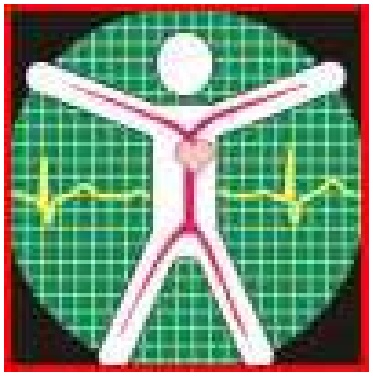


KINE 639 - Dr. Green

Section 2

Electrophysiology and ECG Basics

Rate & Axis

Reading in Conover: pages 3-22, 32-44

Introduction to Electrocardiography (ECG, EKG)

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

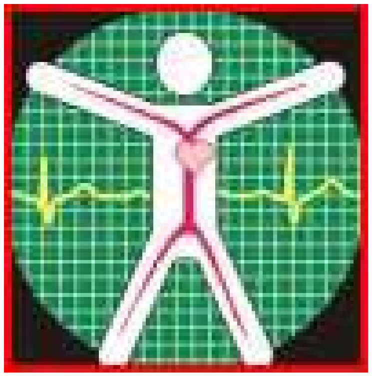
- During the late 1800's and early 1900's, Dutch physiologist Willem Einthoven developed the early elctrocardiogram. He won the Nobel prize for its invention in 1924.

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

- 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

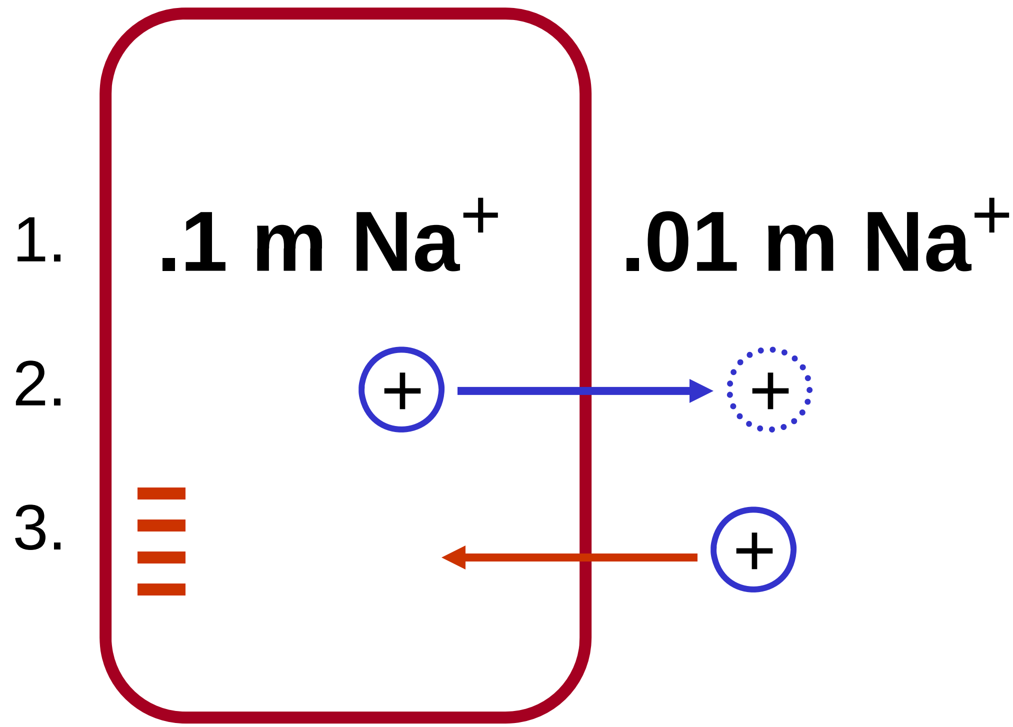


Ion Flux Across a Permeable Membrane

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])

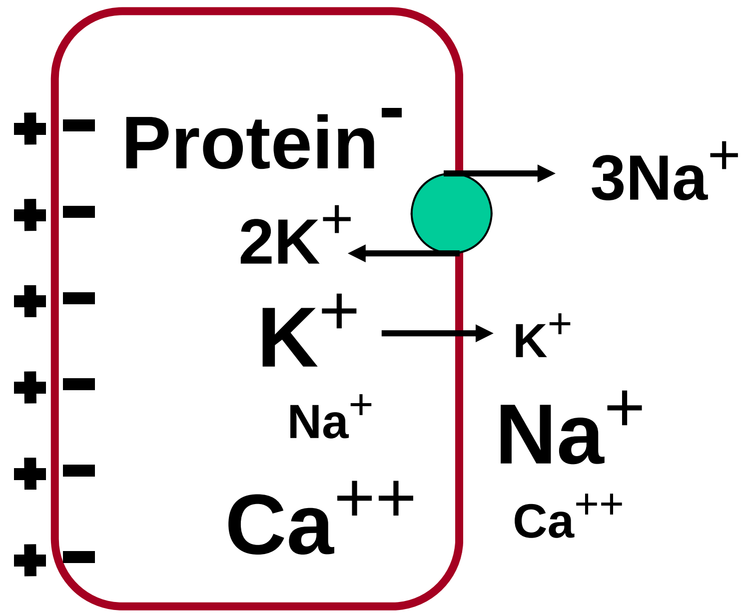
Where E_k = membrane charge (potential) for a given ion

