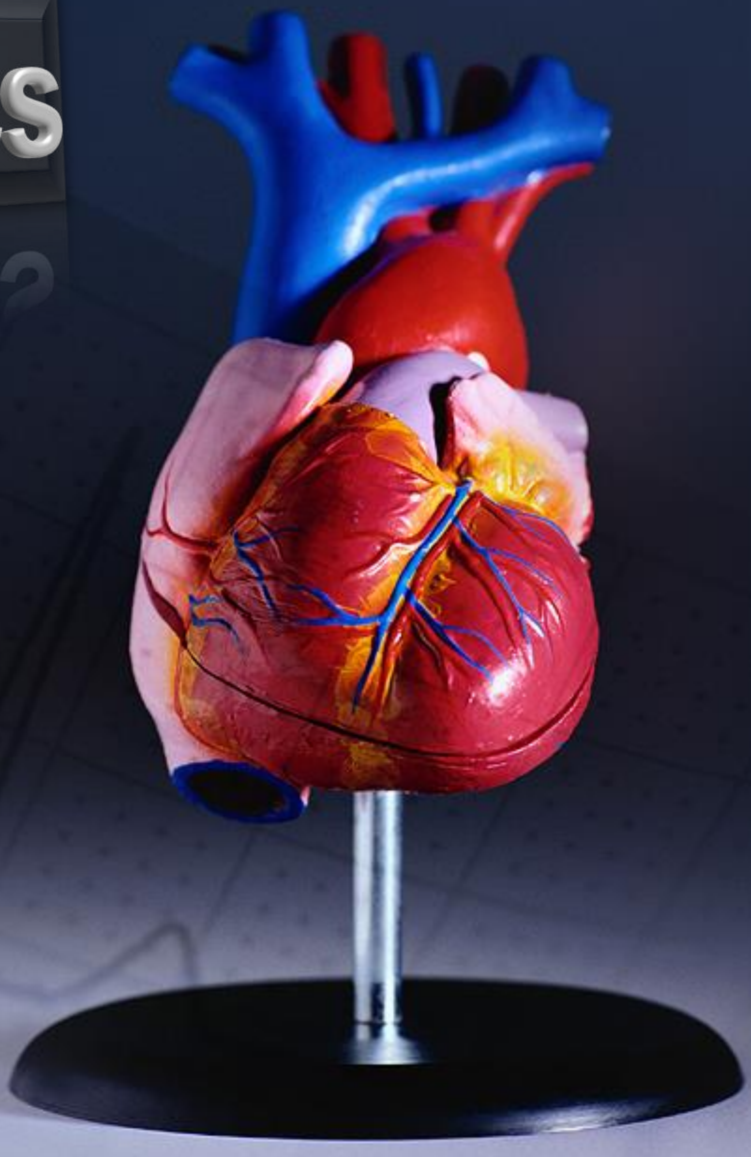
ECG basics



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Introduction

- **<u>Electrocardiography</u>** - graphic recording of the electrical activity (potentials) produced by the <u>conduction system</u> and the <u>myocardium</u> of the heart during its depolariztion / repolarization cycle.

- During the late 1800's and early 1900's, Dutch physiologist Willem Einthoven developed the early elctrocardiogram. He won the Nobel prize for its invention in 1924.

- Hubert Mann first uses the electrocardiogram to describe electrocardiographic changes associated with a heart attack in 1920.

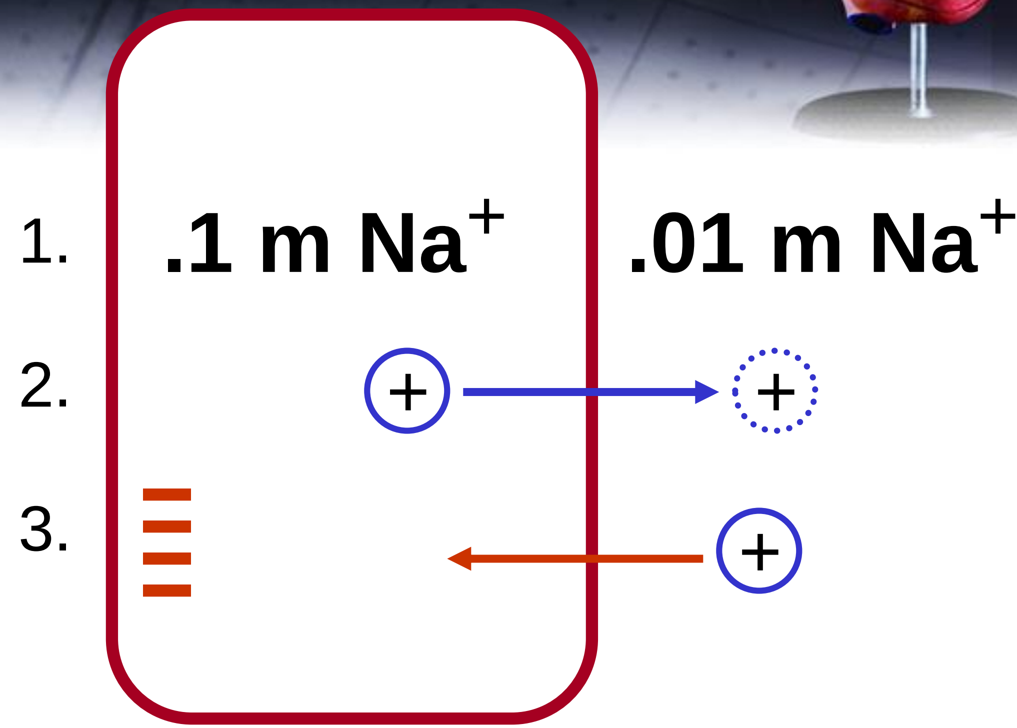
Introduction

- The science of electrocardiography is not exact. The sensitivity and specificity of the tool in relation to various diagnoses are relatively low
- Electrocardiograms must be viewed in the context of demographics, health histories, and other clinical test correlates. They are especially useful when compared across time to see how the electrical activity of the heart has changed (perhaps as the result of some pathology).

Cardiac Electrophysiology

Ion Flux Across a Permeable Membrane

1. A higher concentration ([ ]) of sodium exists inside the cell
2. Sodium diffuses down its concentration gradient
3. The loss of the positive sodium ion leaves the inside of the cell negative, setting up an electrostatic force trying to pull the sodium ions back into the cell



The balance of electrostatic and concentration forces for each ion in the cell are described by the Nernst equation

E_k = -61.5mv log ([ion inside] / [ion outside])

Where E_k = membrane charge (potential) for a given ion

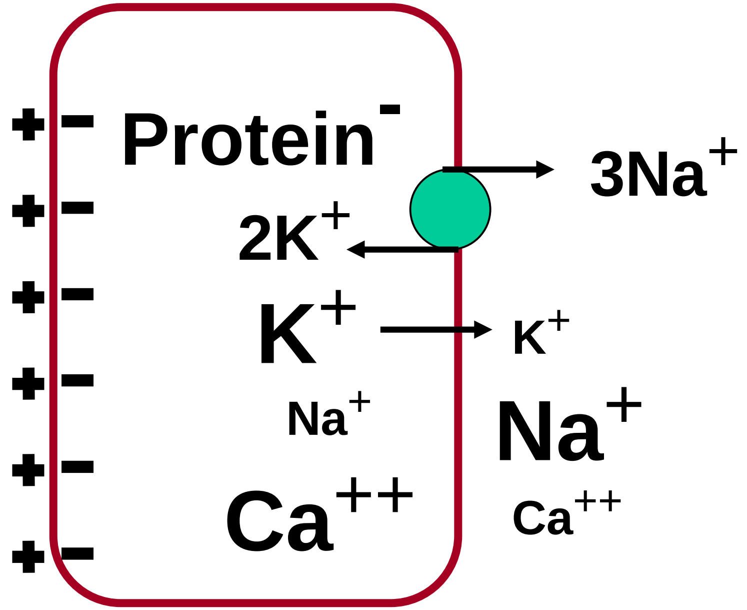
Tutorial:

Generation of a Resting Myocardium Membrane Potential

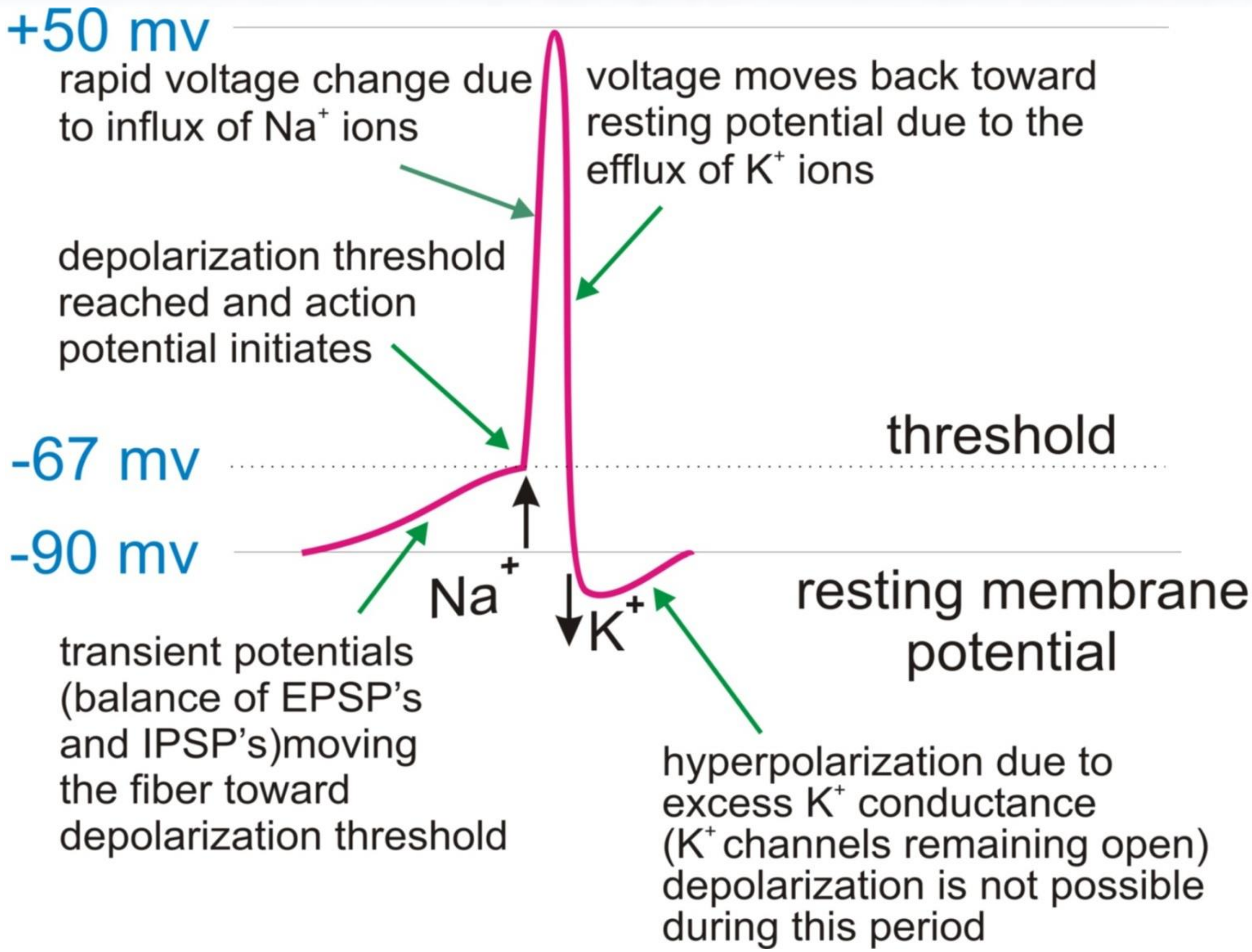
1. During repolarization, $Na^{+}K^{+}$ ATP-ase pumps $3Na^{+}$out and $2K^{+}$ in r u intracellular negativity
2. At rest, membrane permeability to K^{+} high
   - K^{+} diffuses down concentration gradient r u intracellular negativity
   - primary contributor to intracellular negativity and the resulting membrane potential
3. Membrane permeability to Na^{+} and Ca^{++} is low r little Na^{+}or Ca^{++} diffusion takes place
4. You have 2 forces acting on each of the ions: electrostatic forces and concentration forces
   - balance of forces for each ion calculated using **Nernst equation**
   - E_k = -61.5mv log ([ion inside] / [ion outside])
5. Balance of forces for all ions can be described by
   Chord Conductance Equation

$$E_m = \frac{g_{K+}\,E_{K+}}{\text{🌢g's}} + \frac{g_{Na+}\,E_{Na+}}{\text{🌢g's}} + \frac{g_{Ca++}\,E_{Ca++}}{\text{🌢g's}}$$

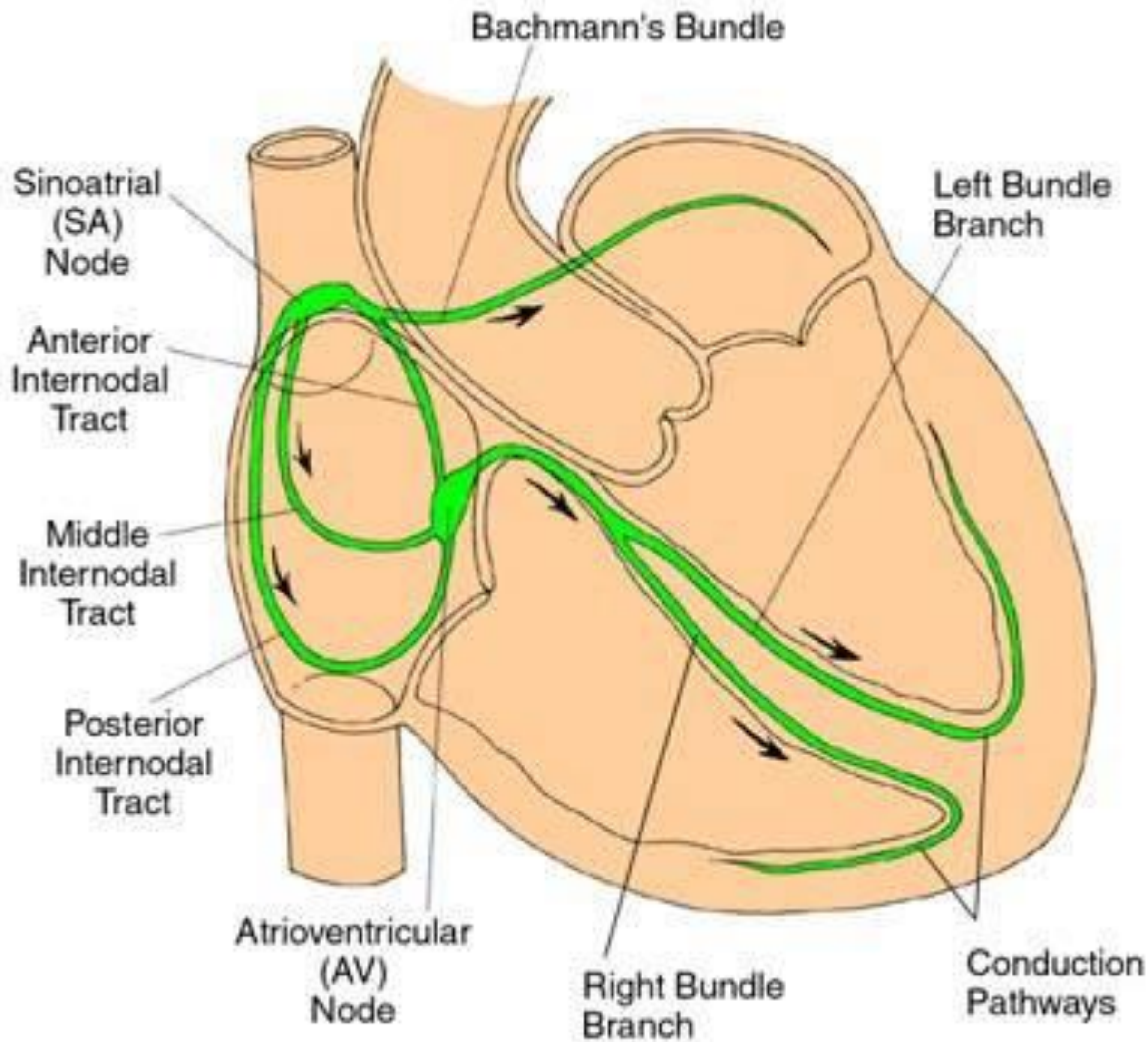
Where: E_m = resting membrane potential
g_{K+} = cell permeability to K^{+}…(Na^{+}…Ca^{++})
E_{K+} = Nernst value for K^{+}…(Na^{+}…Ca^{++})



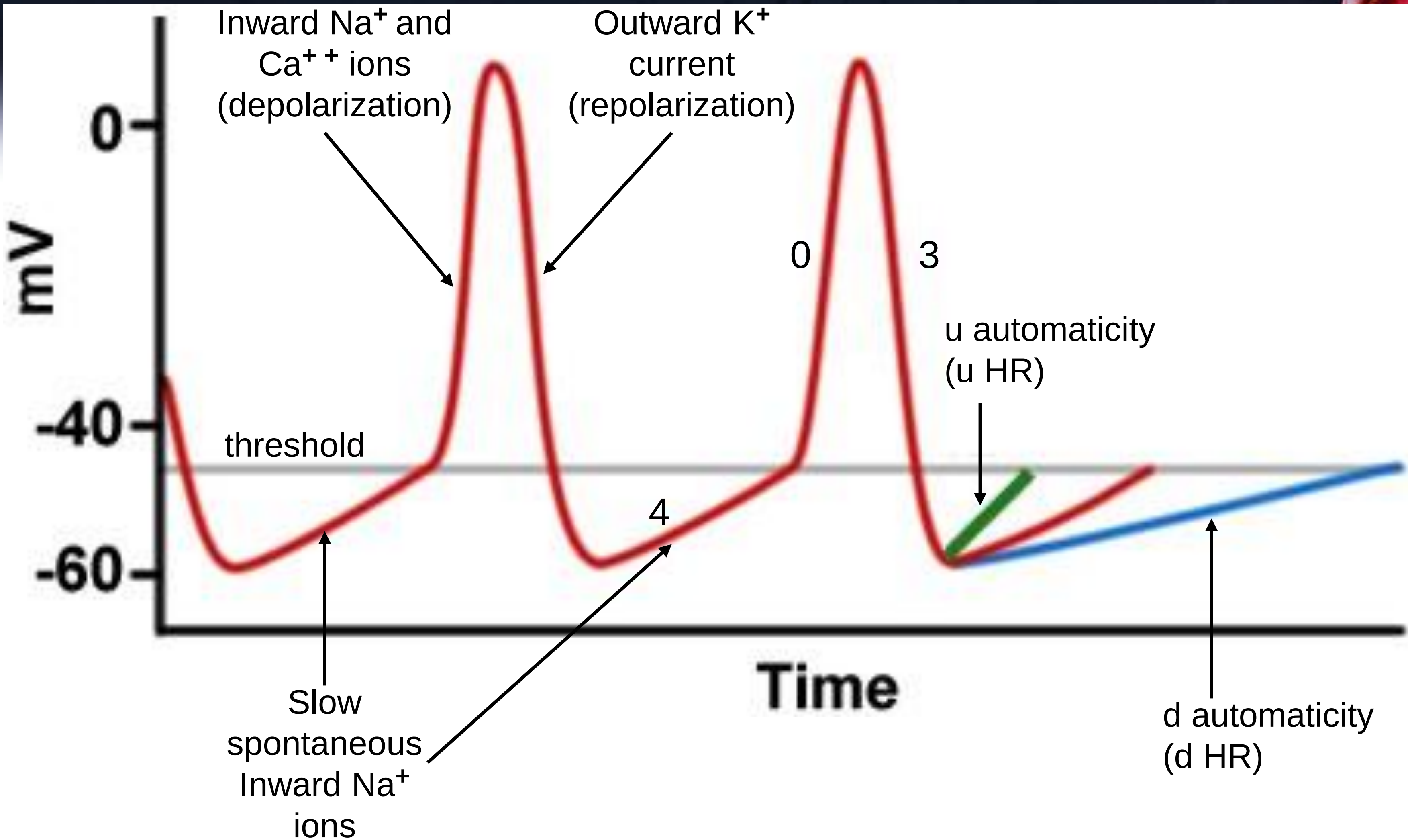
Skeletal Muscle or Neuron Action Potential



The Electrical System of the Heart

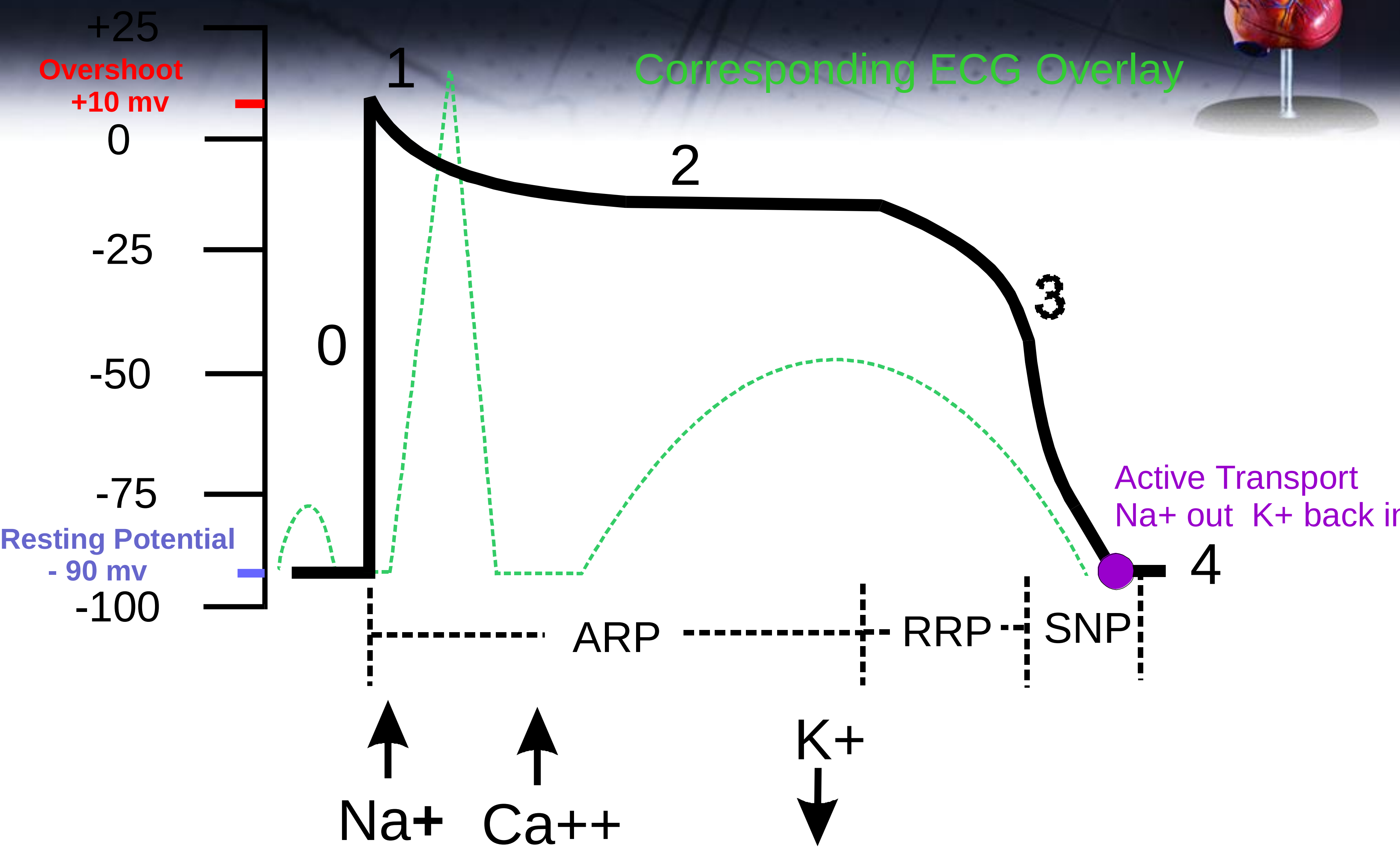


Atrial Muscle (Nodal) Action Potential



Automaticity - a pacemaker cell's ability to spontaneously depolarize, reach threshold, and propagate an AP

