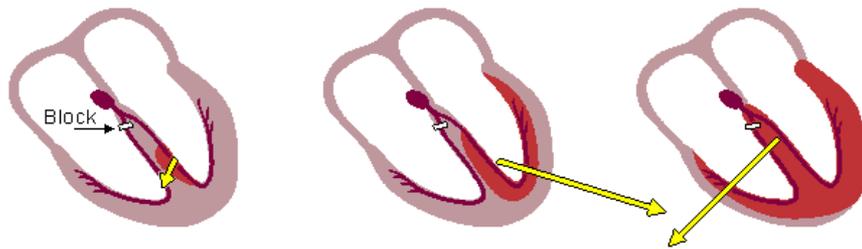
2 Basic causes of reentry



Bundle branch Blocks

Right

Left

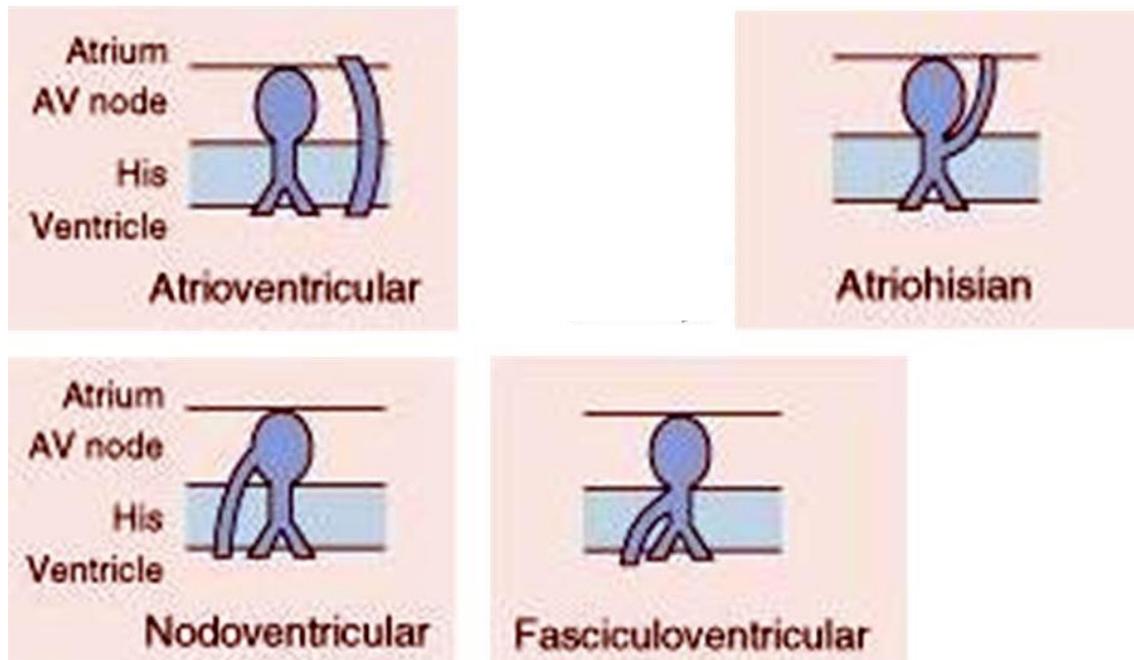


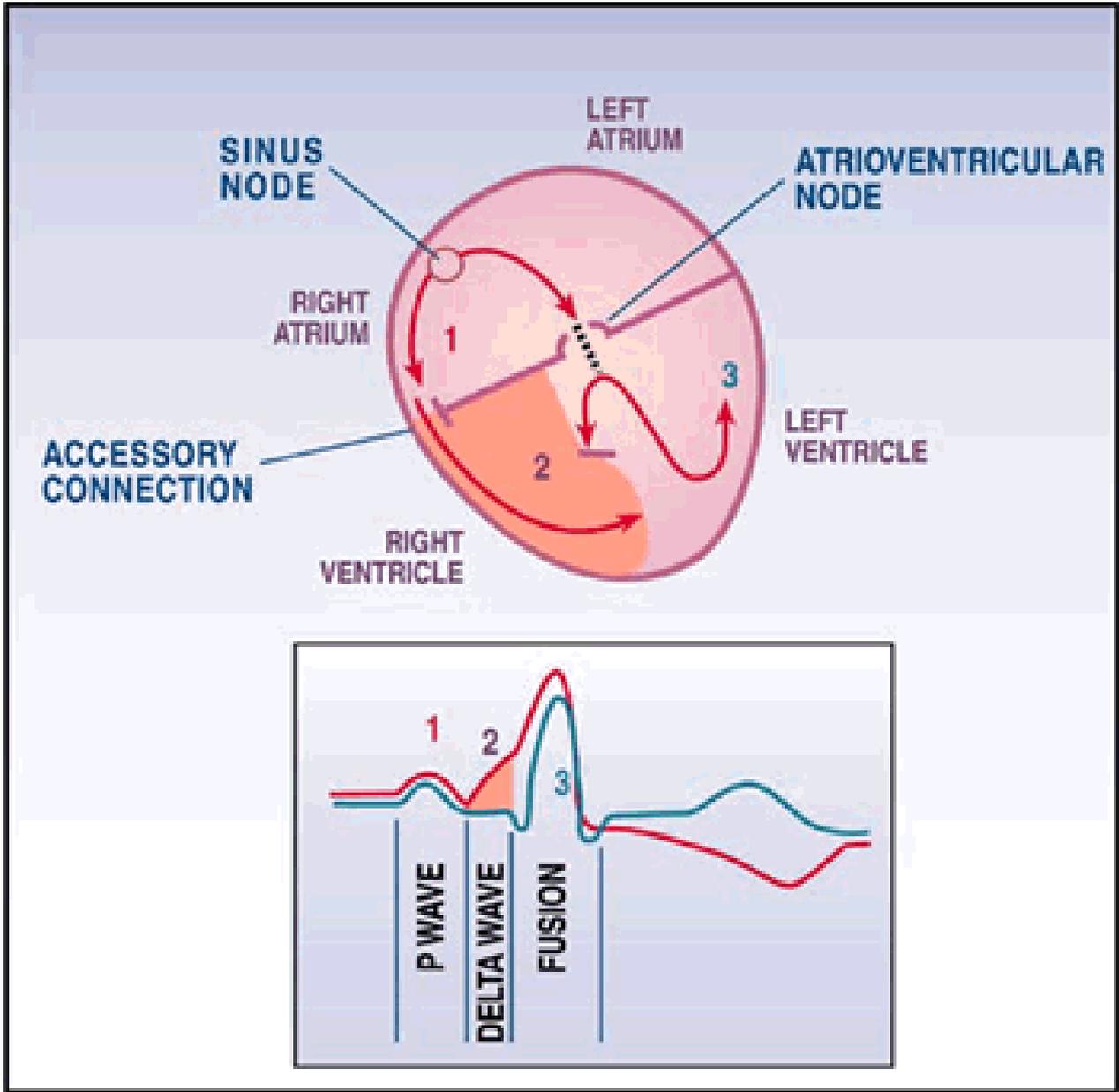
Abnormal conduction – accessory pathways (Wolff-Parkinson-White)

Kent pathway - NSA → to the ventricle base

James pathways - NSA. → to Hiss bundle

Mahaim pathway - Hiss b. → to the ventricle base





Reentry in Wolff-Parkinson-White Syndrome