Generation of a Resting Myocardium Membrane Potential

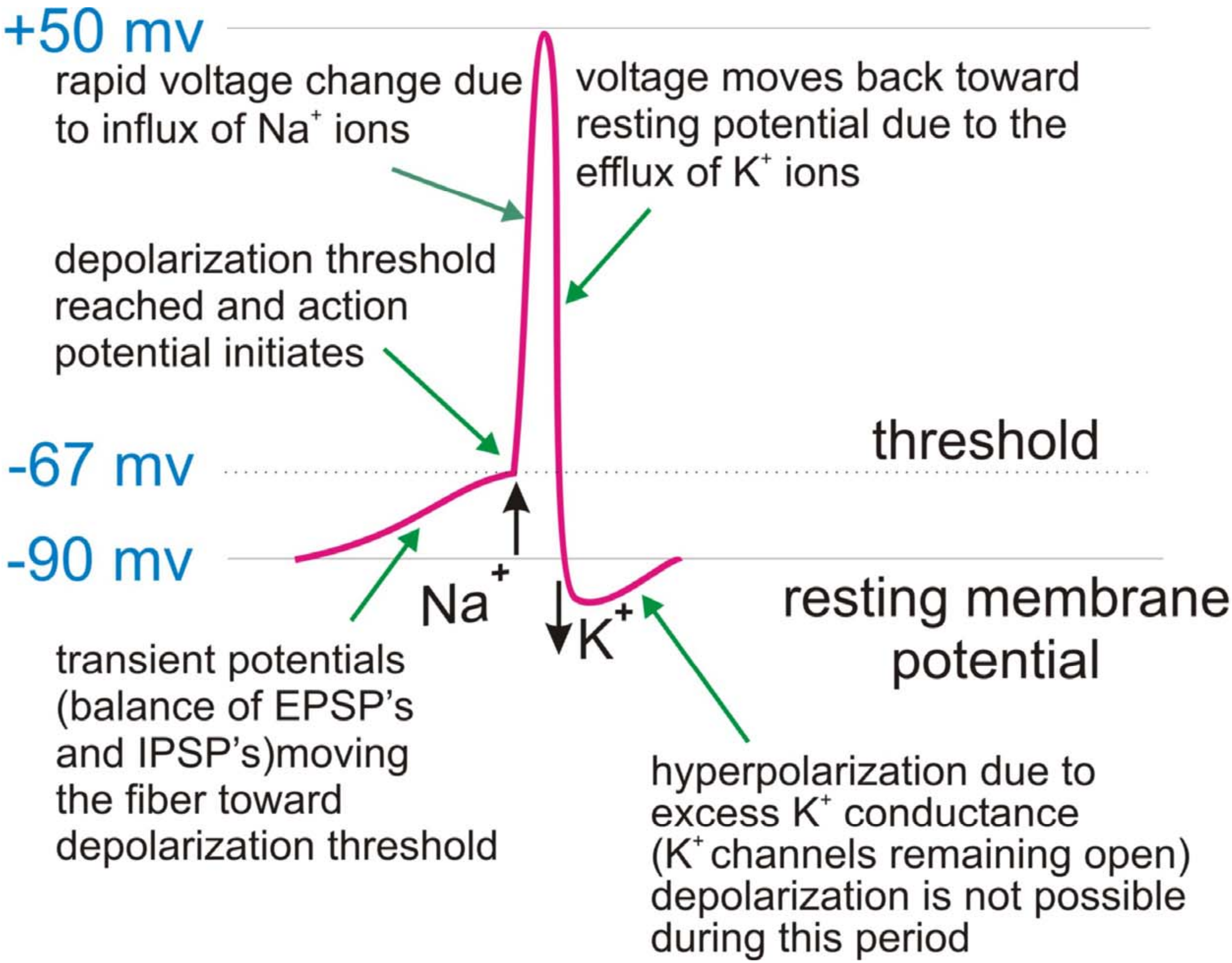
1. During repolarization, Na^+K^+ ATP-ase pumps $3Na^+$out and $2K^+$ in $\rightarrow \uparrow$ intracellular negativity
2. At rest, membrane permeability to K^+ high
   - K^+ diffuses down concentration gradient out of the cell $\rightarrow \uparrow$ intracellular negativity
   - primary contributor to intracellular negativity and the resulting membrane potential
3. Membrane permeability to Na^+ and Ca^{++} is low $\rightarrow$ 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**