Myocardium Muscle Action Potential



Depolarization Sequence of a “Strip” of 5 Myocardial Cells

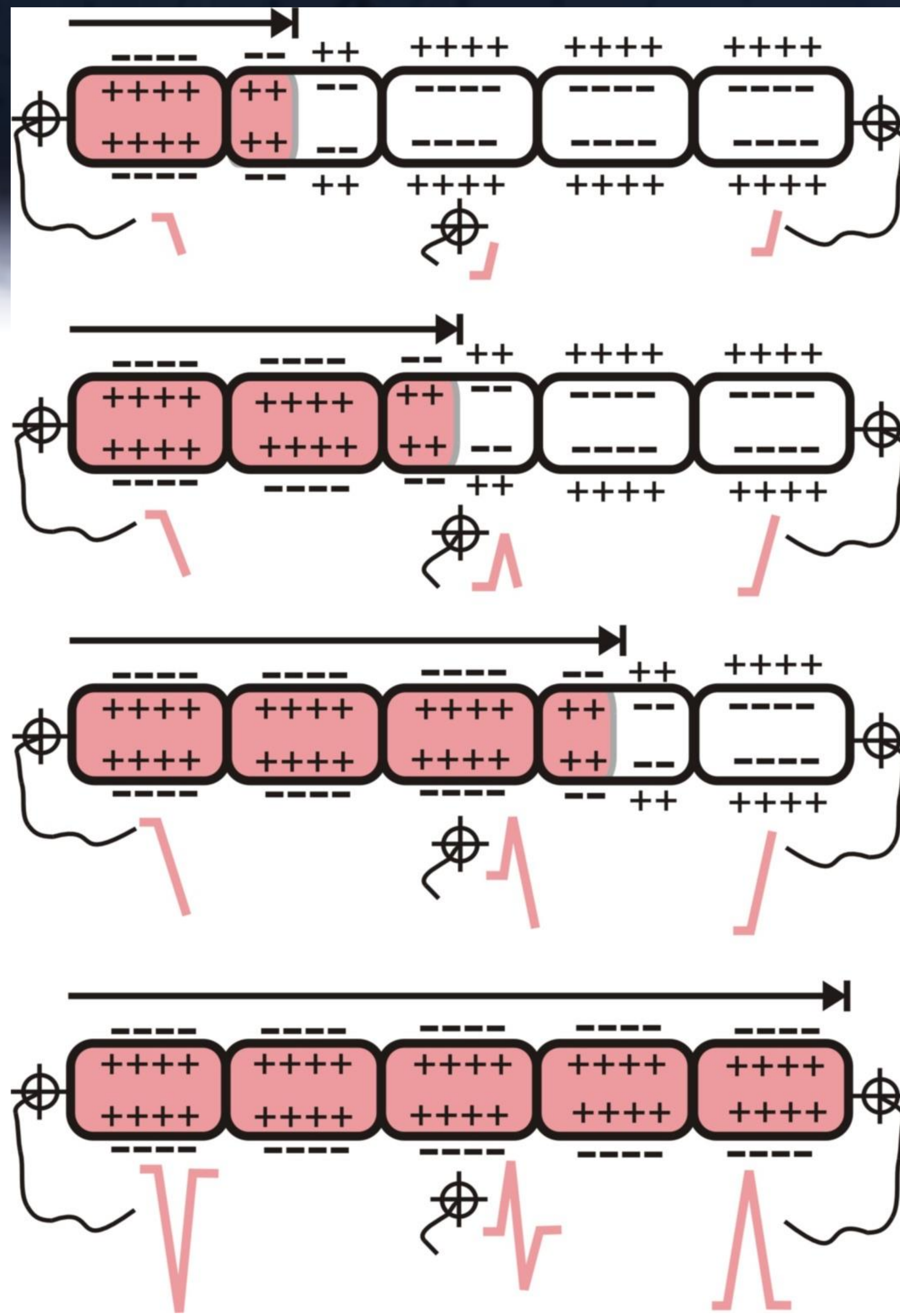
Depolarization progressing from left to right

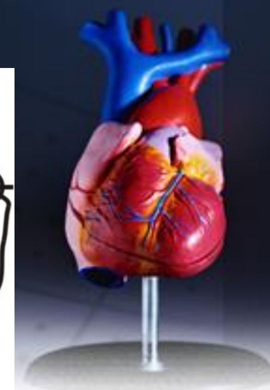
1.

2.

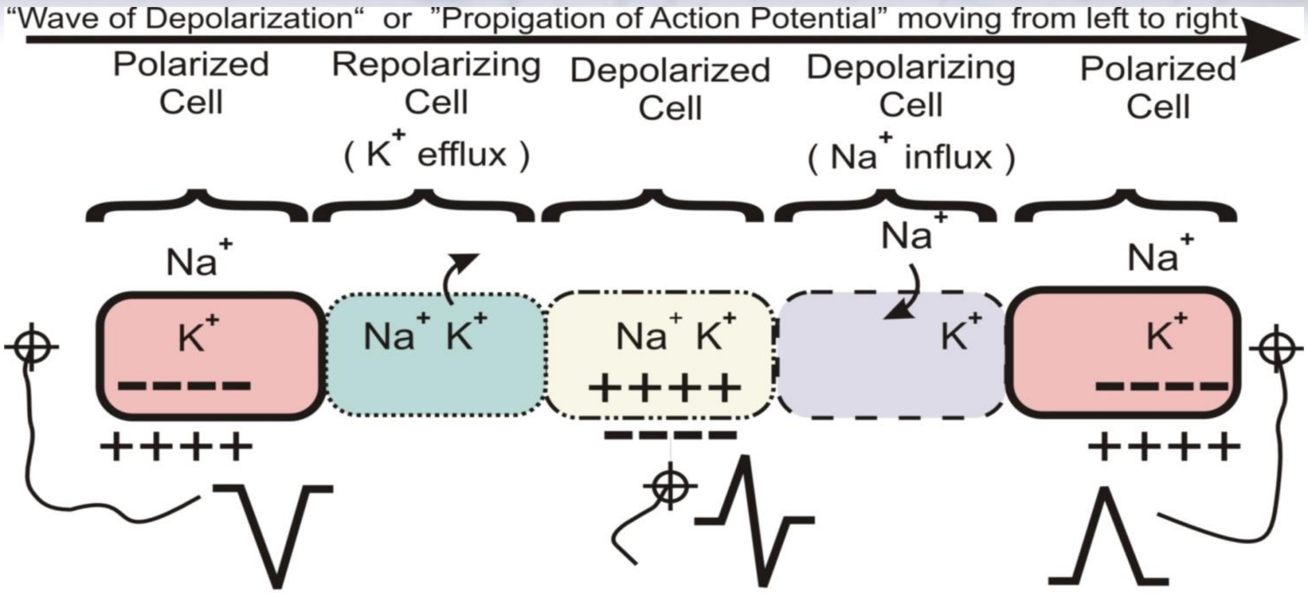
3.

4.





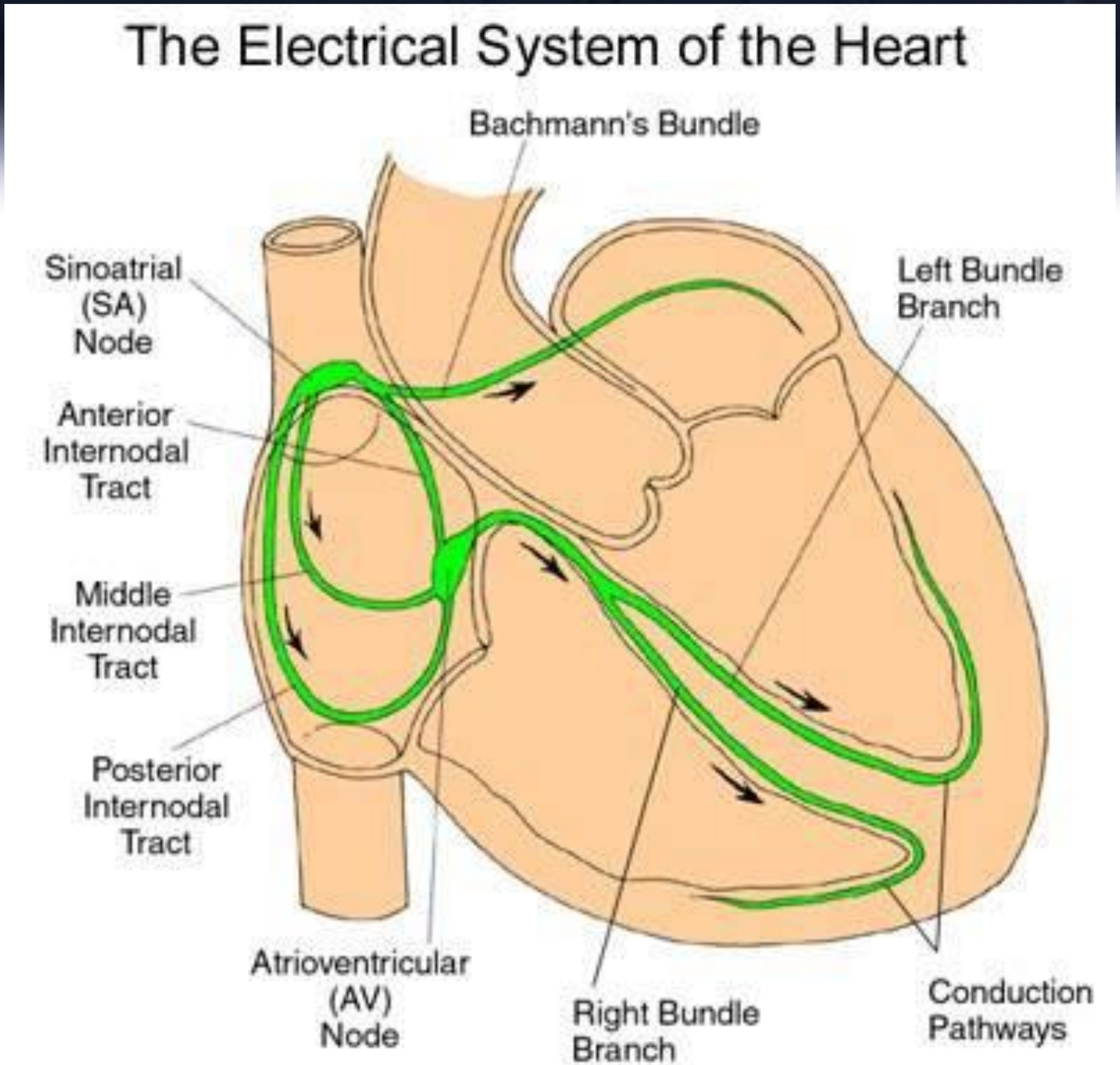
Depolarization Sequence of a "Strip" of 5 Myocardial Cells



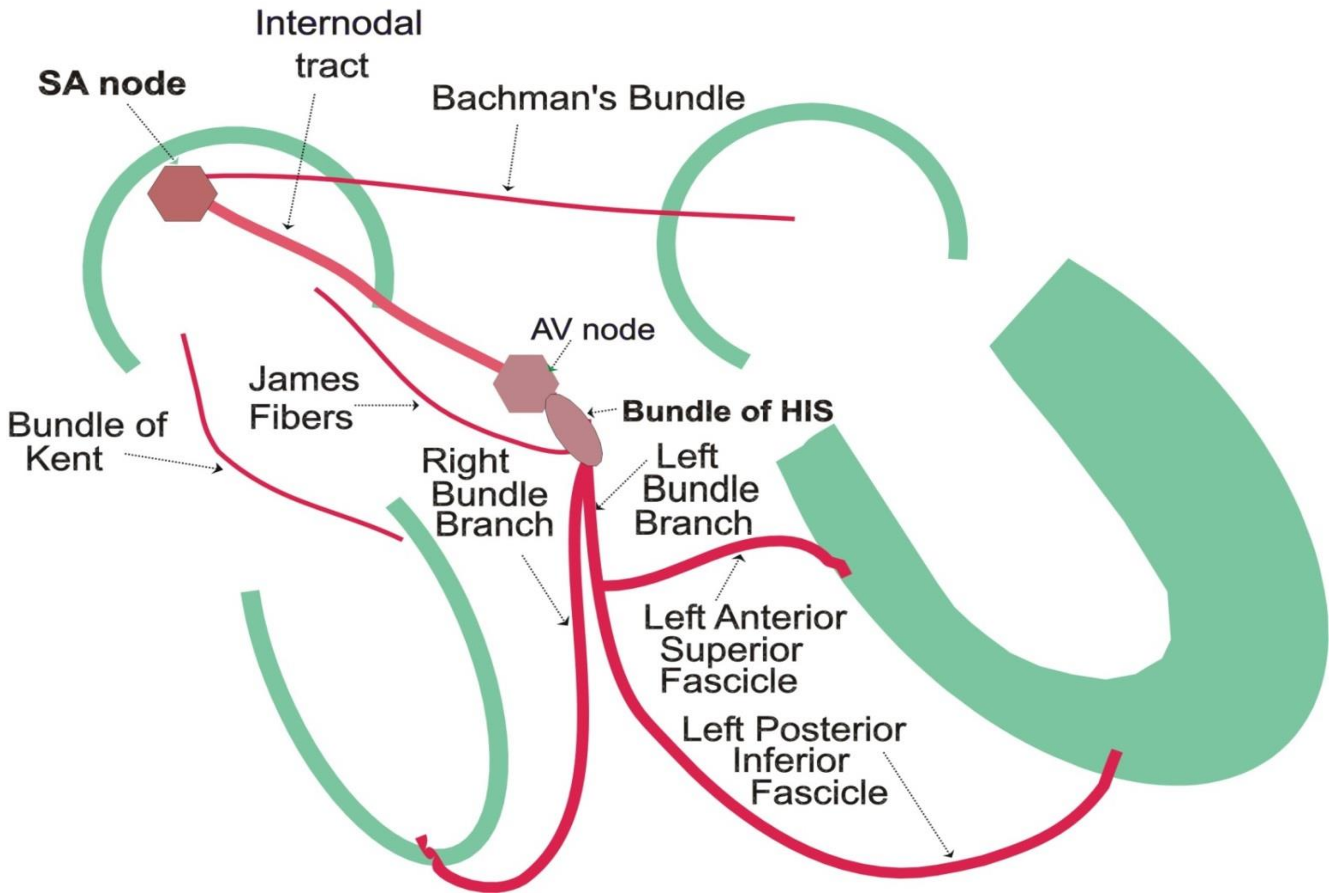
The needle of this recording electrode inscribes a totally negative complex because the wave of depolariztion is moving away from it during the entire time the strip is depoarizing

The needle of this recording electrode is biphasic because half of the time the wave of depolarization is moving towards it while the other half of the time it is moving away

The needle of this recording electrode inscribes a totally positive complex because the wave of depolariztion is moving towards it during the entire time the strip is


The Electrical System of the Heart
Bachmann's Bundle
Sinoatrial (SA) Node
Left Bundle Branch
Anterior Internodal Tract
Middle Internodal Tract
Posterior Internodal Tract
Atrioventricular (AV) Node
Right Bundle Branch
Conduction Pathways

The Conduction System of the Heart



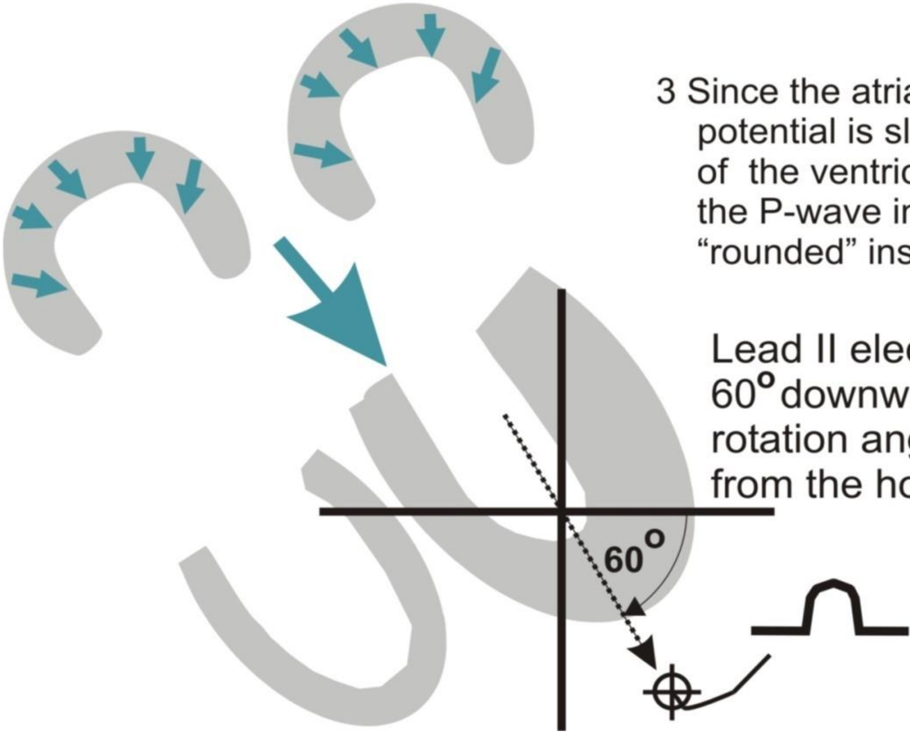
Generation of the Electrocardiogram

Atrial Depolarization and the Inscription of the P-wave

1. Atrial depolarization proceeds from the top of the atria downward in all directions.

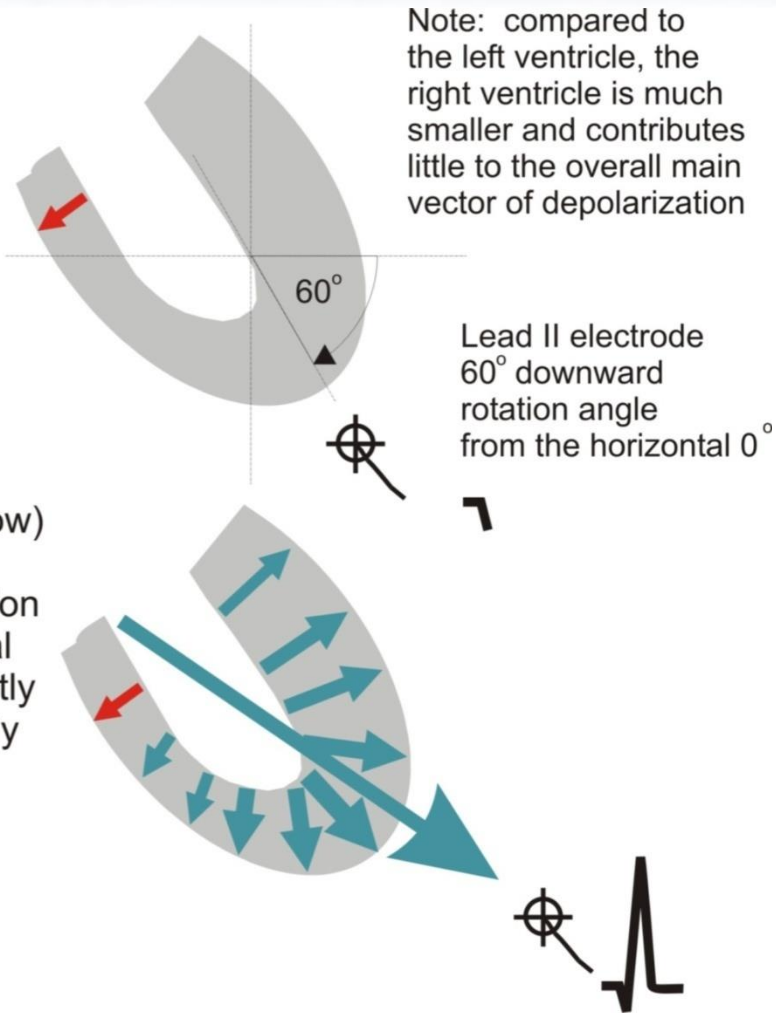
2. Summing these vectors of depolarization results in the main atrial depolarization vector oriented as shown (large green arrow). It is moving towards the positive electrode of the lead, resulting in an upward deflection of the ECG stylus.

3 Since the atrial muscle action potential is slow, relative to that of the ventricular mycoardium the P-wave inscription is "rounded" instead of a spike.

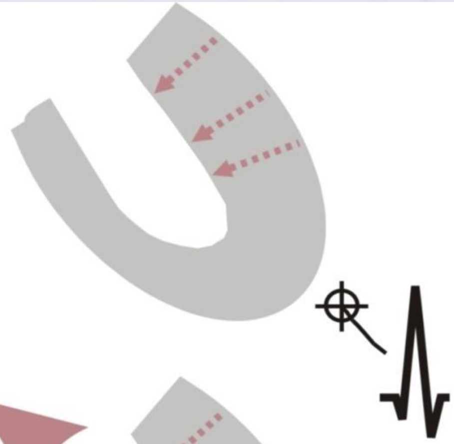


Ventricular Depolarization and the Inscription of the QRS complex

1. Septum depolarizes from the inside out and the resulting depolarization wave moves away from the electrode recording Lead II
2. The rest of the ventricle depolarizes counter-clockwise from the inside out and creates the main cardiac vector (large arrow) which is essentially, the algebraic sum of all of the small depolarization vectors. This vector is, in a normal heart, almost always moving directly toward Lead II, generating a mostly positive QRS complex

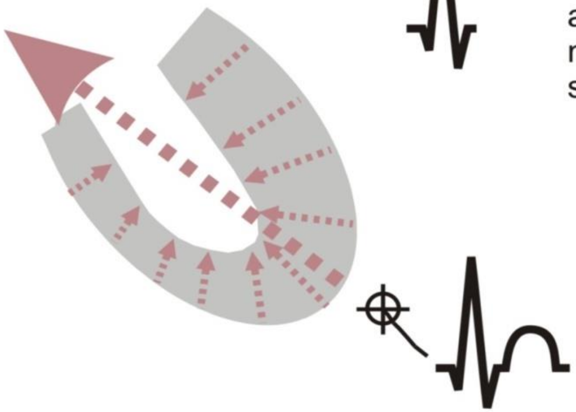


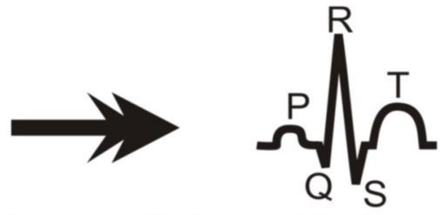
Ventricular Repolarization and the Inscription of the T-wave



3. Repolarization can be thought of as beginning where depolarization left off and proceeding clockwise from the lateral wall back to the septum..

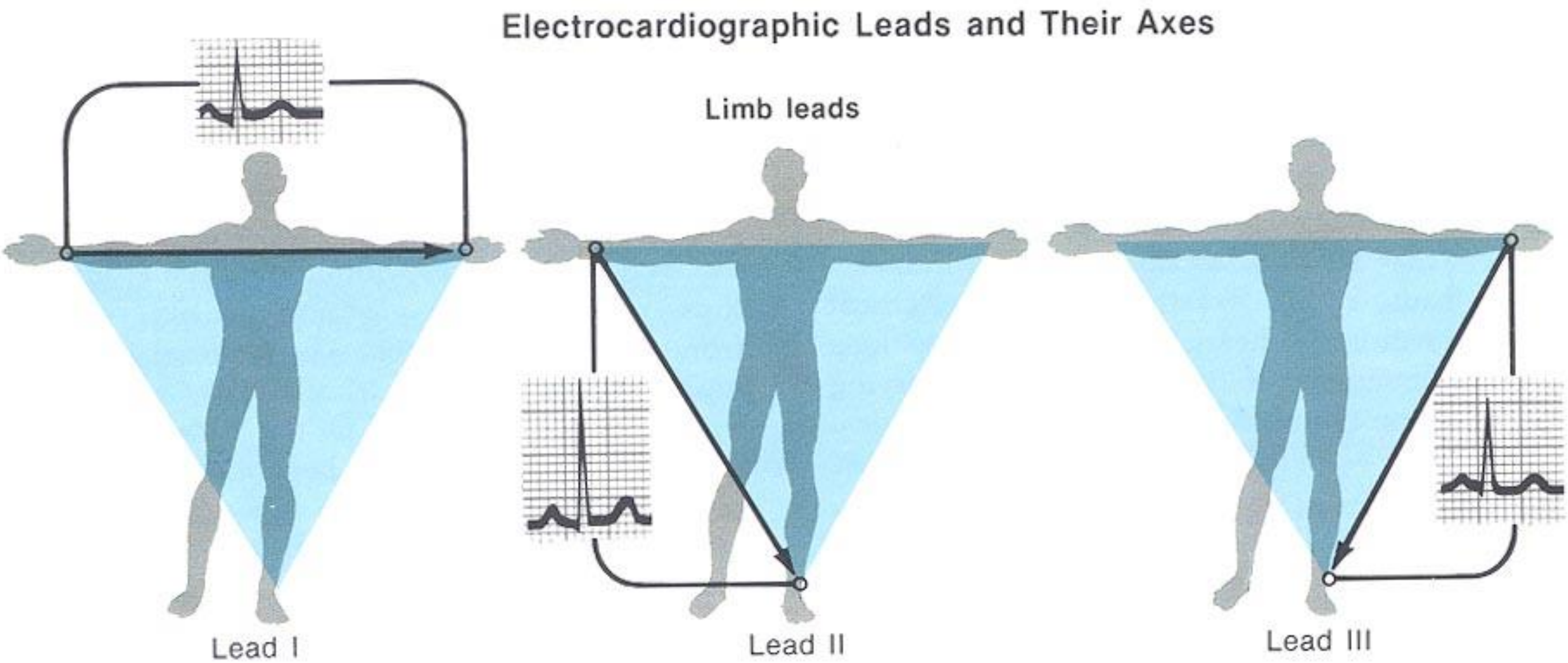
4. The repolarization process proceeds at a much slower rate than depolarization so the wave inscribed (T-wave) is wide and rounded. The repolarization vector is moving away from the Lead II electrode so the inscribed T-wave is always positive





5. Putting the P-wave with the ventricular generated complex yields the entire ECG complex, representing atrial depolarization, atrial repolarization (hidden in ventricular depolarization), ventricular depolarization, and ventricular repolarization)

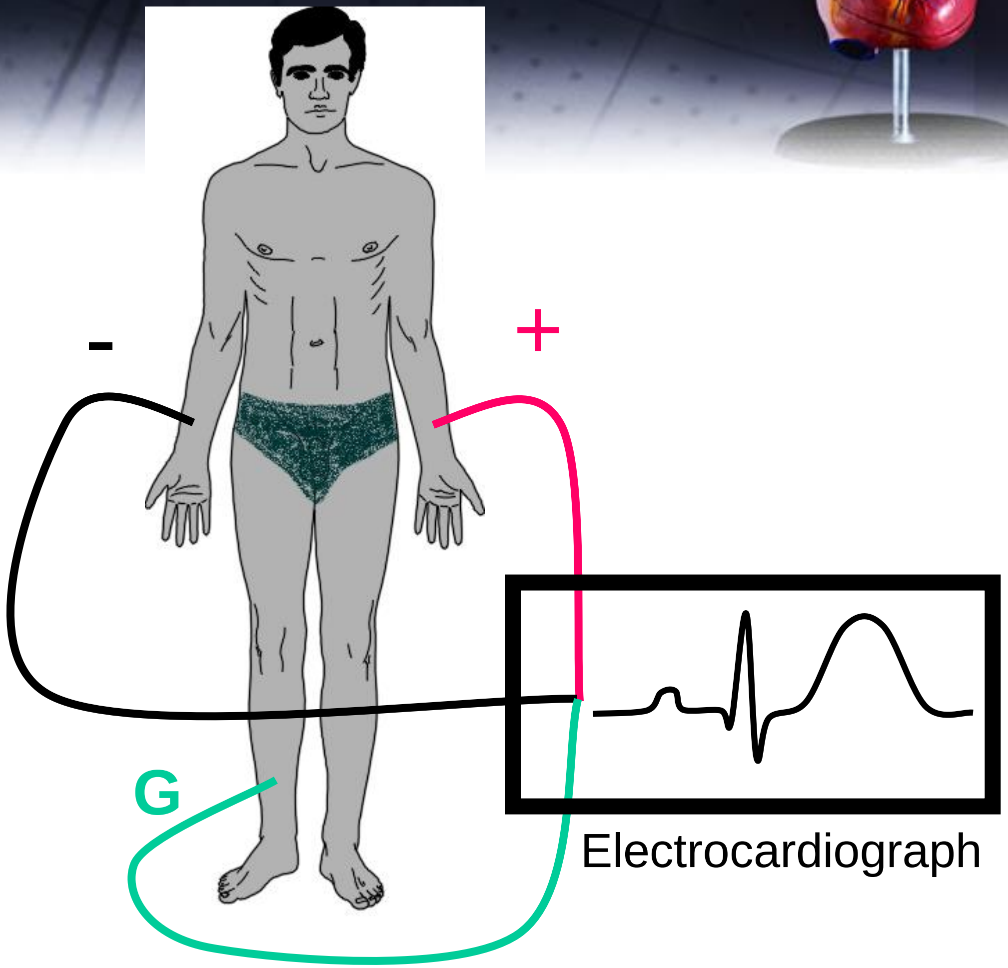
ECG Limb Leads



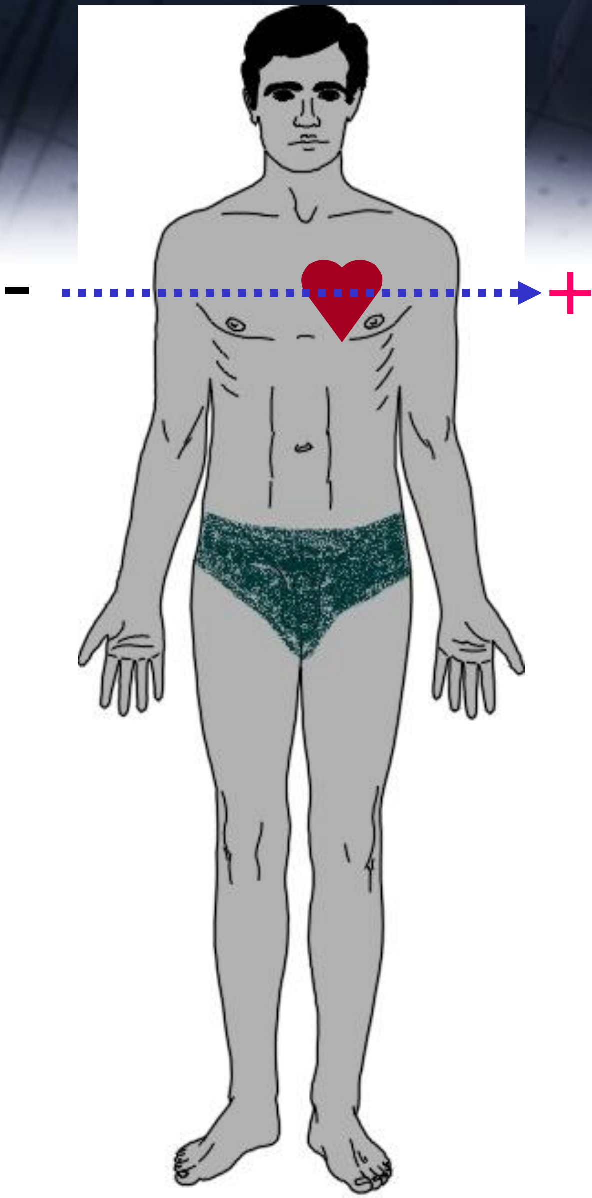
The Concept of a "Lead"

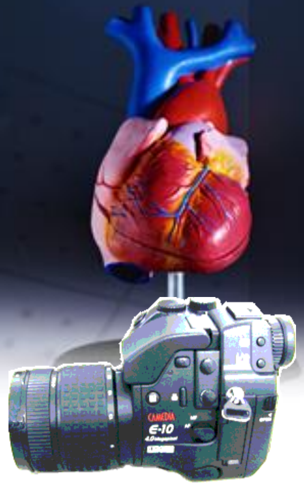
Lead I

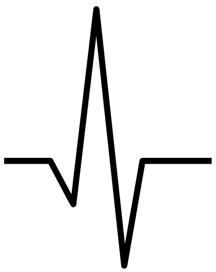
- Right arm (RA) negative, left arm (LA) positive, right leg (RL) ground……this arrangement of electrodes enables a "directional view" recording of the heart's electrical potentials as they are sequentially activated throughout the entire cardiac cycle



The Concept of a "Lead"







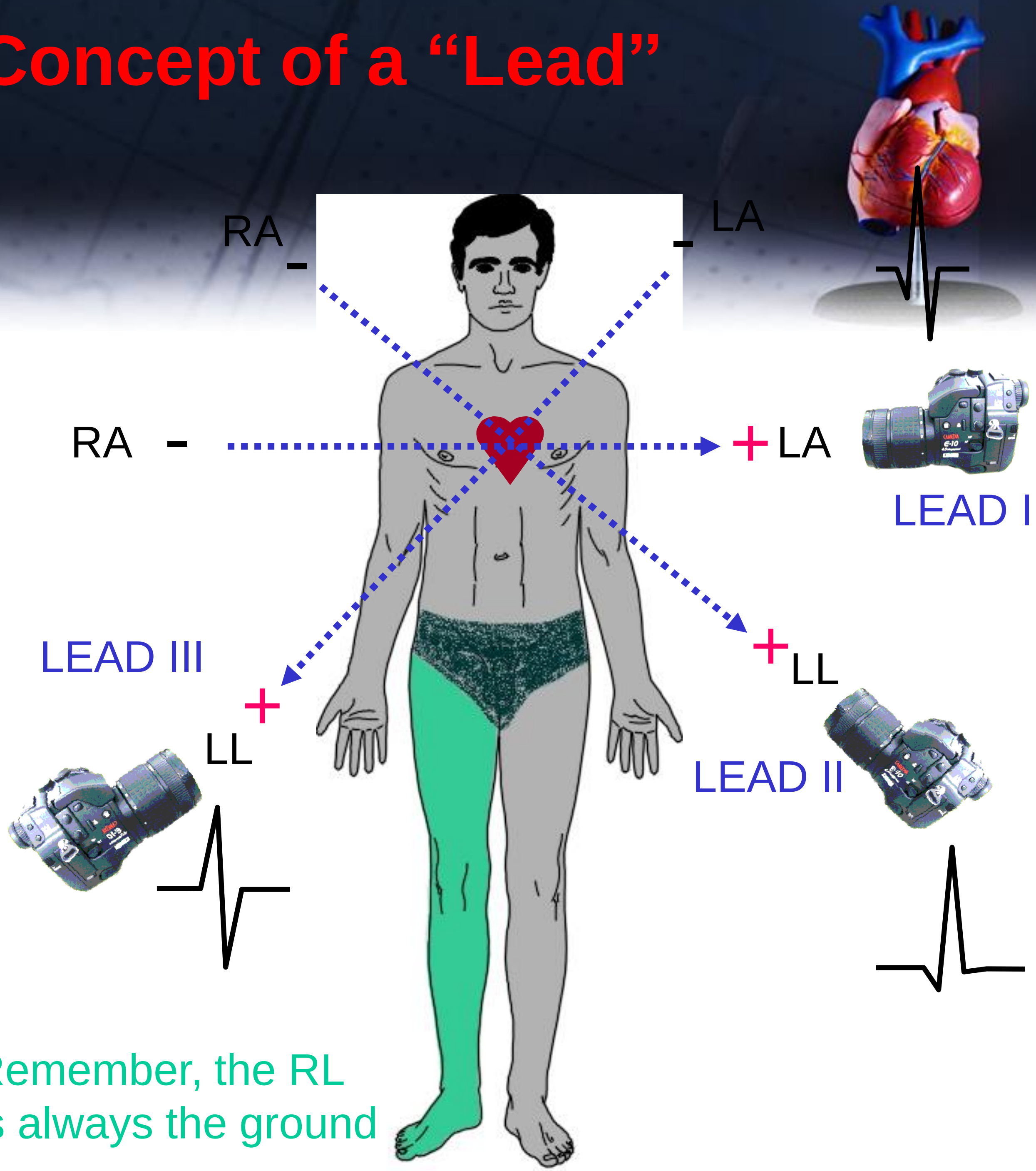
Lead I

- The directional flow of electricity from Lead I can be viewed as flowing from the RA toward the LA and passing through the heart. Also, it is useful to imagine a camera lens taking an "electrical picture" of the heart with the lead as its line of sight

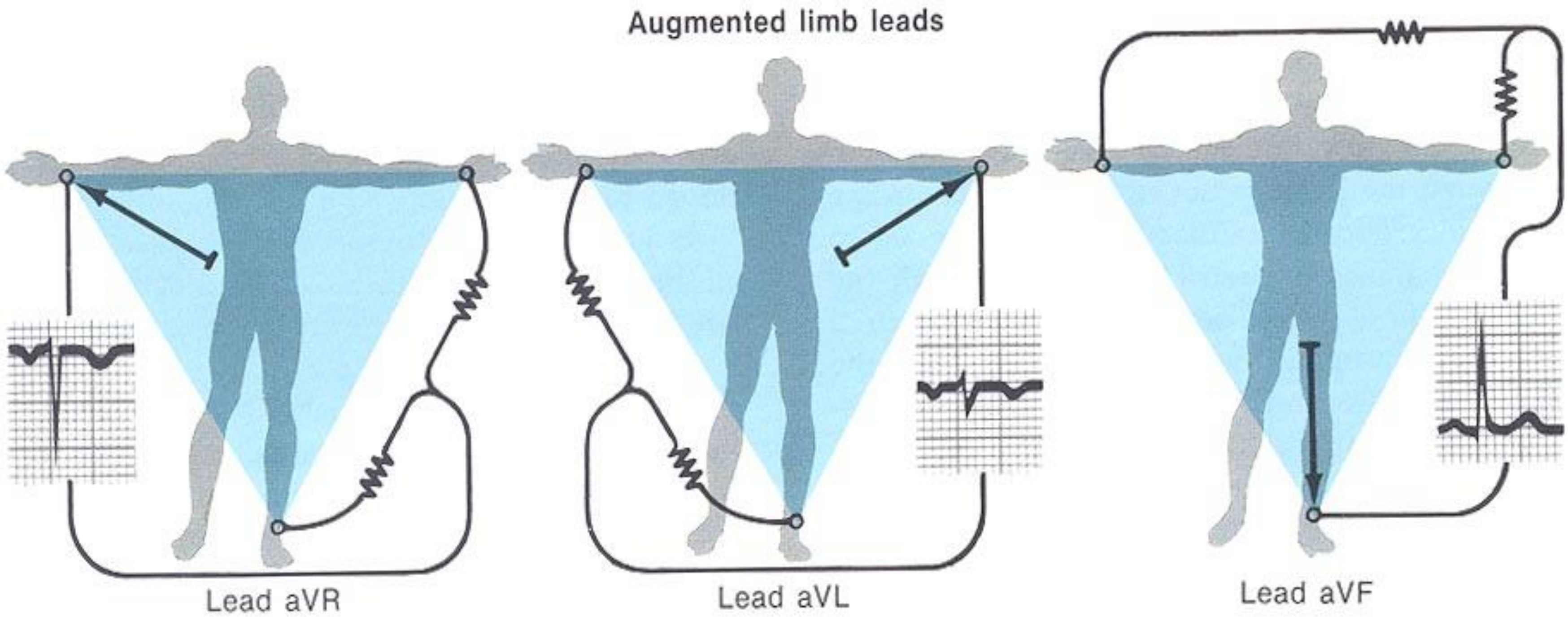
The Concept of a "Lead"

Leads I, II, and III

- By changing the arrangement of which arms or legs are positive or negative, two other leads (II & III) can be created and we have two more "pictures" of the heart's electrical activity from different angles



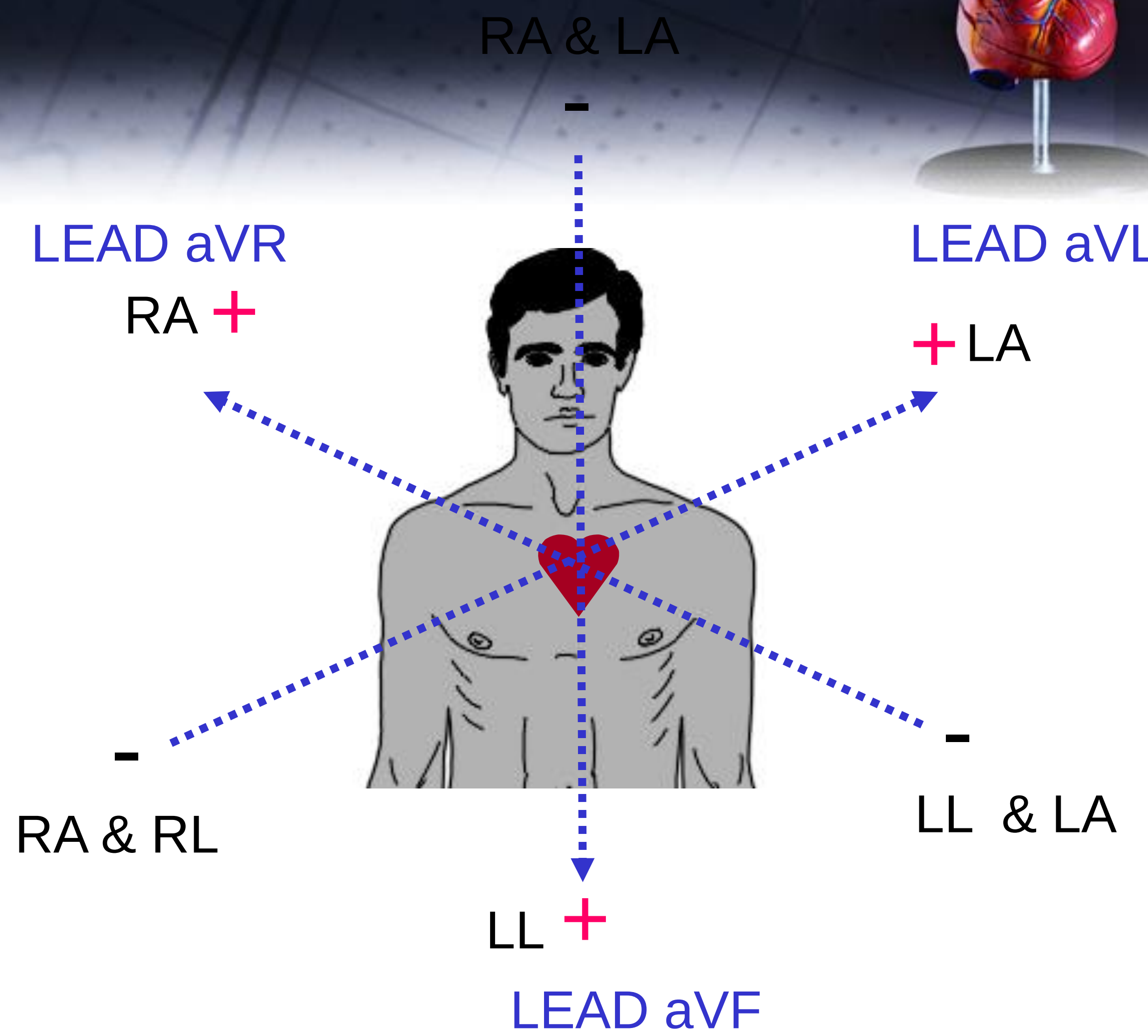
ECG Augmented Limb Leads



The Concept of a "Lead"

Augmented Voltage leads
AVR, AVL, and AVF

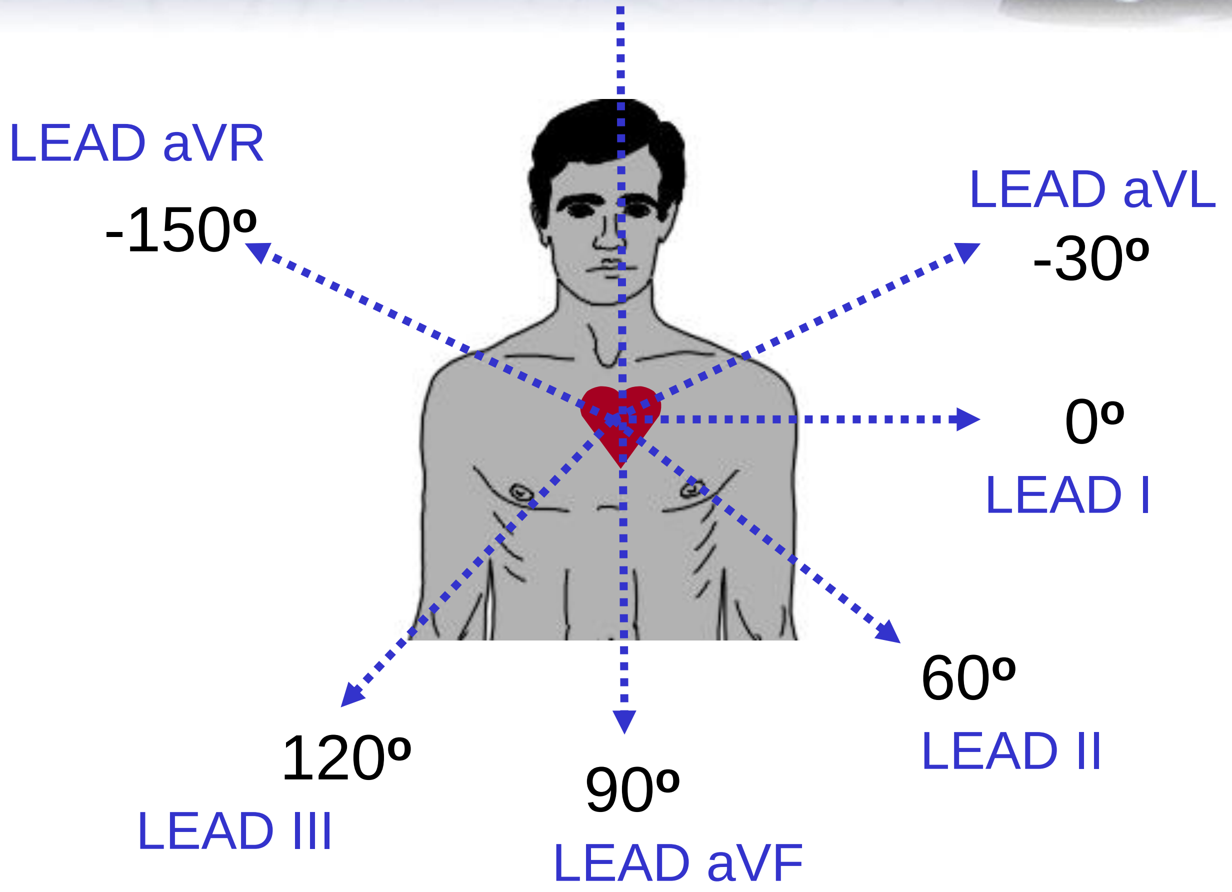
- By combining certain limb leads into a <u>central terminal</u>, which served as the negative electrode, other leads could be formed to "fill in the gaps" in terms of the angles of directional recording. These leads required augmentation of voltage to be read and are thus labeled.