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

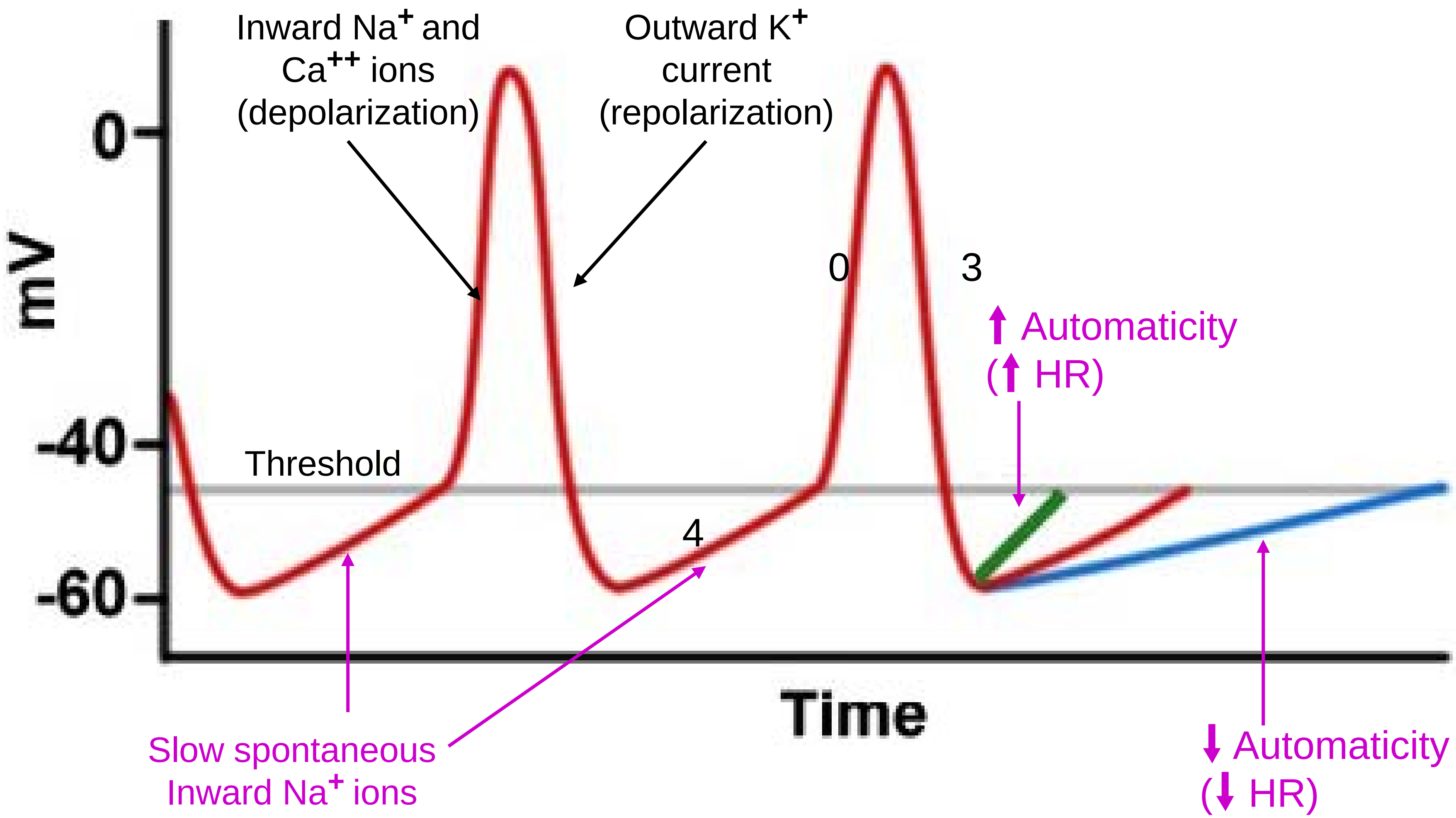
Where: E_m = resting membrane potential
g_{K+} = cell permeability to K^+…(Na^+…Ca^{++})
E_{K+} = Nernst value for K^+…(Na^+…Ca^{++})