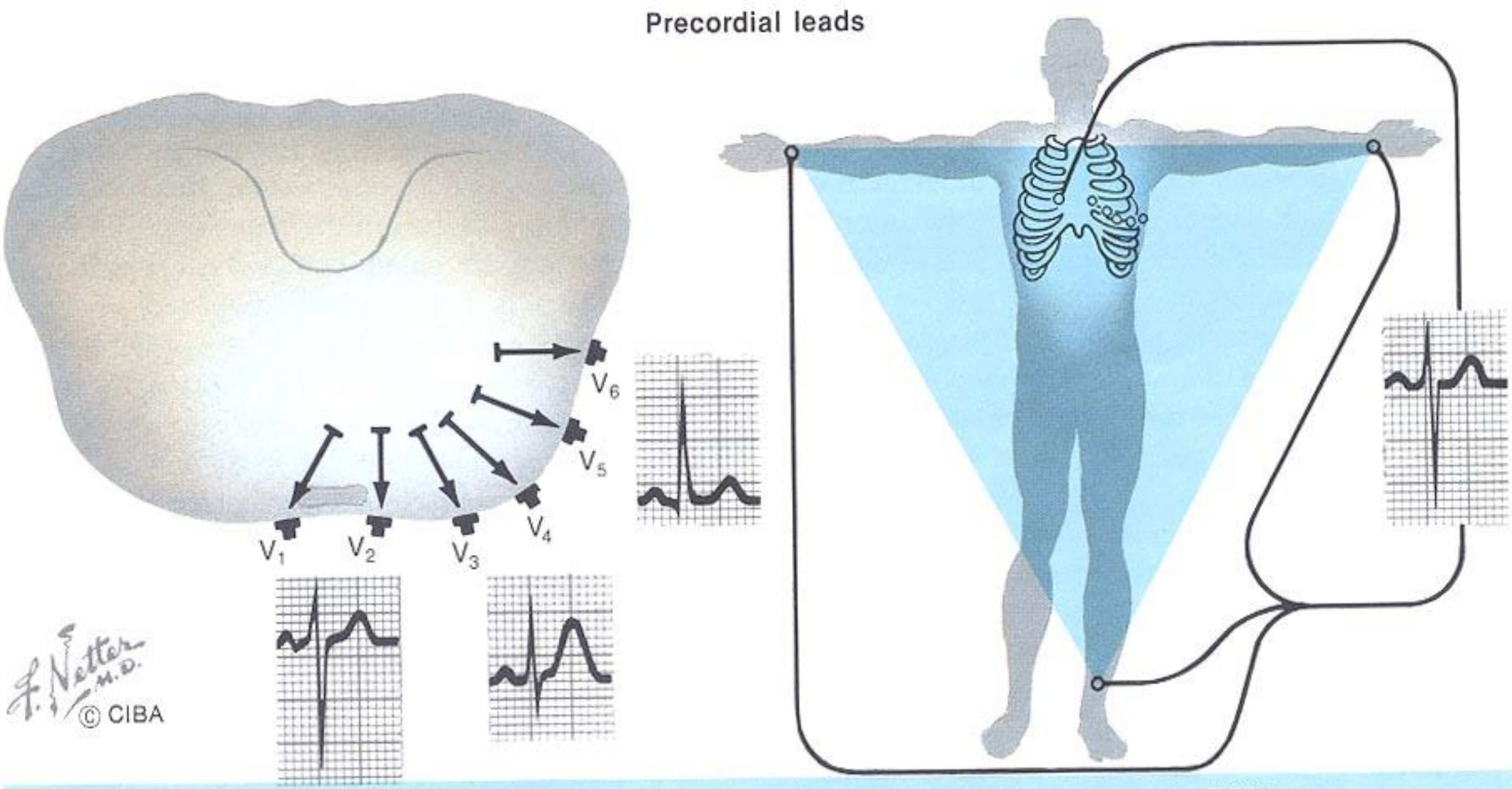
The Concept of a "Lead"

Summary of the "Limb Leads"

- Each of the limb leads (I, II, III, aVR, aVL, aVF) can be assigned an angle of clockwise or counterclockwise rotation to describe its position in the frontal plane



ECG Precordial Leads

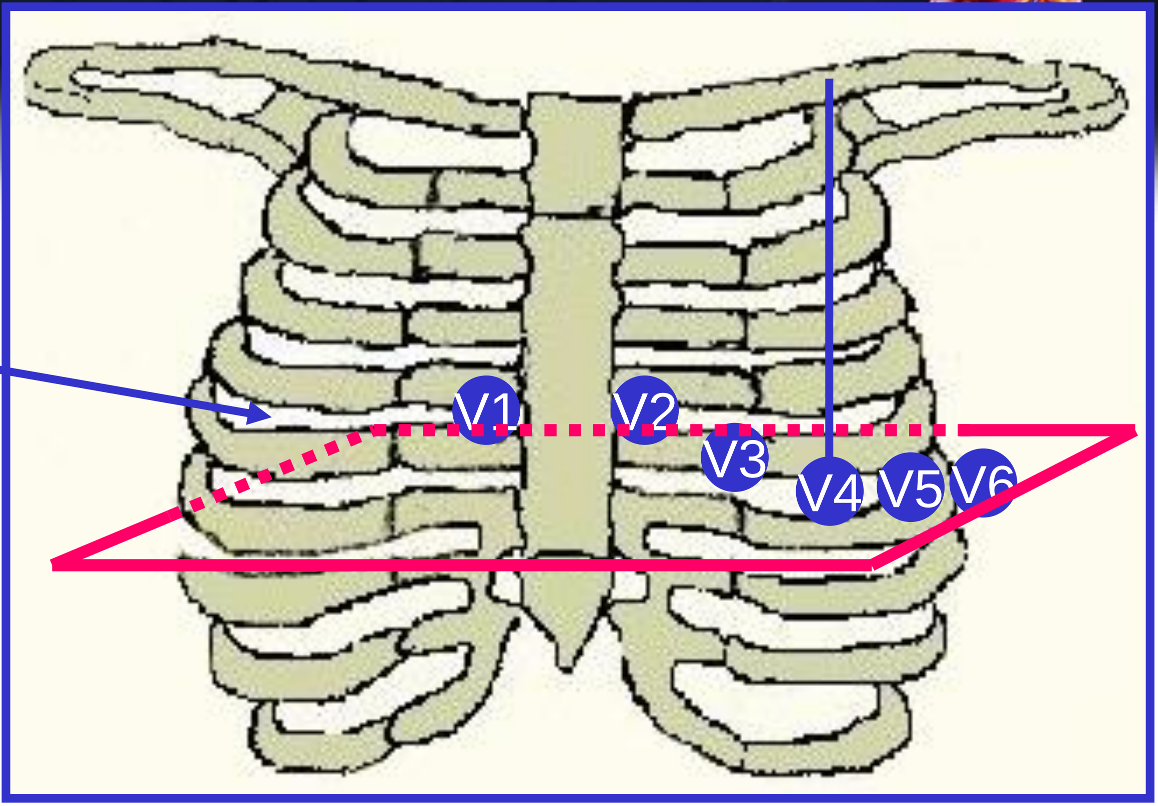


When current flows toward arrowheads (axes), upward deflection occurs in ECG
When current flows away from arrowheads (axes), downward deflection occurs in ECG
When current flows perpendicular to arrows (axes), no deflection occurs

The Concept of a “Lead”

The “Precordial Leads”

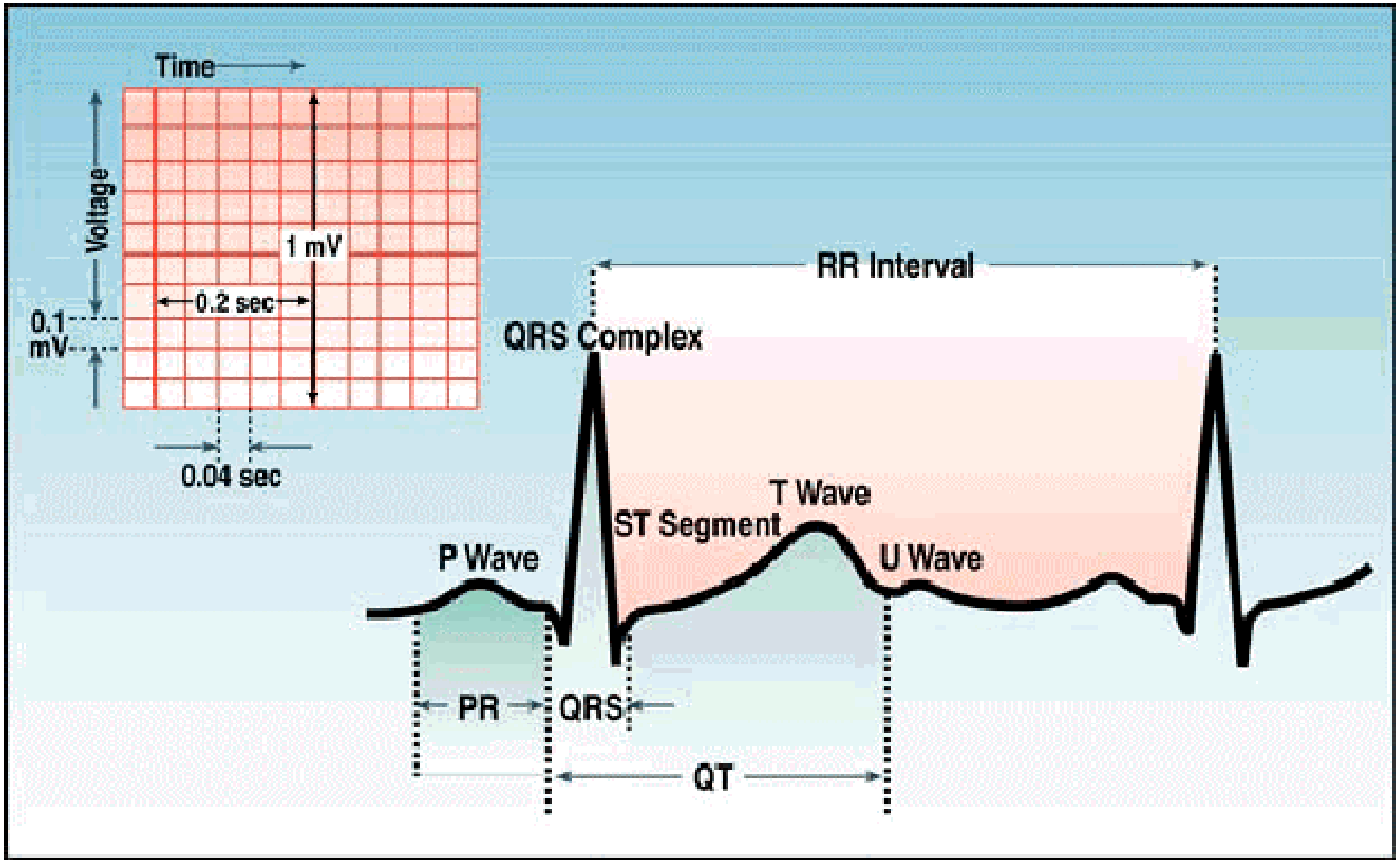
4th intercostal space



- Each of the precordial leads is unipolar (1 electrode constitutes a lead) and is designed to view the electrical activity of the heart in the **horizontal** or **transverse plane**

- V1 - 4th intercostal space - right margin of sternum
- V2 - 4th intercostal space - left margin of sternum
- V3 - linear midpoint between V2 and V4
- V4 - 5th intercostal space at the mid clavicular line
- V5 - horizontally adjacent to V4 at anterior axillary line
- V6 - horizontally adjacent to V5 at mid-axillary line

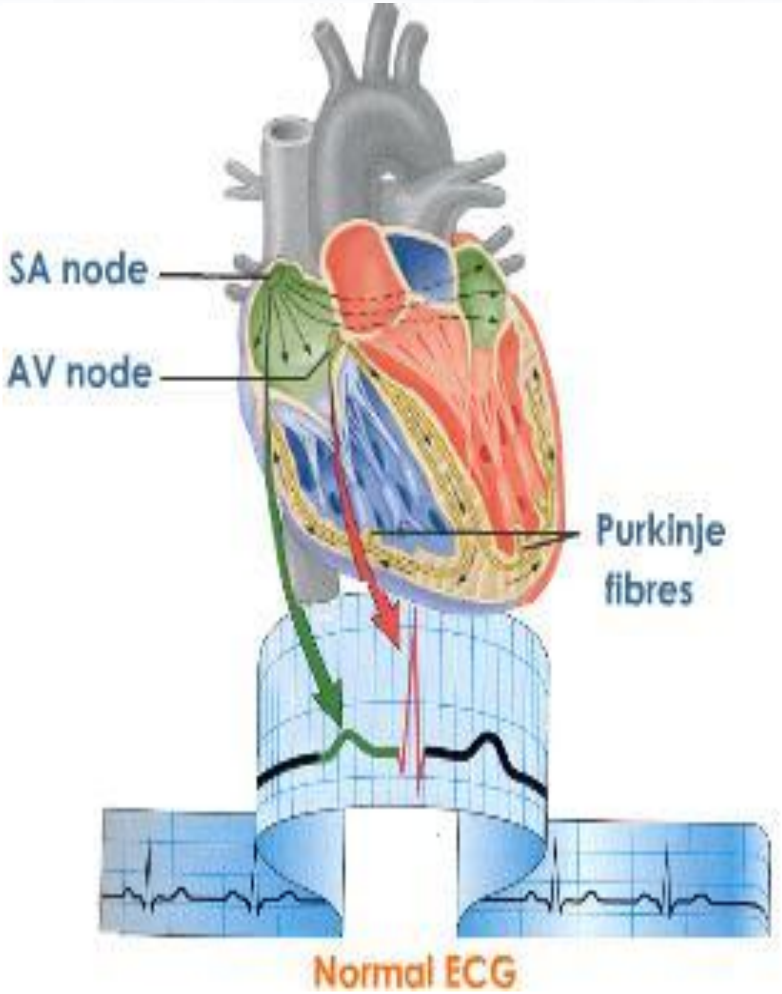
ECG contents

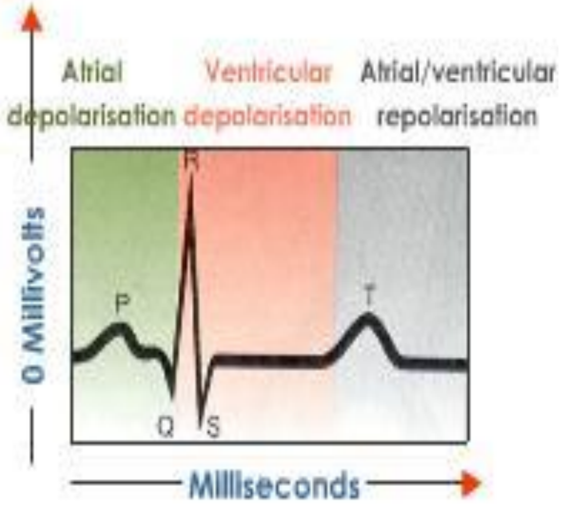


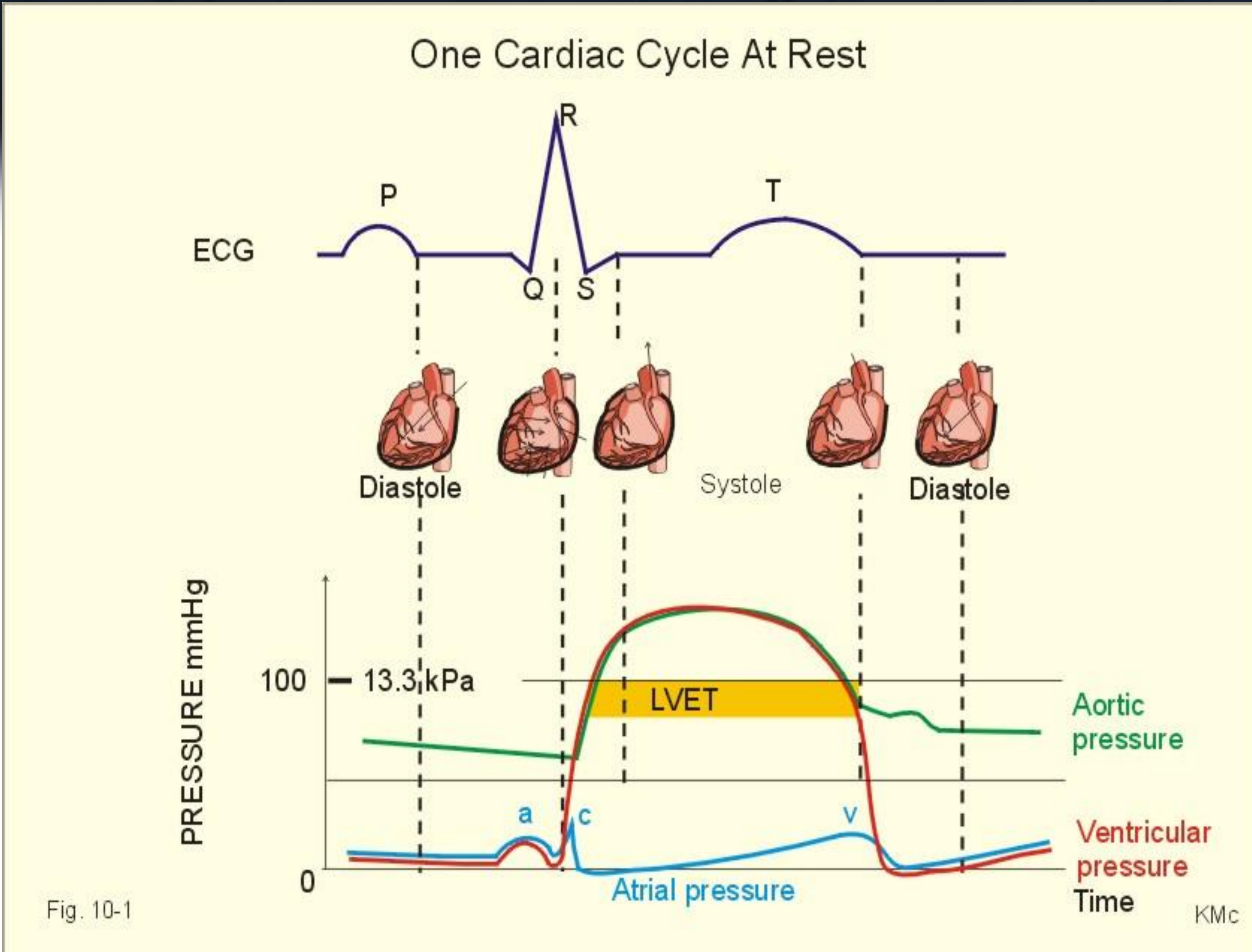
Portions of ECG

- P wave- corresponds to atrial depolarization or contraction.
  - May be positive, negative or biphasic depending on the lead
- QRS waves- corresponds to ventricular depolarization or contraction
  - Q wave- first negative deflection
  - R wave- first positive deflection
  - S wave- negative deflection that follows the R wave
- T wave- corresponds with ventricular repolarization or relaxation
- Every QRS complex HAS to have a T wave following it.

Portions of ECG

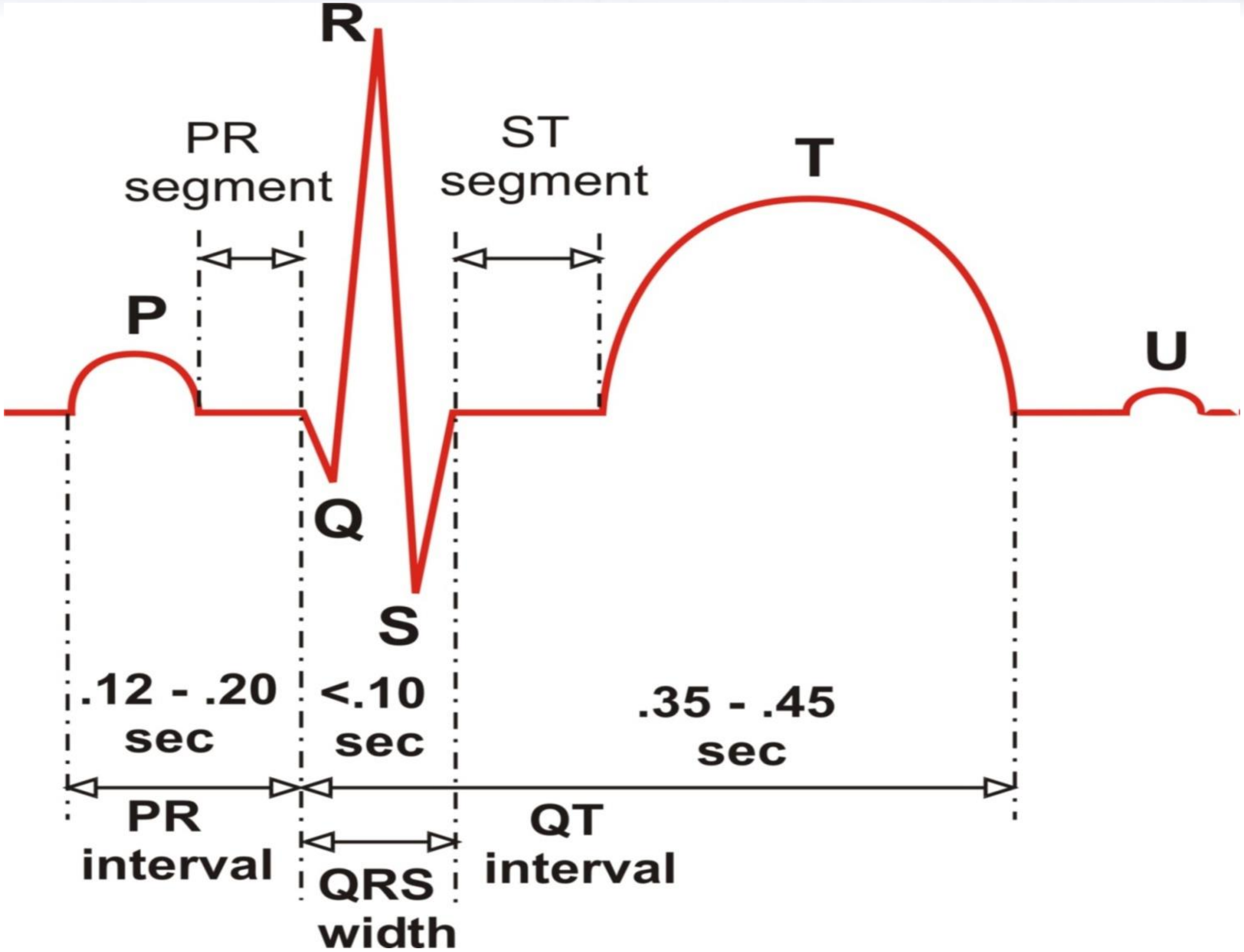




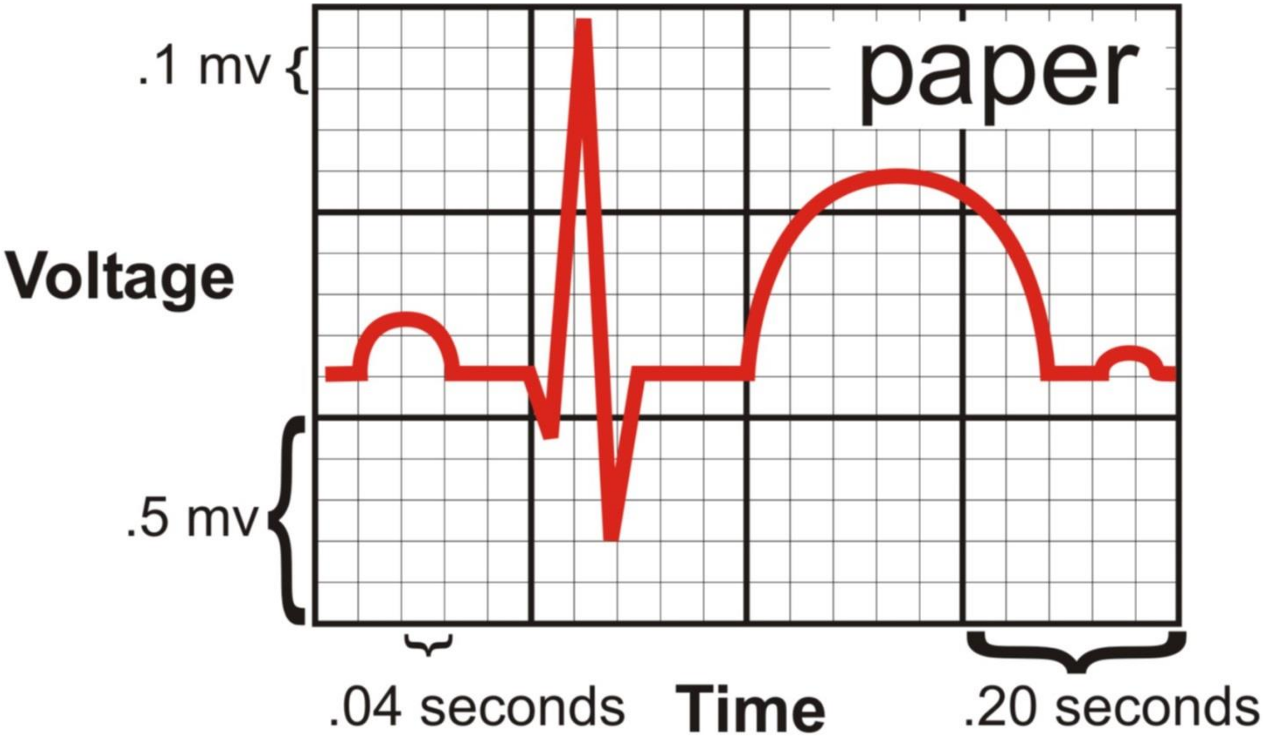


One Cardiac Cycle At Rest
R
P
T
ECG
Q
S
Diastole
Systole
Diastole
PRESSURE mmHg
100
13.3 kPa
LVET
Aortic pressure
a
c
v
Ventricular pressure
0
Atrial pressure
Time
Fig. 10-1
KMc

ECG contents



ECG Paper and related Heart Rate & Voltage Computations



Paper speed = 25mm / second

Heart Rate = number of R-waves in a 6 second strip divided by 10
= 1500 divided by the number of small boxes between consecutive R-waves
= large square estimation counts (300 - 150 - 100 - 75 - 60 - 50 - 43)

CMFT

ugme

undergraduate medical education

Applications of the Electrocardiogram

- Acute onset of dyspnea
- Shock
- Fainting or seizures
- Monitoring during and after surgery (monitors depth of anesthesia as well as cardiac monitoring).
- All cardiac murmurs
- Cardiomegaly that is found on thoracic radiographs
- Preoperatively
- Cyanosis

Applications of ECG

- Evaluating effect of cardiac drugs
- Periocardiocentesis
- Systemic diseases
- Electrolyte disturbances

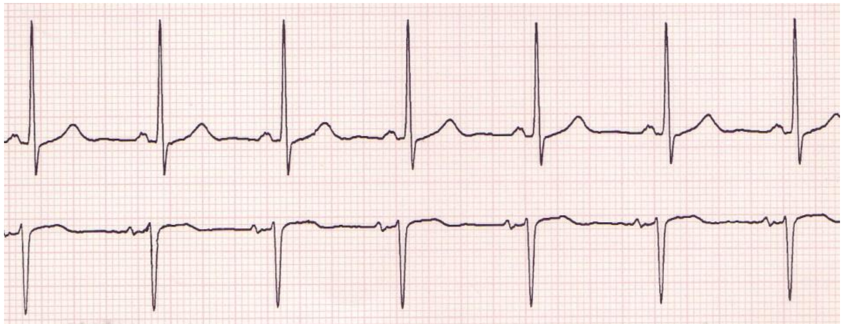
Performing an ECG

- Standing or right lateral recumbency.
- Alcohol or conductive gel

- Typical recordings should be a minimum of 30 seconds but a good recording should be about 2 minutes long.

Considerations

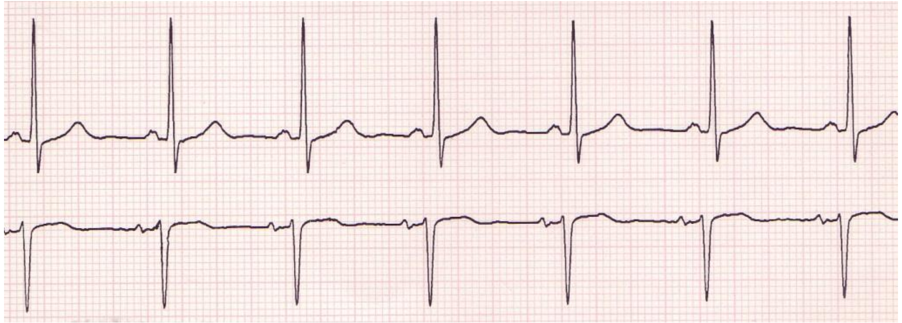
- Center the recording on the paper (if using paper printout) so that both the top and bottom of the waveforms can be seen. Adjust the position control if the tracing wanders



- Decrease the sensitivity to ½ cm=1 mv if the QRS complexes go off the paper

Considerations

- Increase the length of the tracing if an arrhythmia is seen



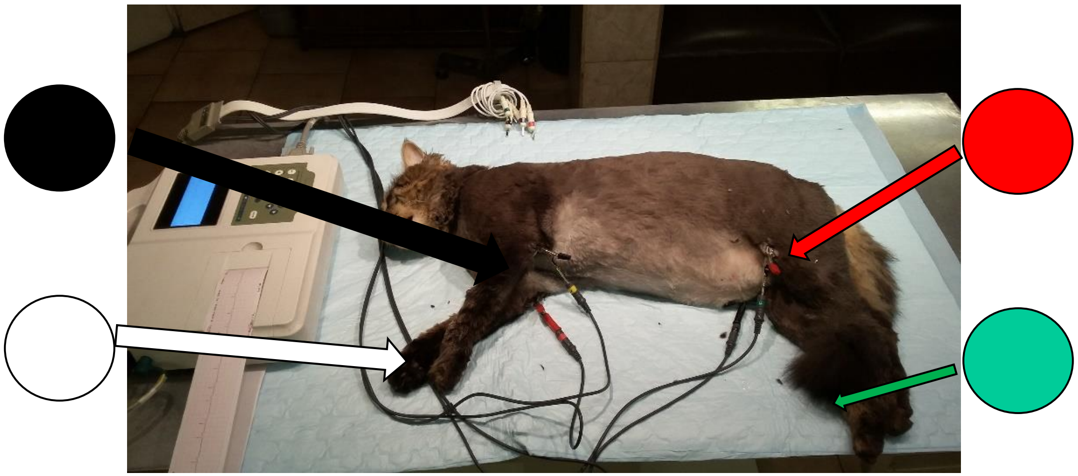
- R waves should be positive on lead I. If negative, check the lead wires to determine whether they are attached to the correct limbs. If connections are correct, then a true abnormality exists.

UK Lead convention

- RED – Right Fore
- YELLOW – Left Fore
- GREEN – Left Hind
- BLACK – Right Hind (reference electrode)

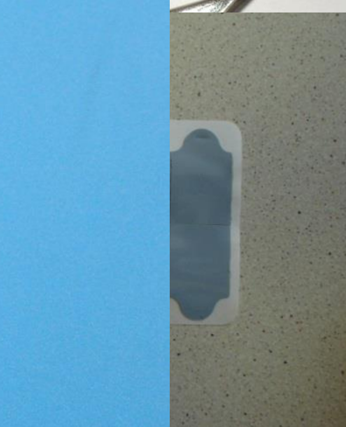
USA Lead convention

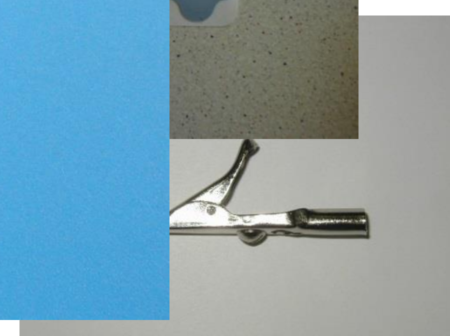
- RED – Left Hind
- WHITE – Right Fore
- BLACK – Left Fore
- GREEN – Right Hind (reference electrode)



Methods of attach

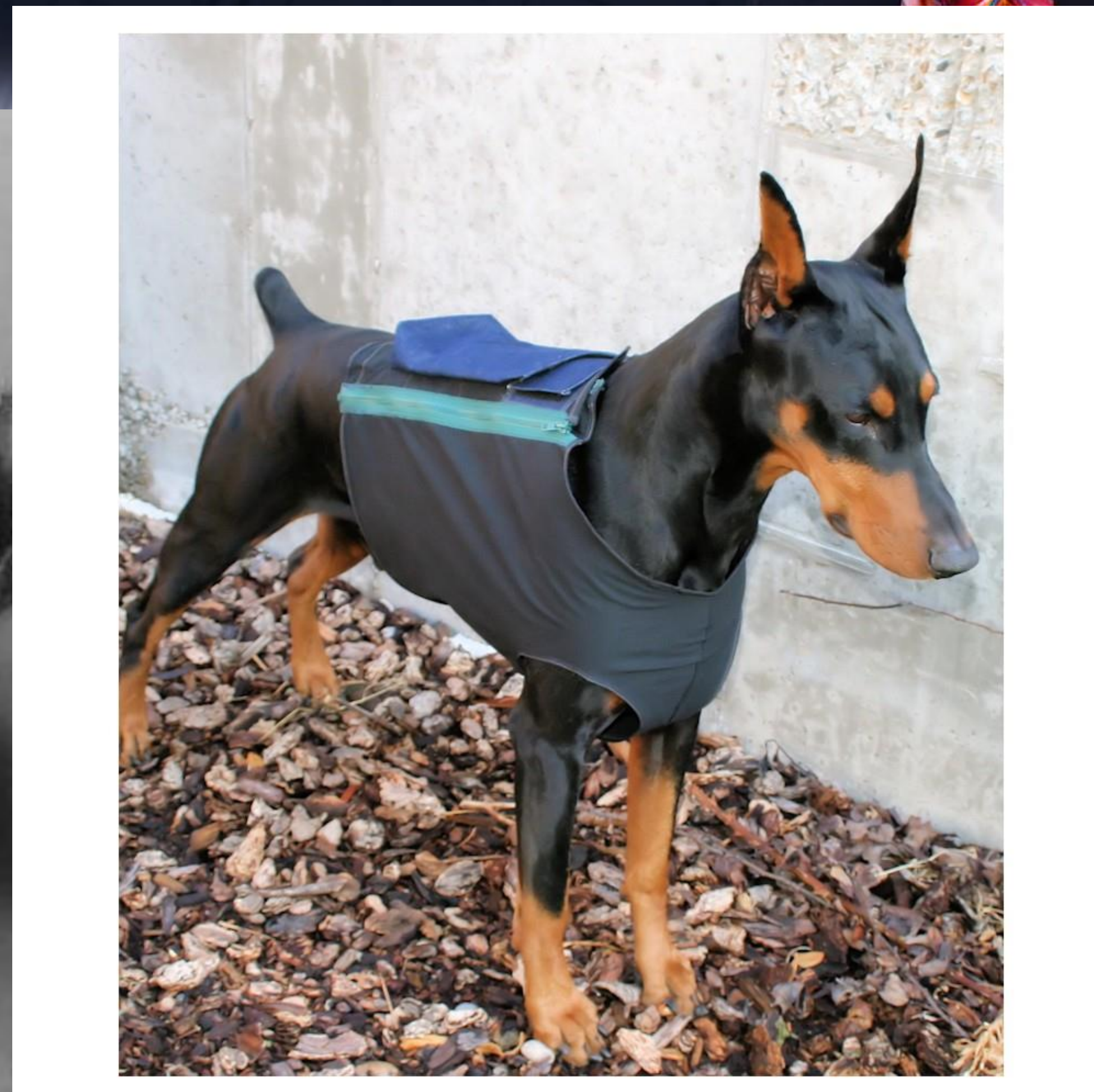
- Prim
  - Ma rea .
  - Mi
  - Minimize r
- Opt
  - C
  - S
  - Limb Pla
  - Hypoder





Minimise contact resistance

- Ha ven wh
- Re
  - pads
- Fo me
- Us

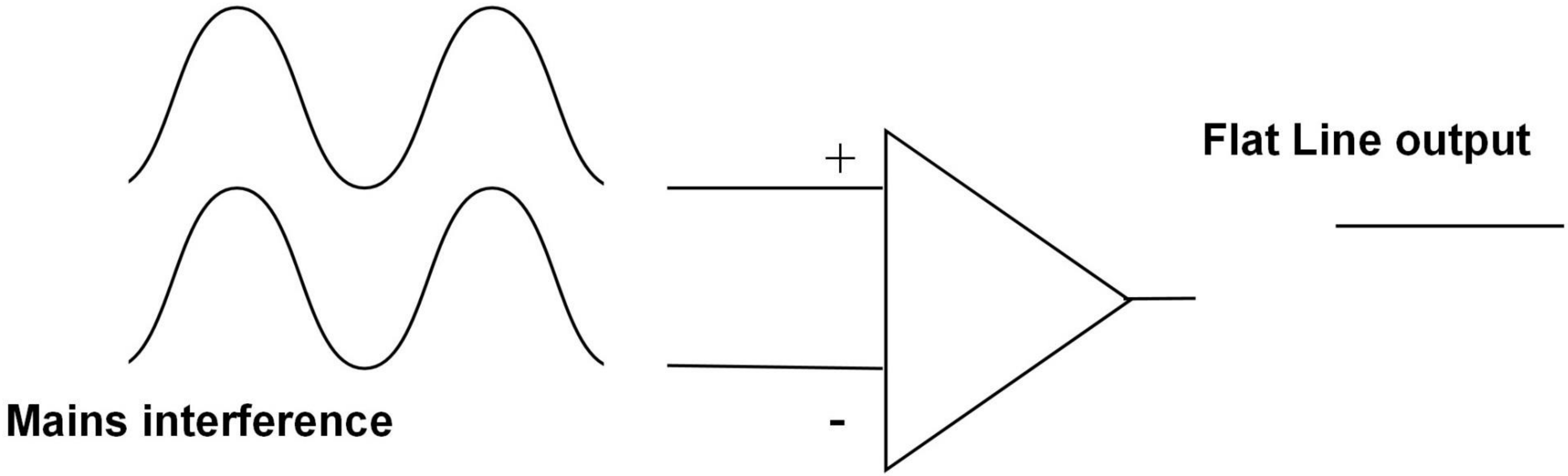


Agent	*Pros*	*Cons*	*Contact Time*
Surgical Spirit	Promotes good contact. Cheap. Easily available	Smell. Irritant. Short contact time	10-15 minutes
Isopropyl Alcohol	Promotes good contact. Reasonably cheap	Smell. Irritant	30-40 minutes
Electrolyte Solution, e.g. Signa Spray by Parker	Non-irritant. Good contact. Low/zero odour	Less readily available. Increased cost	1hour+
Cardiac Gel	Good sustained contact	Less easily available. Increased cost. Messy. Clogs up electrodes.	2 hours+
Self adhesive Electrodes	Clean. New contact every time. Simple to use	More expensive Must prepare area. Not re-usable	2 hours+ Up to days in some cases

Minimise Noise Pickup

- Cable position is extremely important
- Due to phenomenon of Common Mode Rejection
- Simply put – For best rejection of noise all leads must “see” the same interference and so follow the same path

Common Mode Rejection

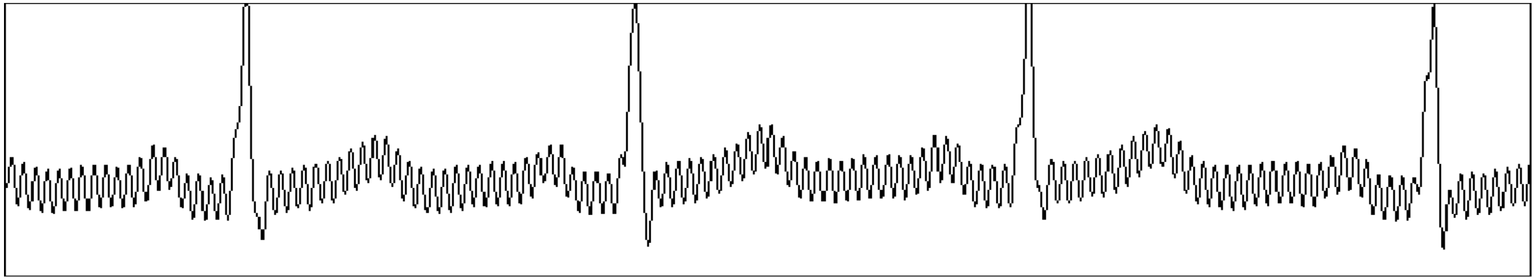


Improving Common Mode Rejection

- Minimise contact resistance
- All leads should be same length especially if unshielded
- All leads should run as close together as possible

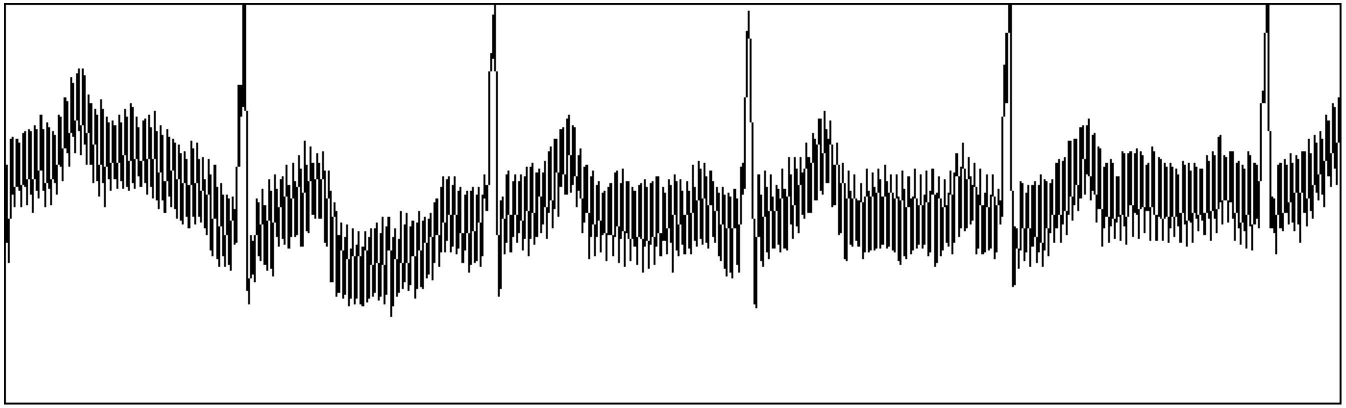
Effect of cable spread

- The two pictures show the ECG of the patient with spread cables and with parallel cables



Solutions for noise reduction

- Test the machine
- Remove Causes of interference

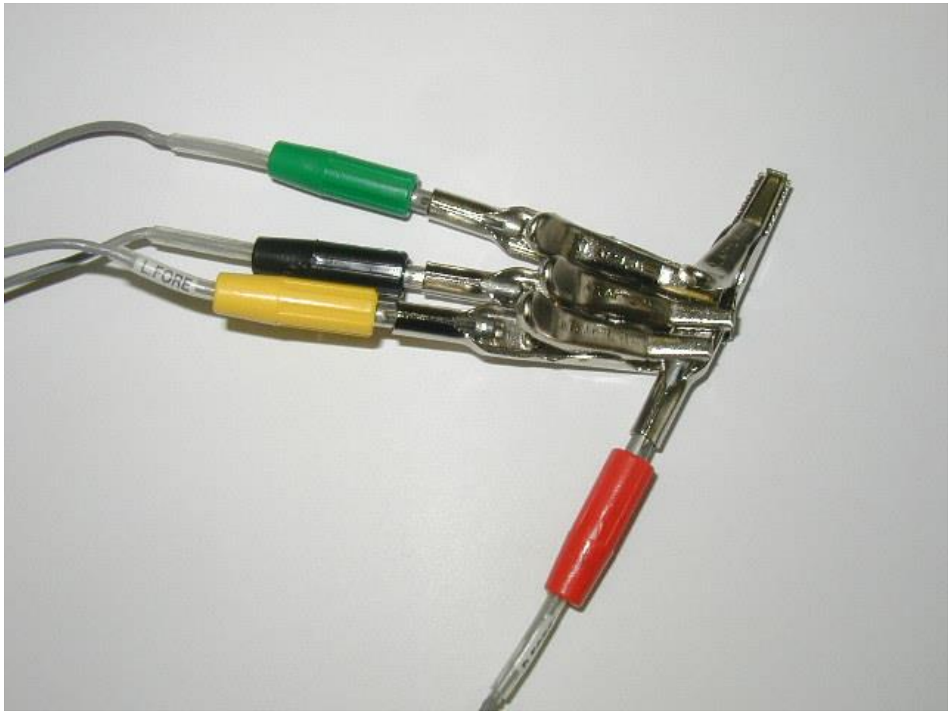


Test the Machine

- Two very simple tests to assess the ECG machine
  - All Leads together
  - Individual Lead test