Skeletal Muscle or Neuron Action Potential

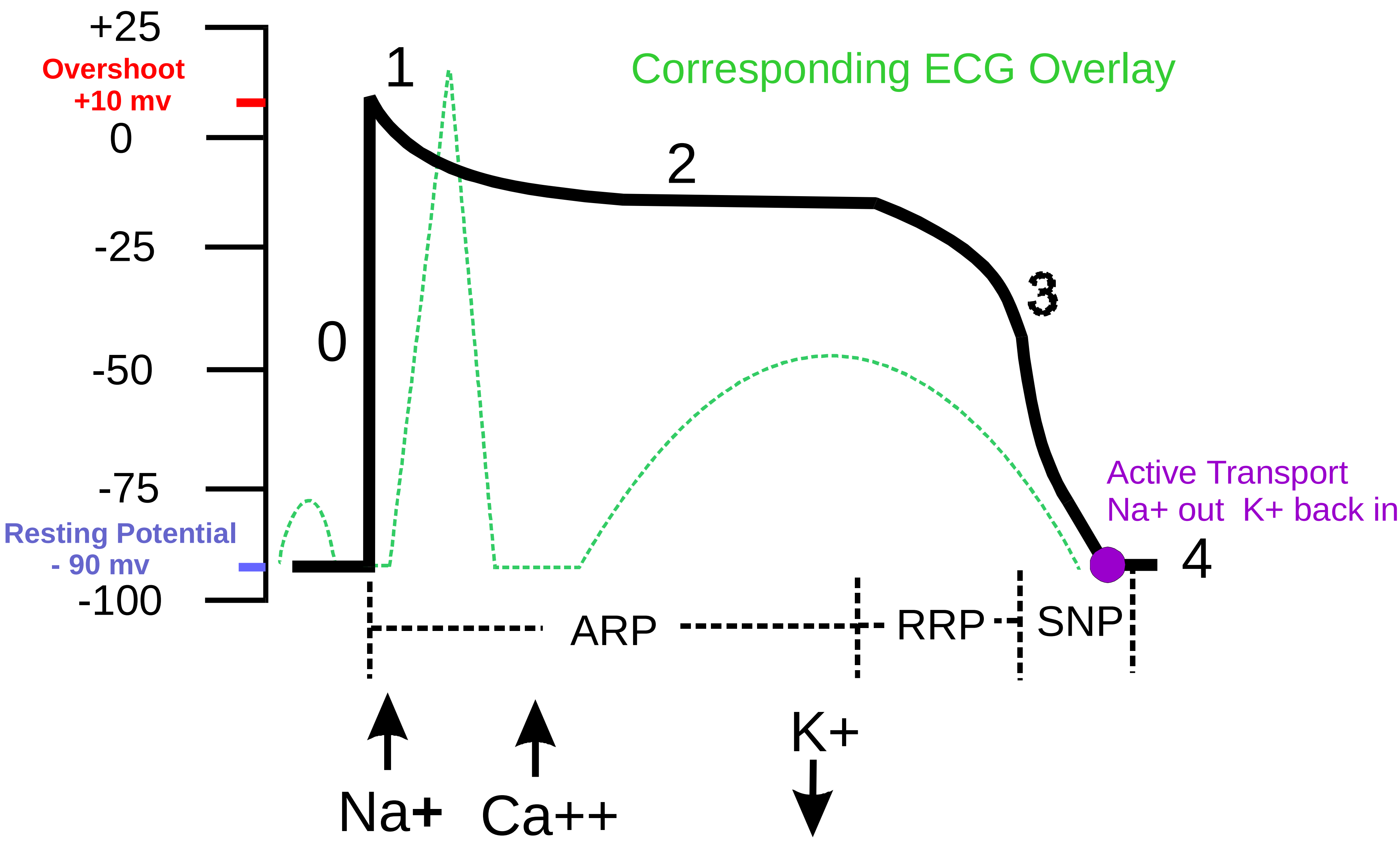


Atrial Muscle (Nodal) Action Potential



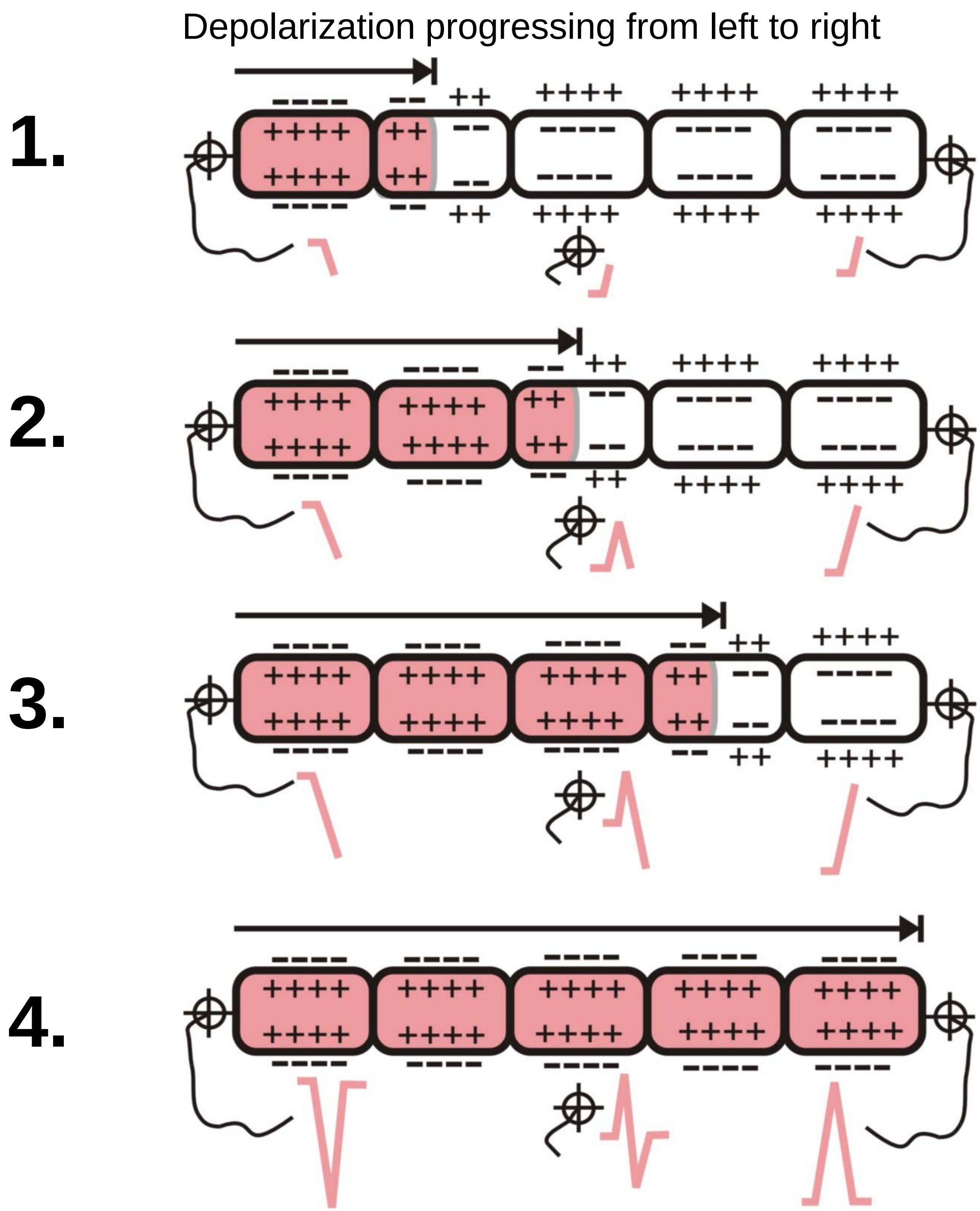
Automaticity - a pacemaker cell's ability to spontaneously depolarize, reach threshold, and propagate an AP