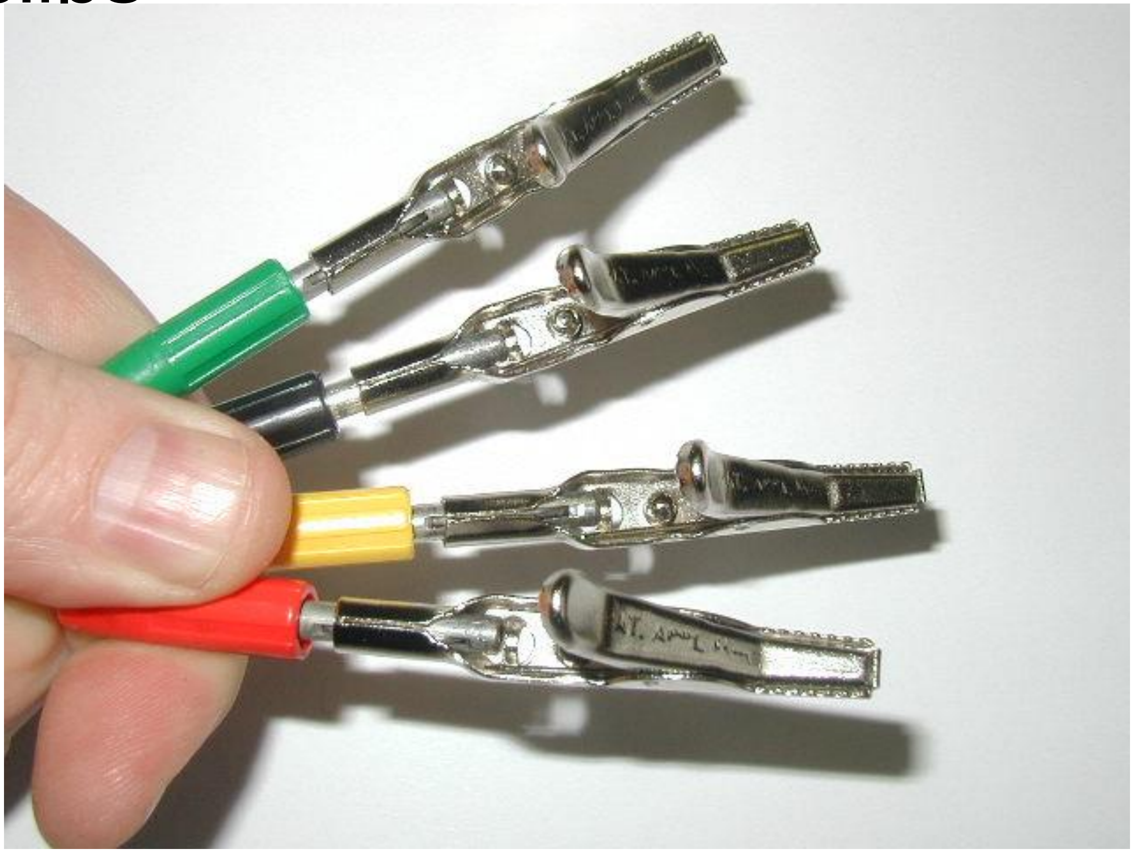
All Leads together

- On all Lead settings of the machine there should be a completely flat line. If not, there is a fault



Individual Lead Test

- Hold all four leads in one hand and fan out the clips



Individual Lead Test

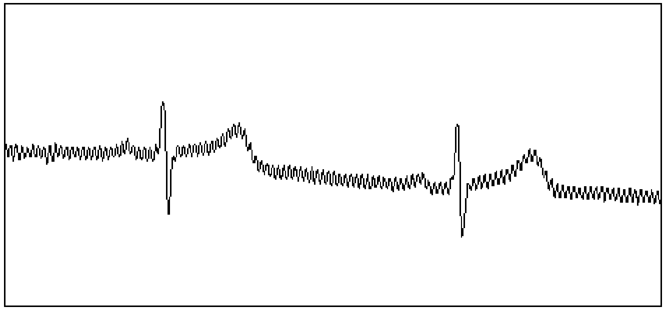
- Touching any one of these leads (except Right Hind) should cause massive stylus movement or screen trace deflection.
- Touch each in turn. A properly functioning machine will have the following response

Individual Lead Test

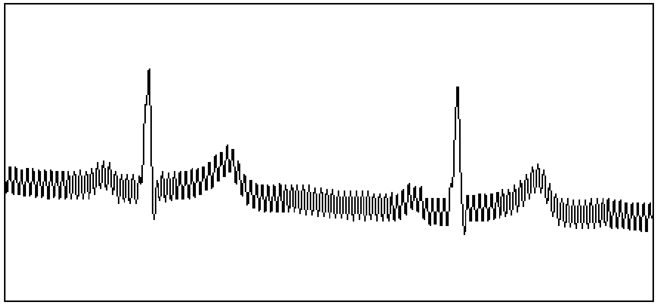
- Lead I
  - Response with Right Fore and Left Fore
  - No response with Left Hind or Right Hind
- Lead II
  - Response with Right Fore and Left Hind
  - No response with Left Fore or Right Hind
- Lead III
  - Response with Left Fore and Left Hind
  - No response with Right Fore or Right hind

Deducing a Lead problem from the ECG Result

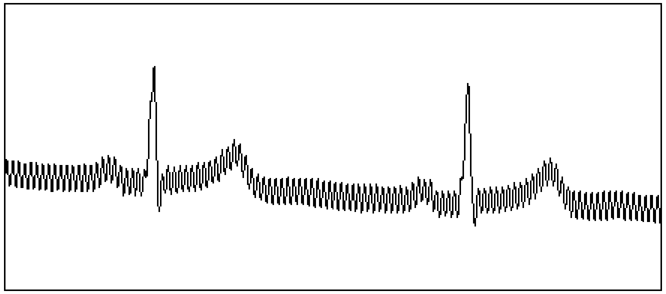
- Right Hind contact problem



Lead I



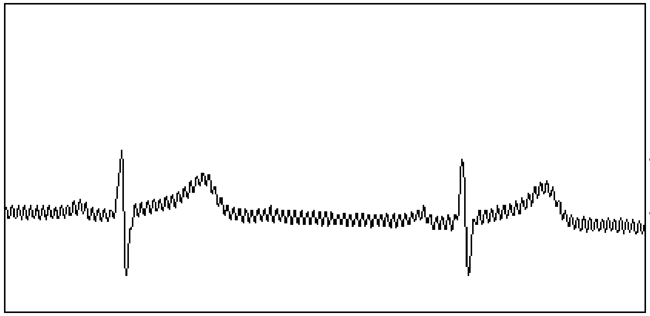
Lead II



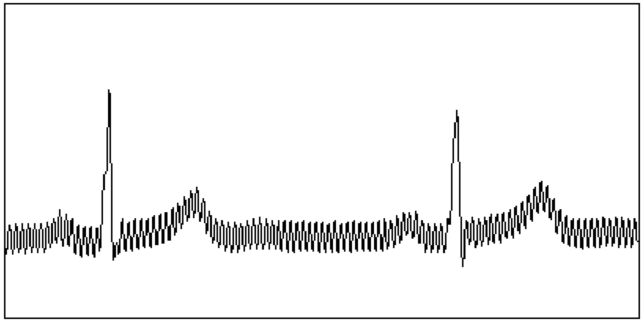
Lead III

Deducing a Lead problem from the ECG Result

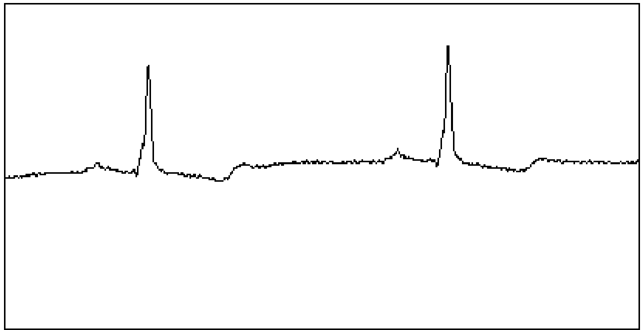
- Right Fore contact problem



Lead I



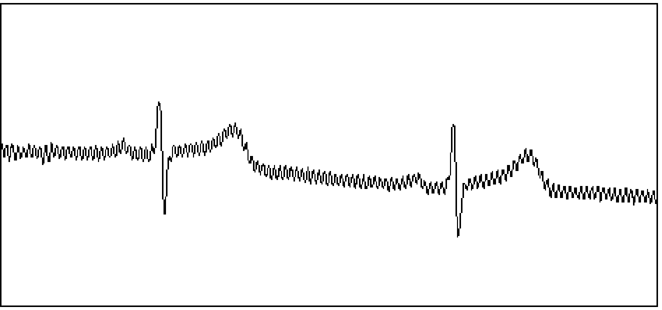
Lead II



Lead III

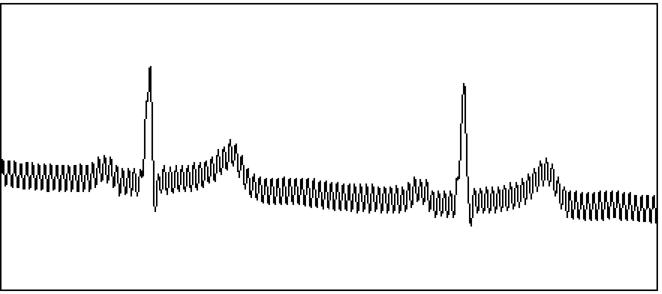
Deducing a Lead problem from the ECG Result

- Left Fore contact problem



Lead I

Lead II

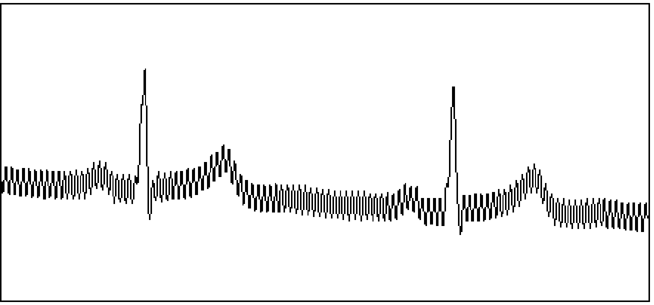


Lead III

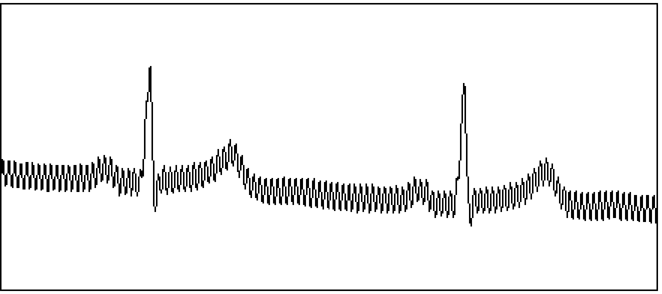
Deducing a Lead problem from the ECG Result

- Left Hind contact problem

Lead I



Lead II



Lead III

Sources of interference

- Movement
- Mobile phones
- Newer digital Cordless phones

Interpretation of ECG

Systematic approach

- Rate
- Rhythm
- Axis
- Wave Morphology
  - P, T, and U waves and QRS complex
- Intervals
  - PR, QRS, QT
- ST Segment

Rate Determination

First measurement to calculate is heart rate. PQRST waves represent one complete cardiac cycle.

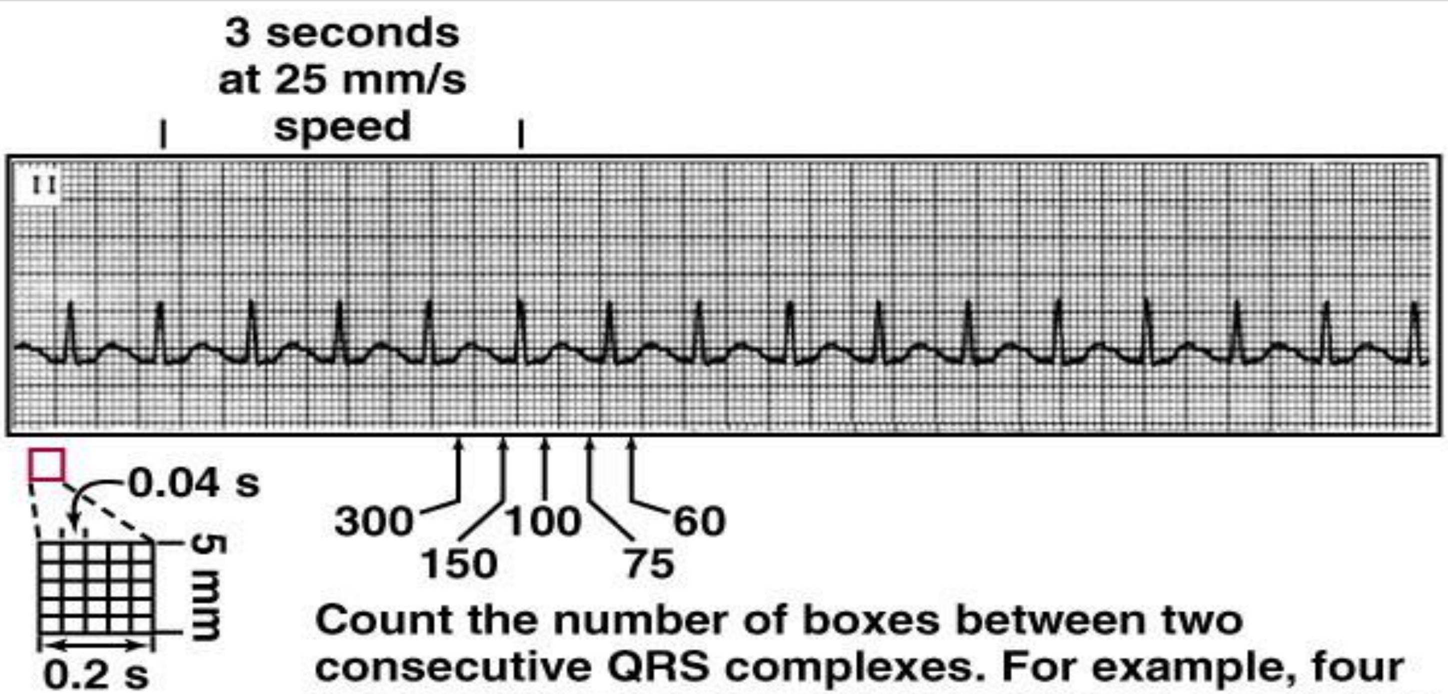
- At standard paper speed, divide 1500 by distance between R to R waves.
- Find R wave on heavy line. Count off 300, 150, 100, 75, 60 for each following line. Where next R lands is quick estimate.
- Multiply number of cycles in 6 second marks by 10.

Rate Determination

21.3HT, A-C. Three methods for determining heart rate.

Rate Determination

Determining heart rate



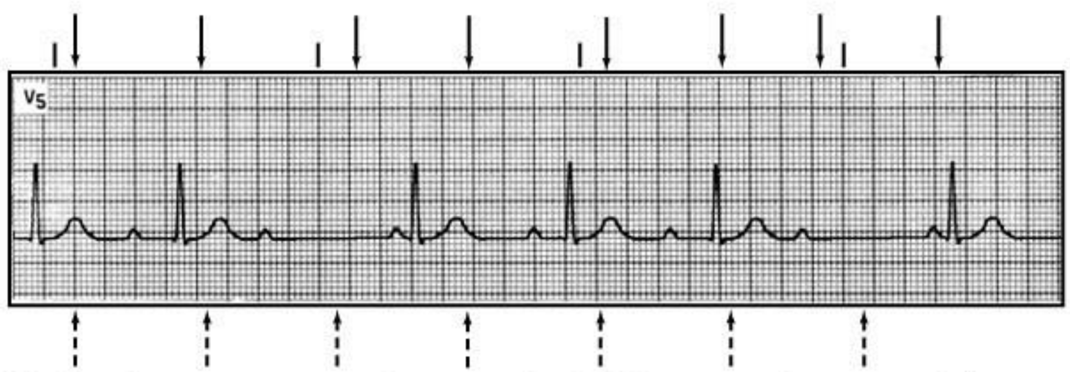
Count the number of boxes between two consecutive QRS complexes. For example, four boxes between two complexes would equate to a heart rate of 75 b/min.

Heart rhythm Determination

- Normal heart rhythm has consistent R-R interval.
- Mild variations due to breathing also normal.

Determining heart rhythm

Actual rhythm. It is normal to have mild variations between beats due to fluctuations in discharge from the SA Node, and due to the altered stroke volumes during inspiration (decreases) and expiration (increases).



If rhythm was regular, each QRS complex would fall on these arrow marks

Heart rhythm Determination

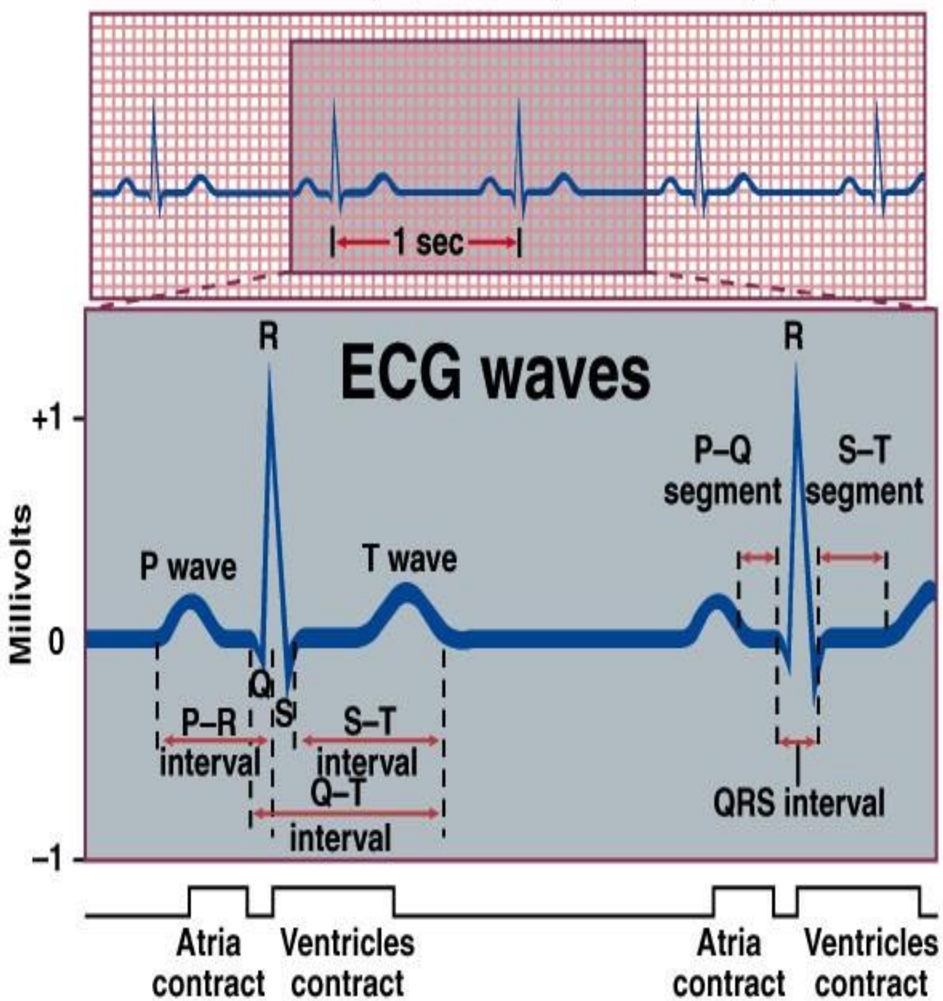
Normal sinus rhythm

- **Rate is 60 to 100**

Heart rhythm Determination

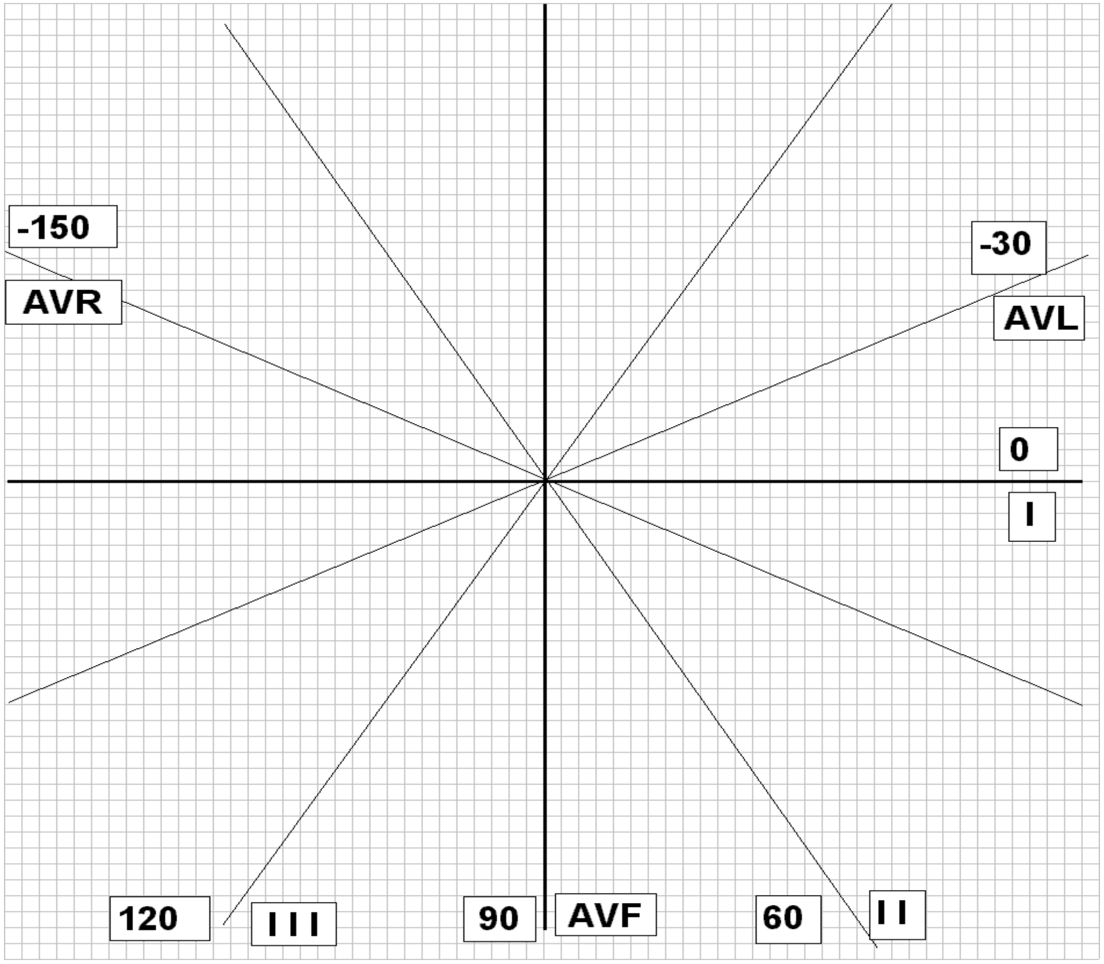
Normal Sinus Rhythm

- Rate: 60-100 b/min
- Rhythm: regular
- P waves: upright in leads I, II, aV_F
- PR interval: < .20 s
- QRS: < .10 s



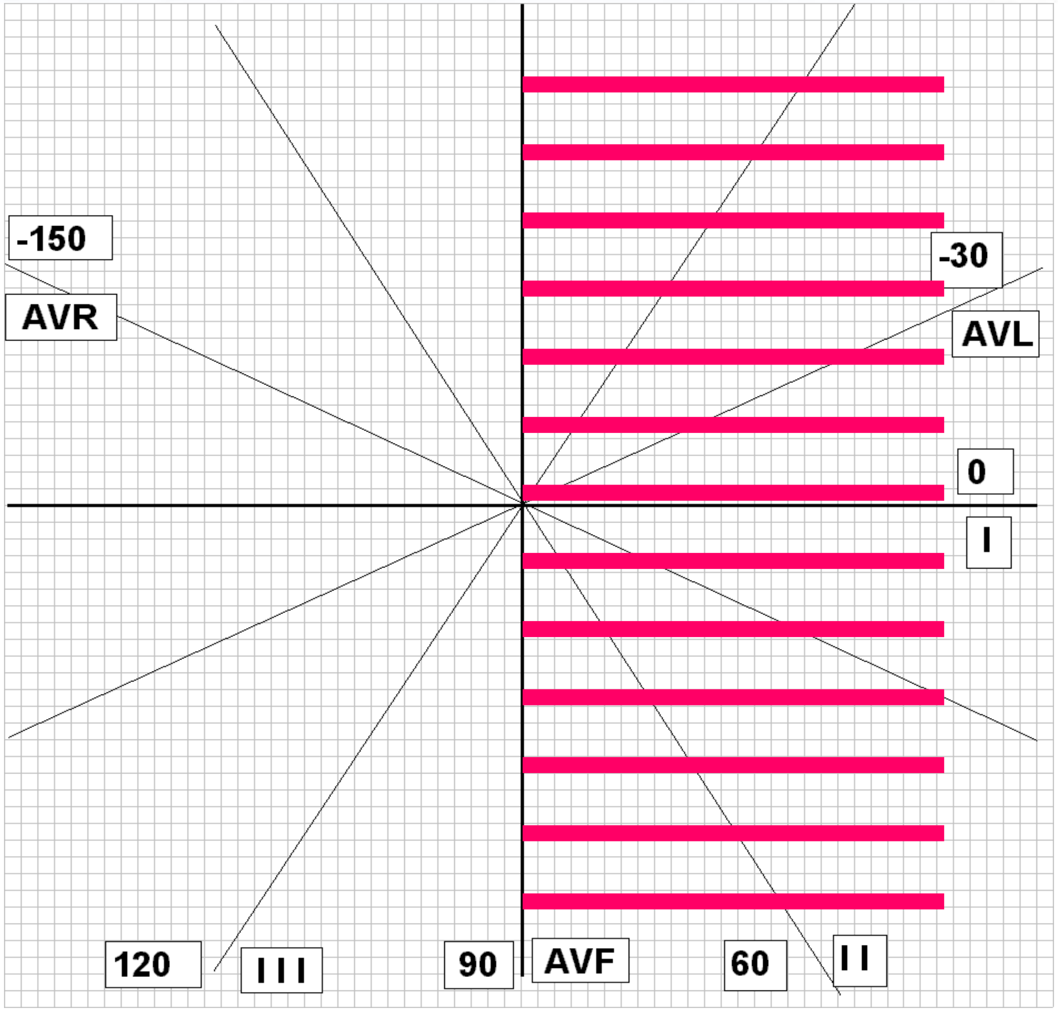
Hexaxial Array for Axis Determination

Determination of the angle of the **main cardiac vector** in the frontal plain



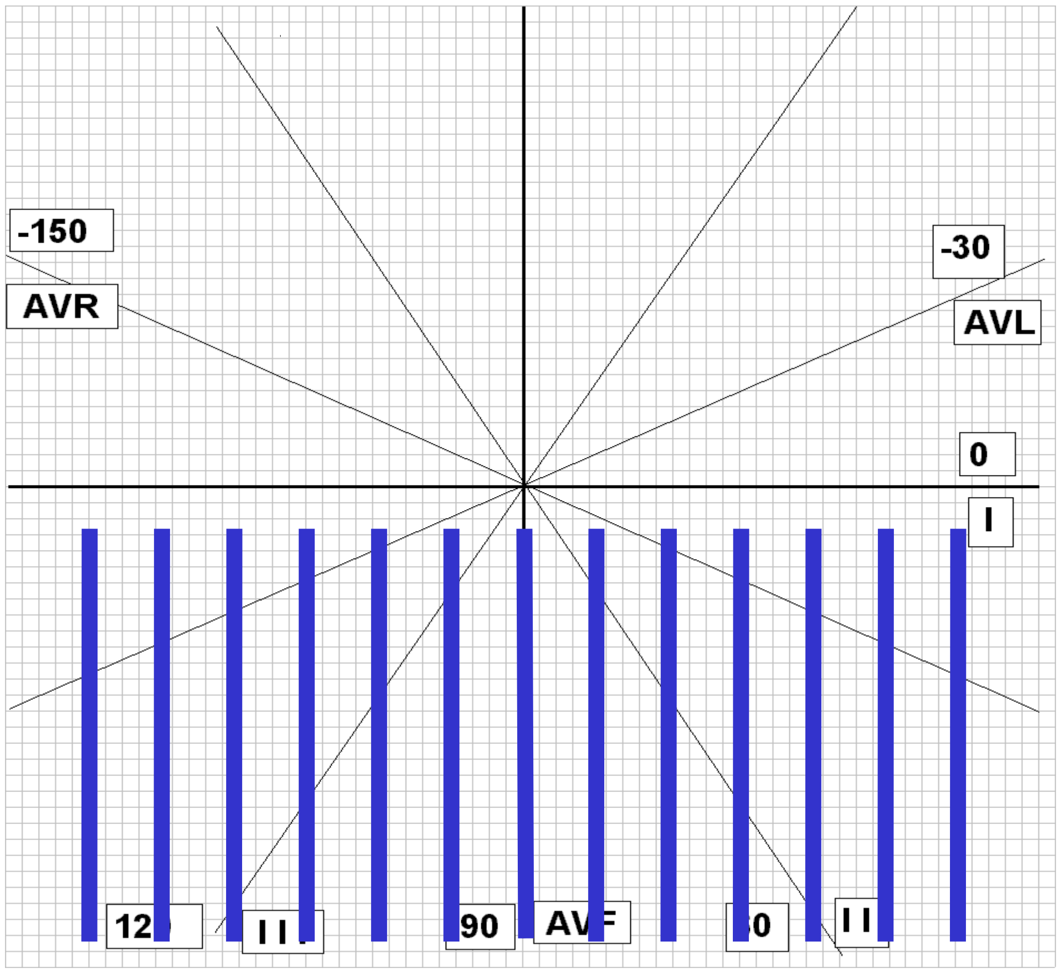
Hexaxial Array for Axis Determination – Example 1

If lead I is mostly positive, the axis must lie in the right half of of the coordinate system (the main vector is moving mostly toward the lead's positive electrode)

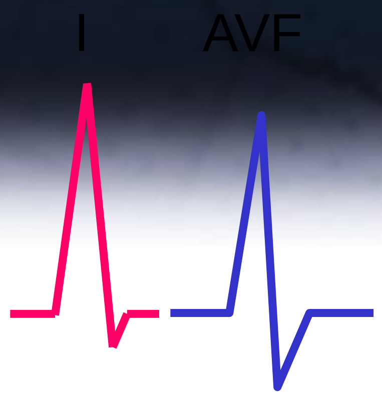


Hexaxial Array for Axis Determination – Example 1

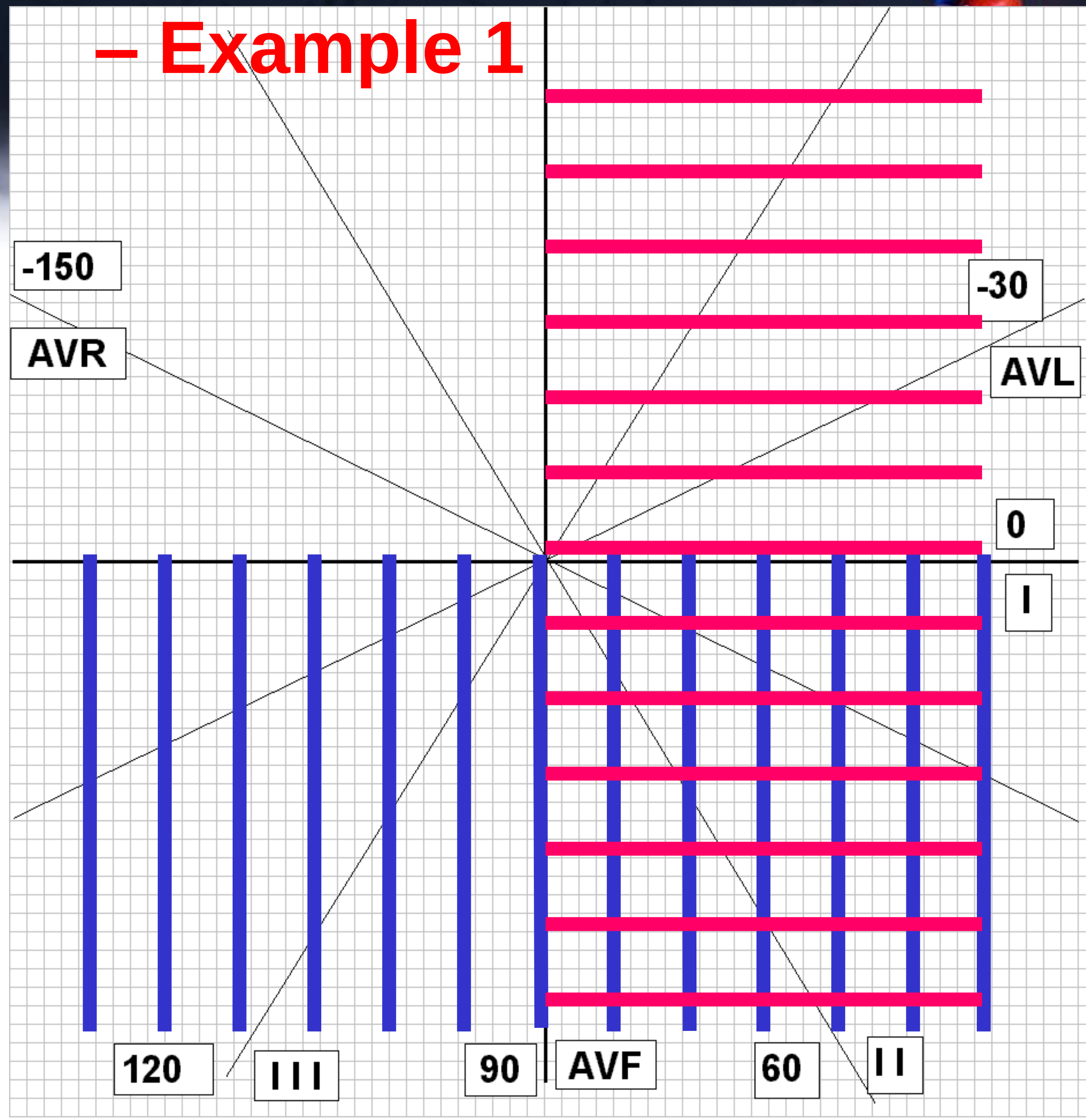
If lead aVF is mostly positive, the axis must lie in the bottom half of of the coordinate system (again, the main vector is moving mostly toward the lead's positive electrode



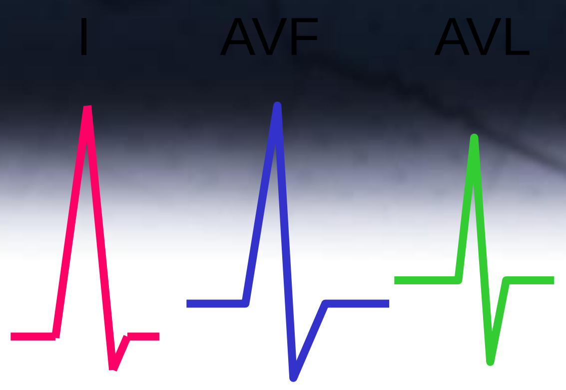
Hexaxial Array for Axis Determination – Example 1



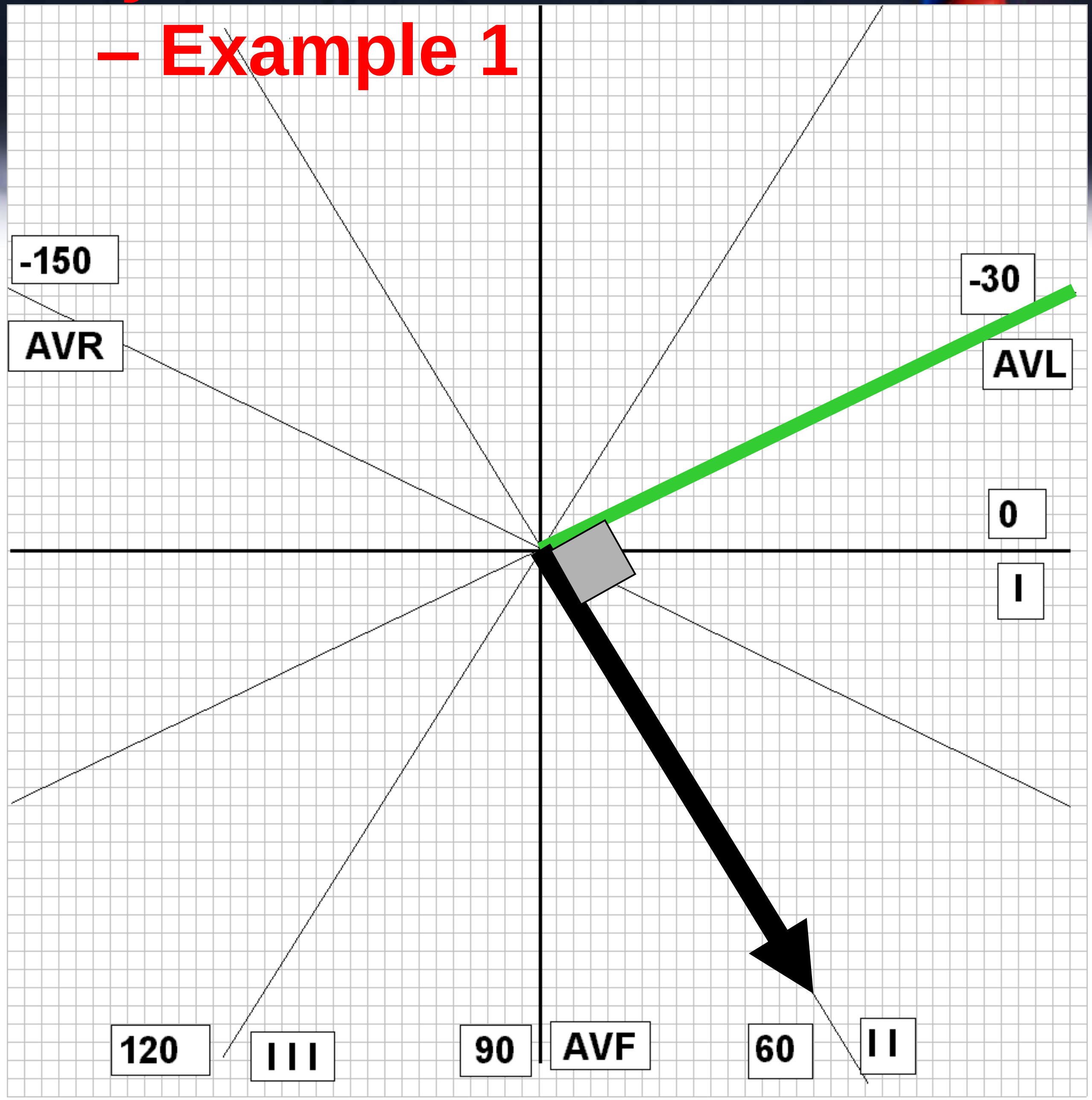
Combining the two plots, we see that the axis must lie in the bottom right hand quadrant



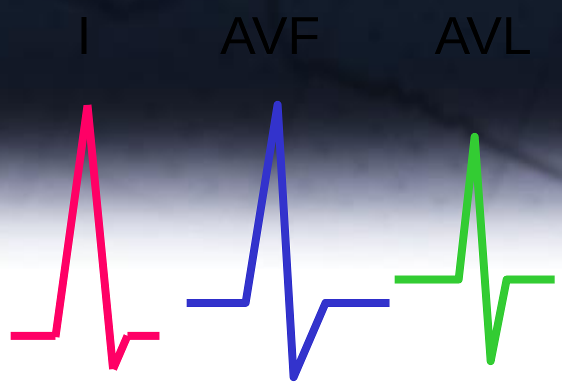
Hexaxial Array for Axis Determination – Example 1

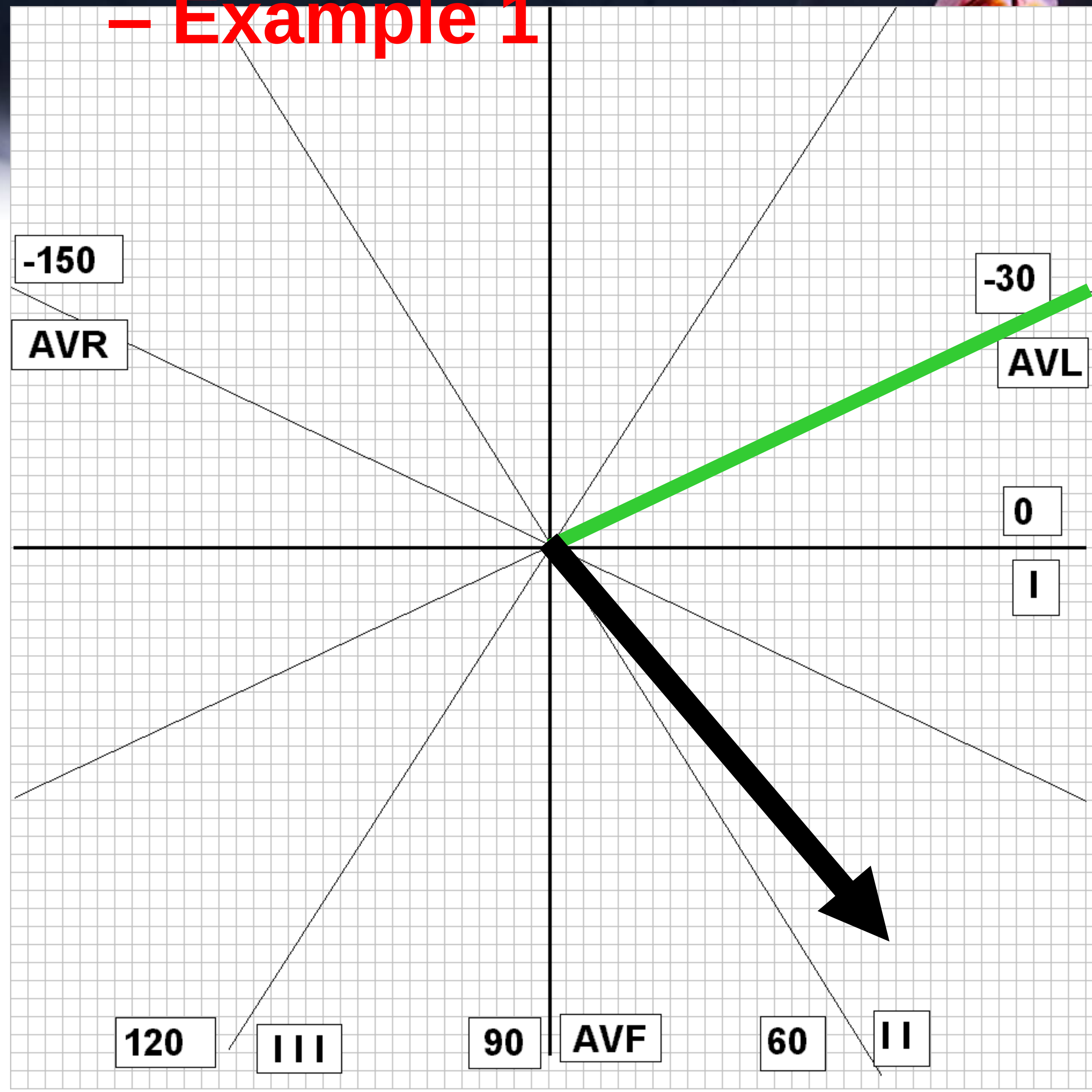


Once the quadrant has been determined, find the most equiphasic or smallest limb lead. The axis will lie about 90º away from this lead. Given that aVL is the most equiphasic lead, the axis here is at approximately 60º.



Hexaxial Array for Axis Determination – Example 1

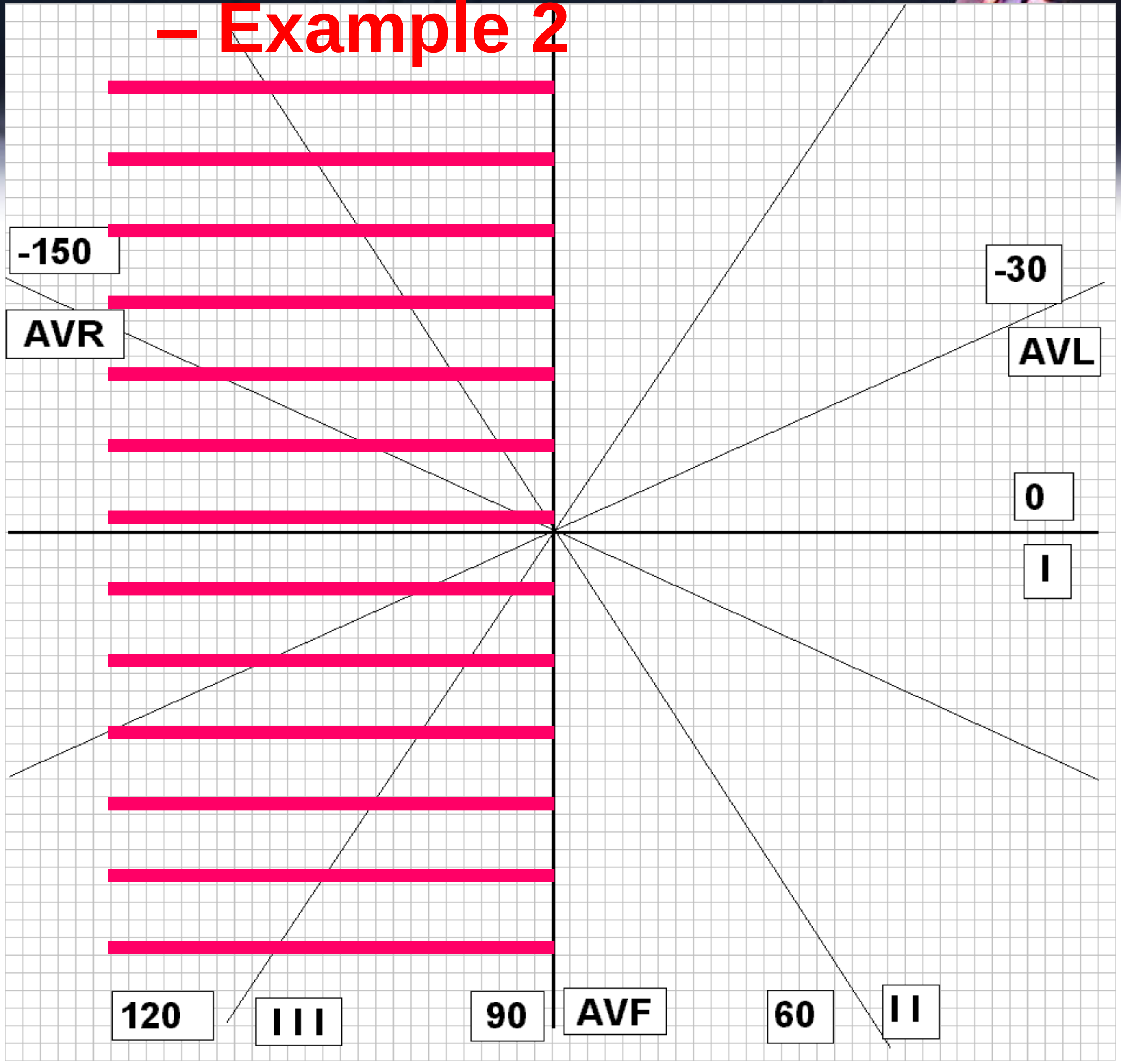




Since QRS complex in aVL is a slightly more positive, the true axis will lie a little closer to aVL (the depolarization vector is moving a little more towards aVL than away from it). A better estimate would be about 50º (normal axis).