Myocardium Muscle Action Potential



Concept 1

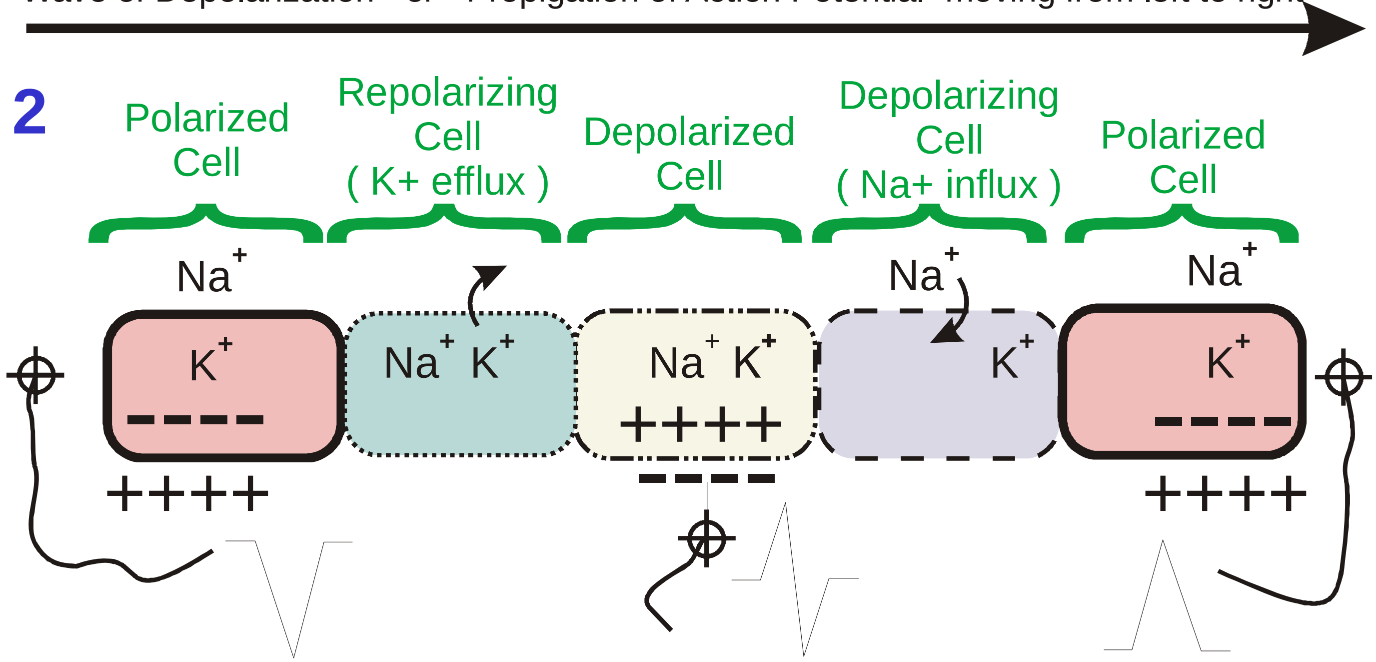
Depolarization Sequence of a "Strip" of 5 Myocardial Cells



Depolarization Wave of a Strip of Nerve Cells (or Myocardial Muscle Cells minus the depiction of Ca^{++} influx)

“Wave of Depolarization“ or ”Propigation of Action Potential” moving from left to right

Concept 2

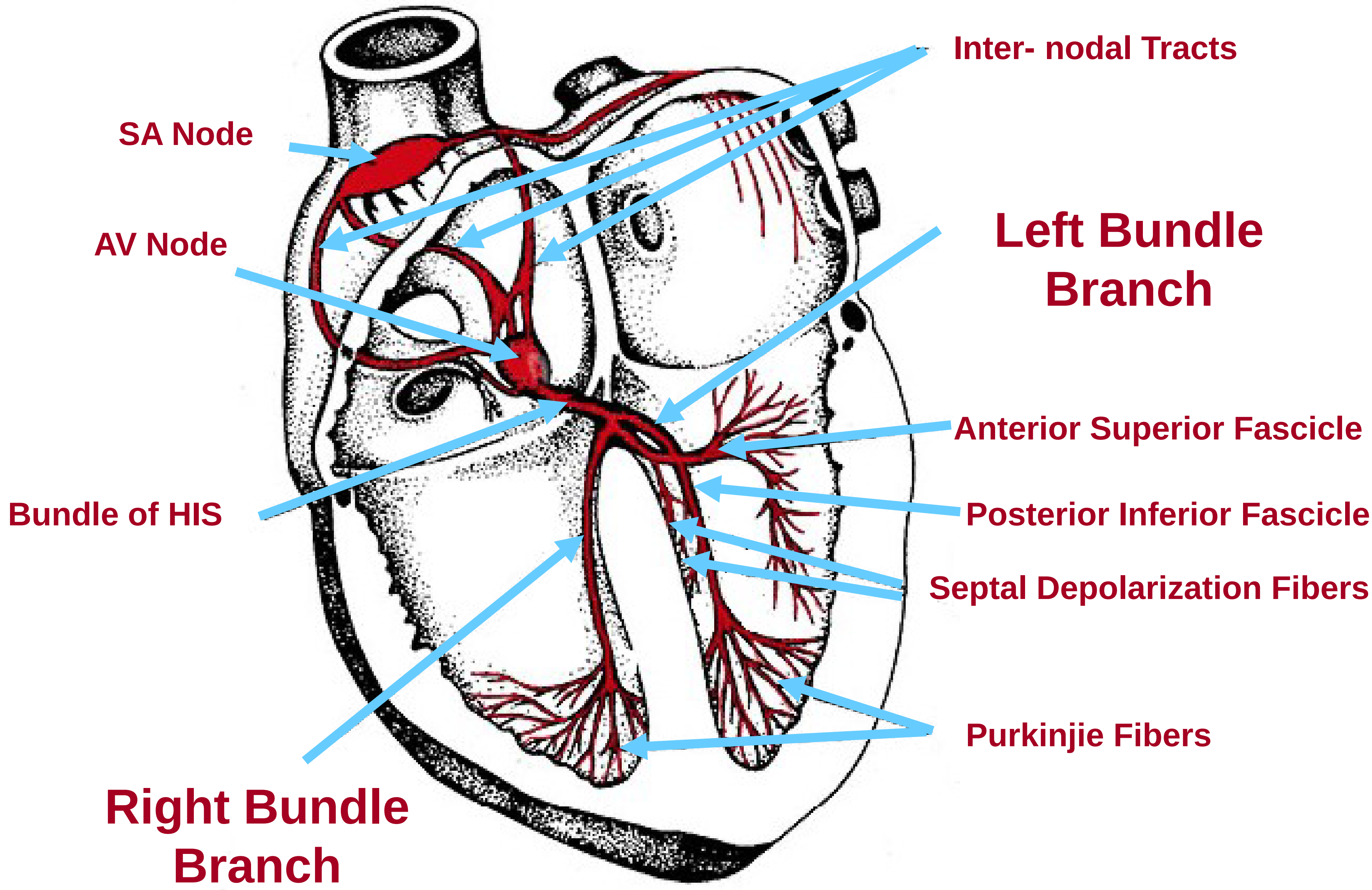


The needle of this recording electrode inscribes a totally negative complex because the wave of depolariztion is moving away from it during the entire time the strip is depoarizing

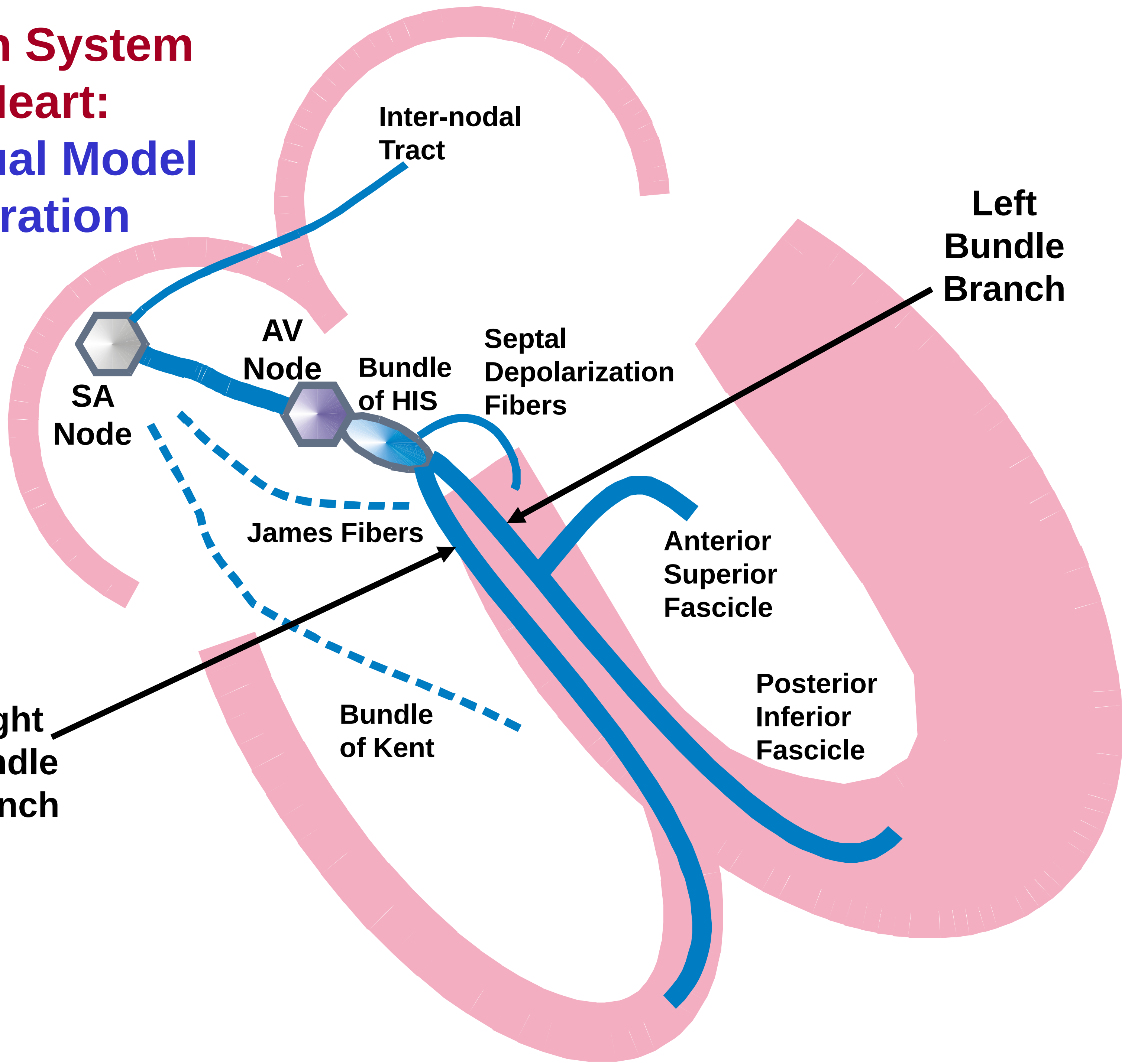
The needle of this recording electrode is biphasic because half of the time the wave of depolarization is moving towards it while the other half of the time it is moving away