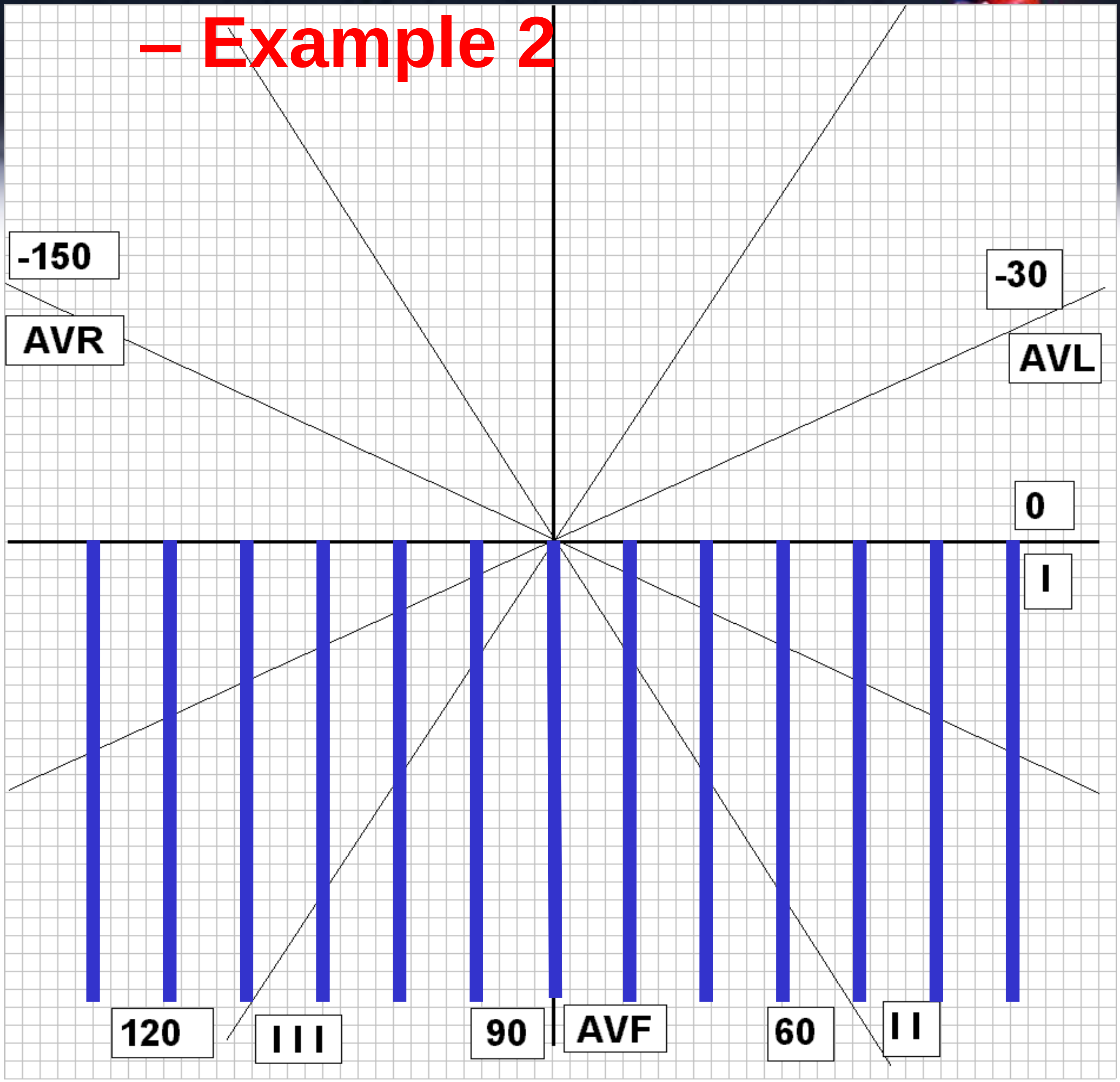
Hexaxial Array for Axis Determination – Example 2

If lead I is mostly negative, the axis must lie in the left half of of the coordinate system.

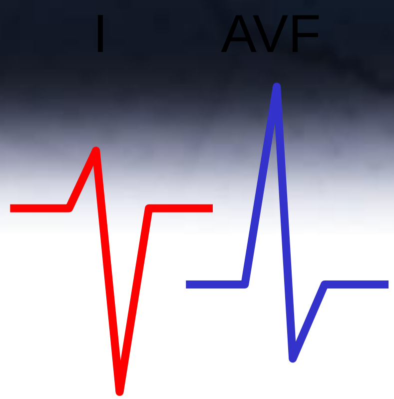


Hexaxial Array for Axis Determination – Example 2

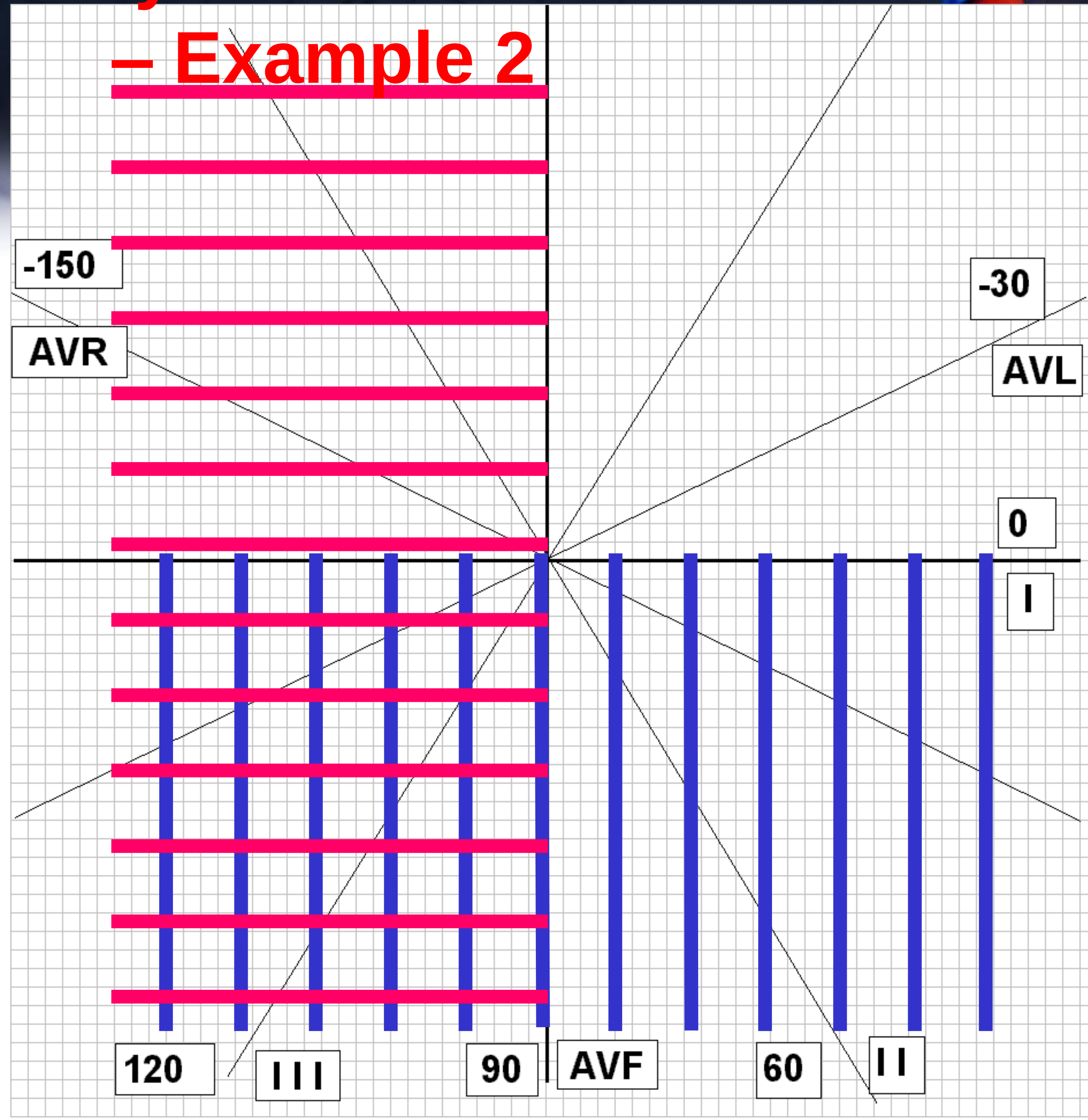
If lead aVF is mostly positive, the axis must lie in the bottom half of
of the coordinate system



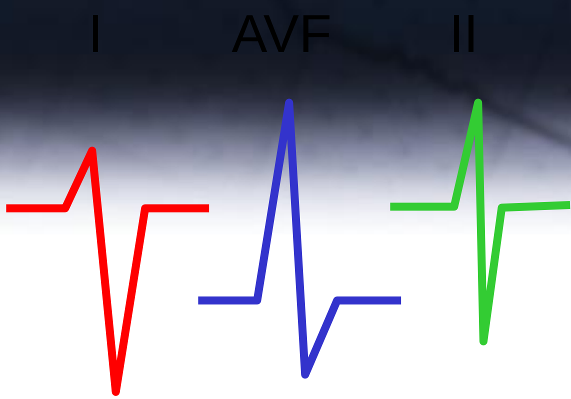
Hexaxial Array for Axis Determination – Example 2



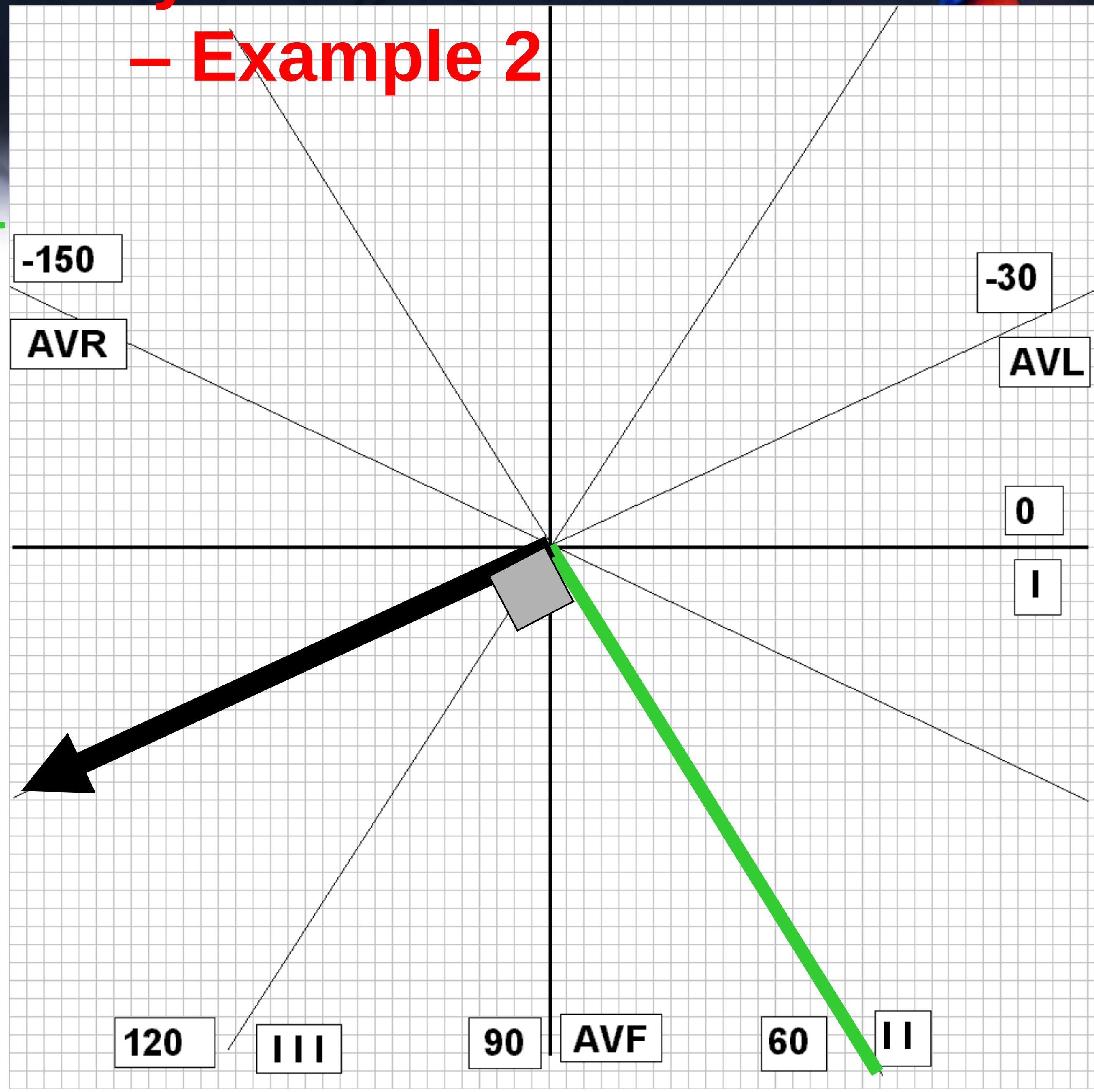
Combining the two plots, we see that the axis must lie in the bottom left hand quadrant (Right Axis Deviation)



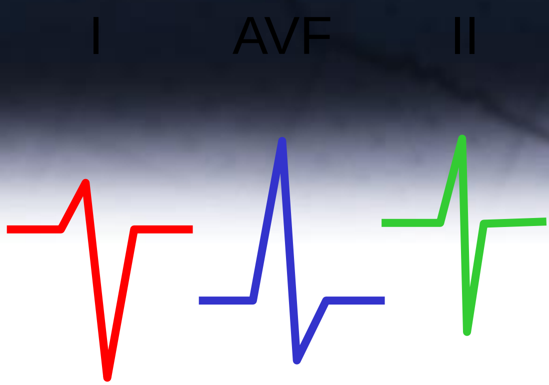
Hexaxial Array for Axis Determination – Example 2



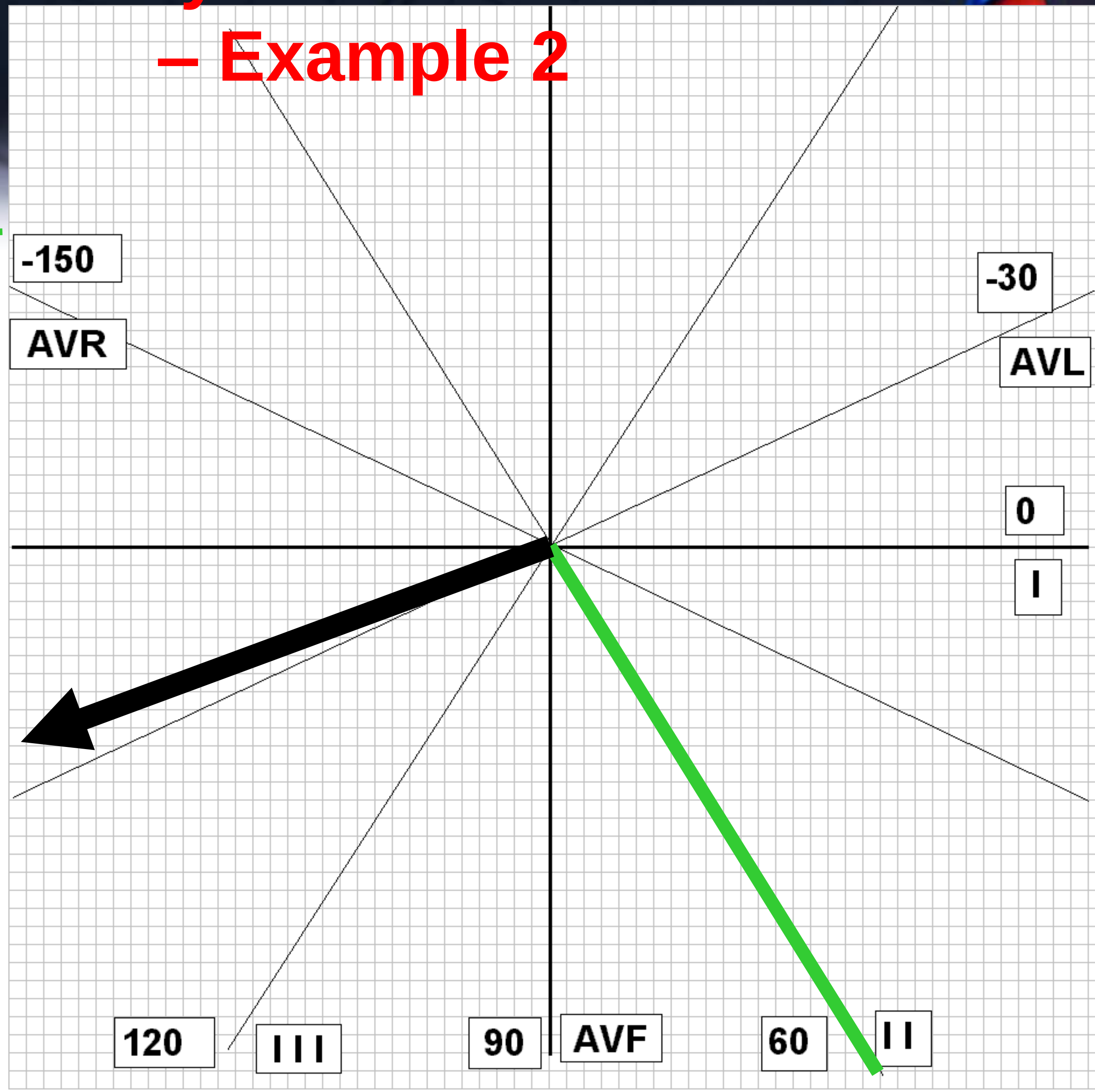
Once the quadrant has been determined, find the most equiphasic or smallest limb lead. The axis will lie about 90º away from this lead. Given that II is the most equiphasic lead, the axis here is at approximately 150º.



Hexaxial Array for Axis Determination – Example 2

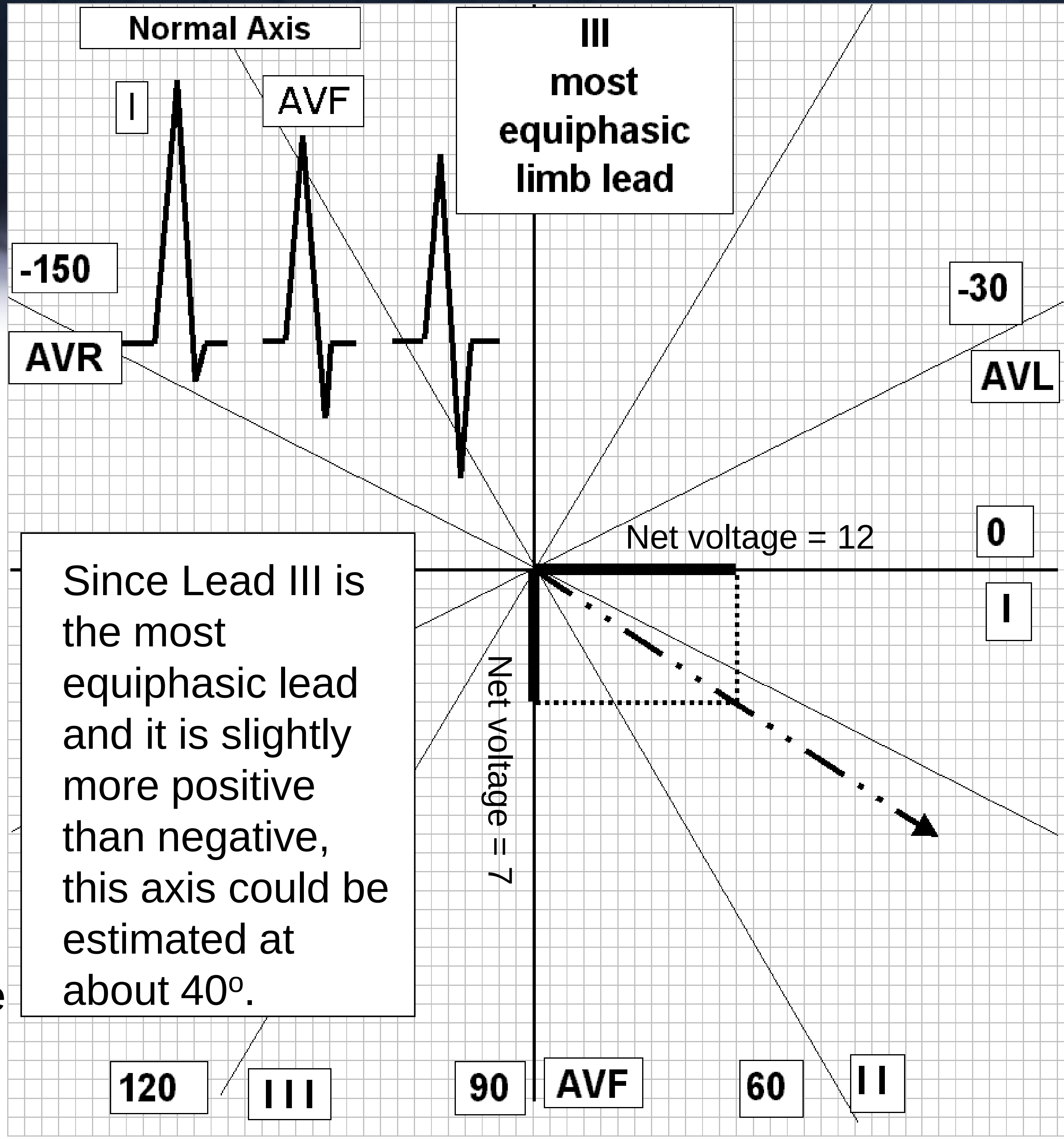


Since the QRS in II is a slightly more negative, the true axis will lie a little farther away from lead II than just 90º (the depolarization vector is moving a little more away from lead II than toward it). A better estimate would be 160º.



Precise Axis Calculation

Precise calculation of the axis can be done using the coordinate system to plot net voltages of perpendicular leads, drawing a resultant rectangle, then connecting the origin of the coordinate system with the opposite corner of the rectangle. A protractor can then be used to measure the deflection from 0.



Since Lead III is the most equiphasic lead and it is slightly more positive than negative, this axis could be estimated at about 40º.

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