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 depolarizing

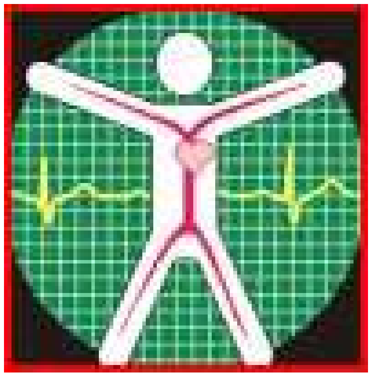
The Electrical System of the Heart



Conduction System of the Heart:
A Conceptual Model for Illustration



Generation of the Electrocardiogram

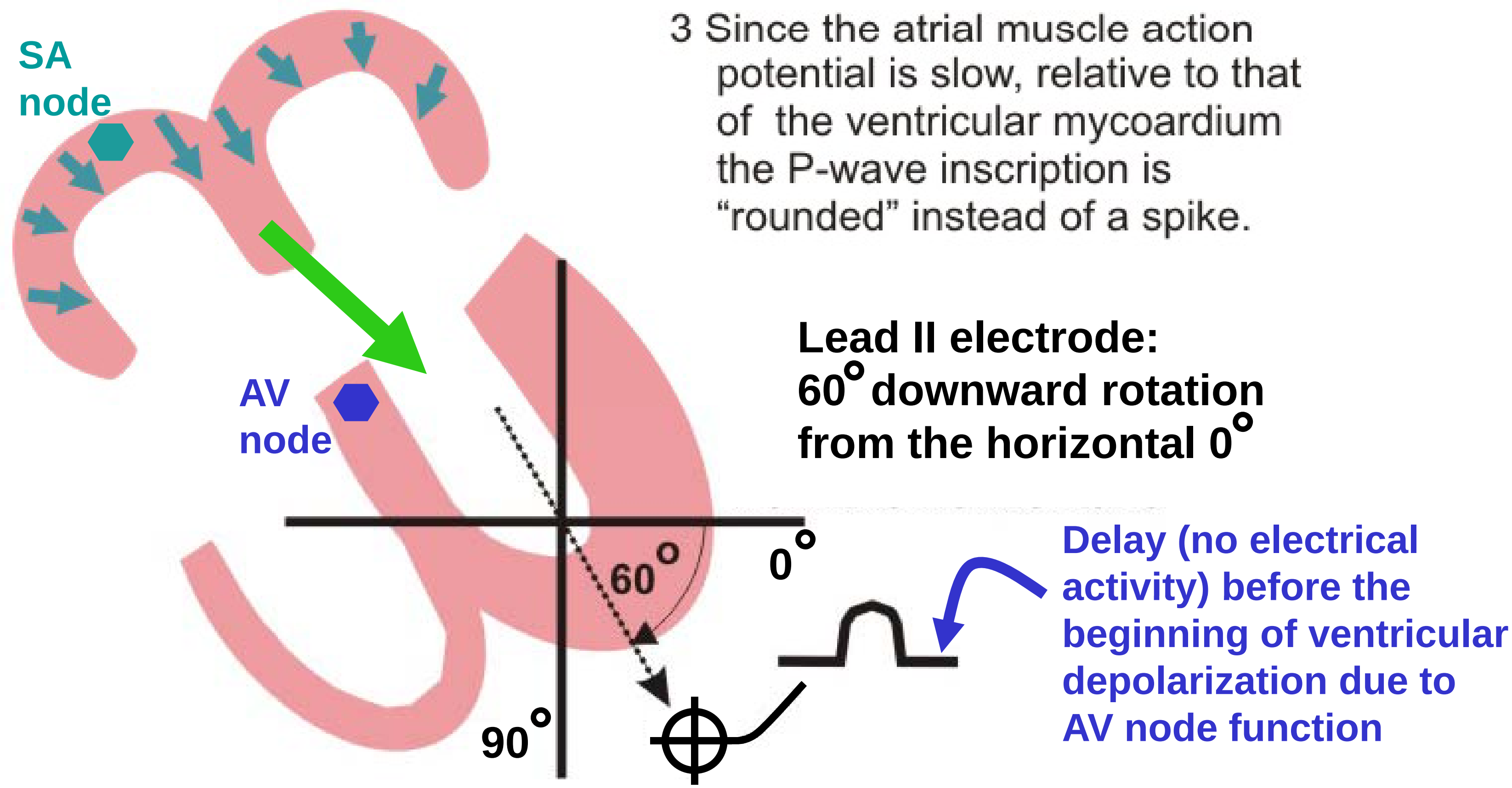


Atrial Depolarization and the Inscription of the P-wave

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.

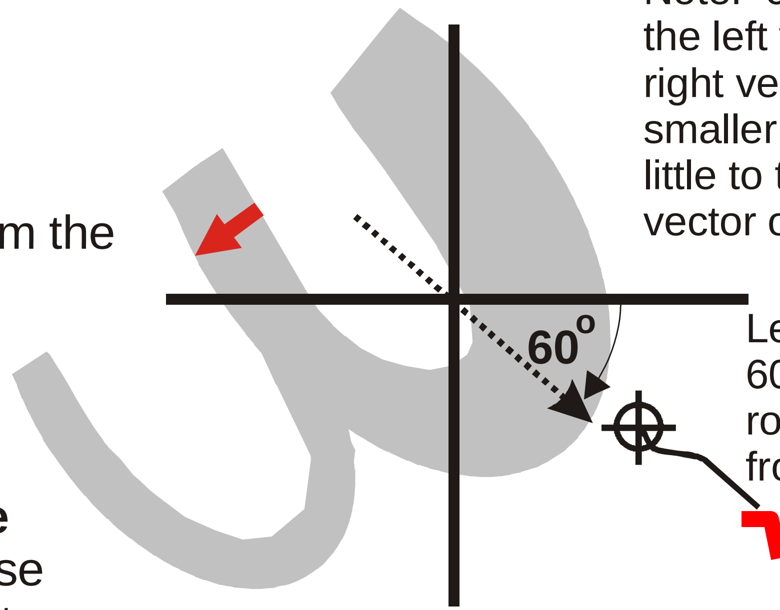
3 Since the atrial muscle action potential is slow, relative to that of the ventricular mycoardium the P-wave inscription is "rounded" instead of a spike.



Ventricular Depolarization and the Inscription of the QRS complex

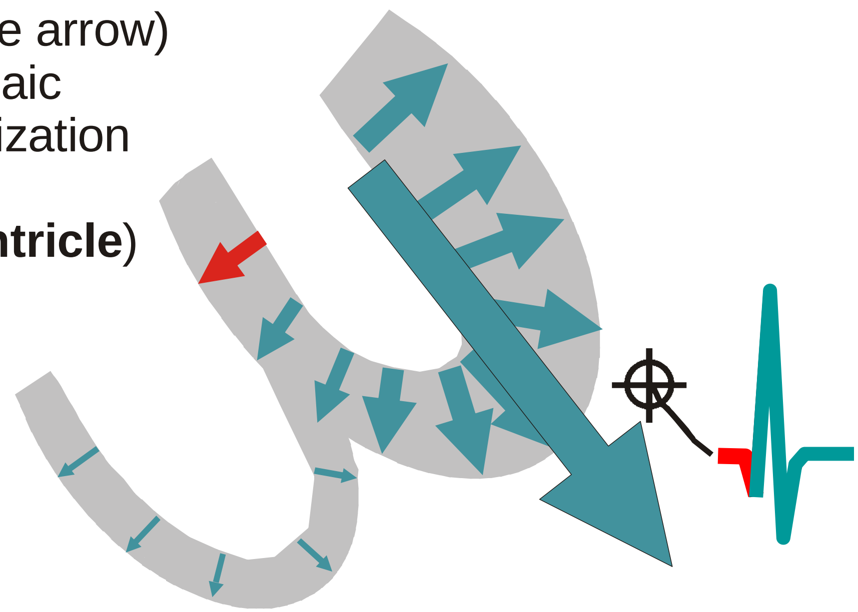
1. The **septum** depolarizes from the inside out and the resulting depolarization wave moves away from the electrode recording Lead II

2. The rest of the **left 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 (including the small contribution from the **right ventricle**) In a normal heart, this vector is always moving directly toward Lead II, generating a mostly positive QRS complex

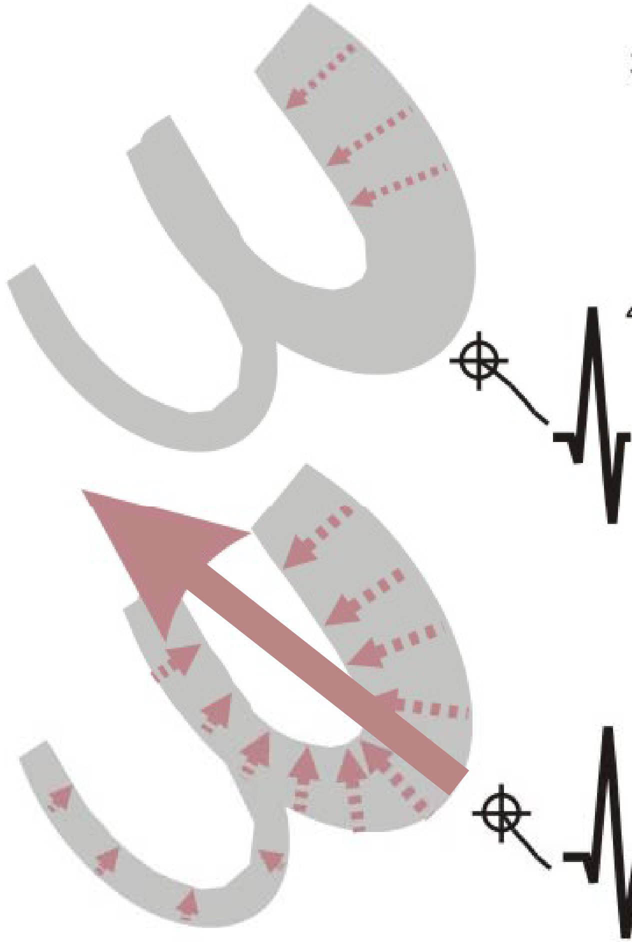


Note: compared to the left ventricle, the right ventricle is much smaller and contributes little to the overall main vector of depolarization

Lead II electrode 60° downward rotation angle from the horizontal 0°

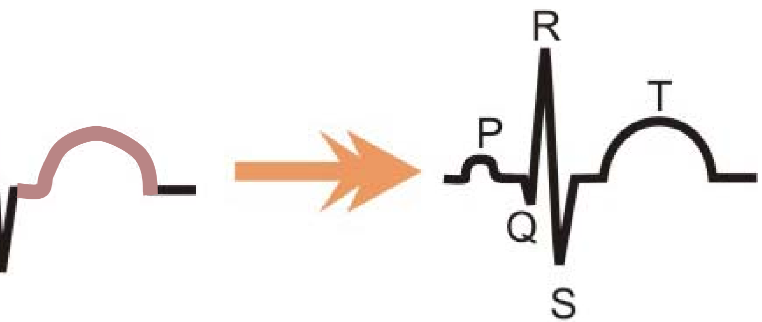


Ventricular Repolarization and the Inscription of the T-wave



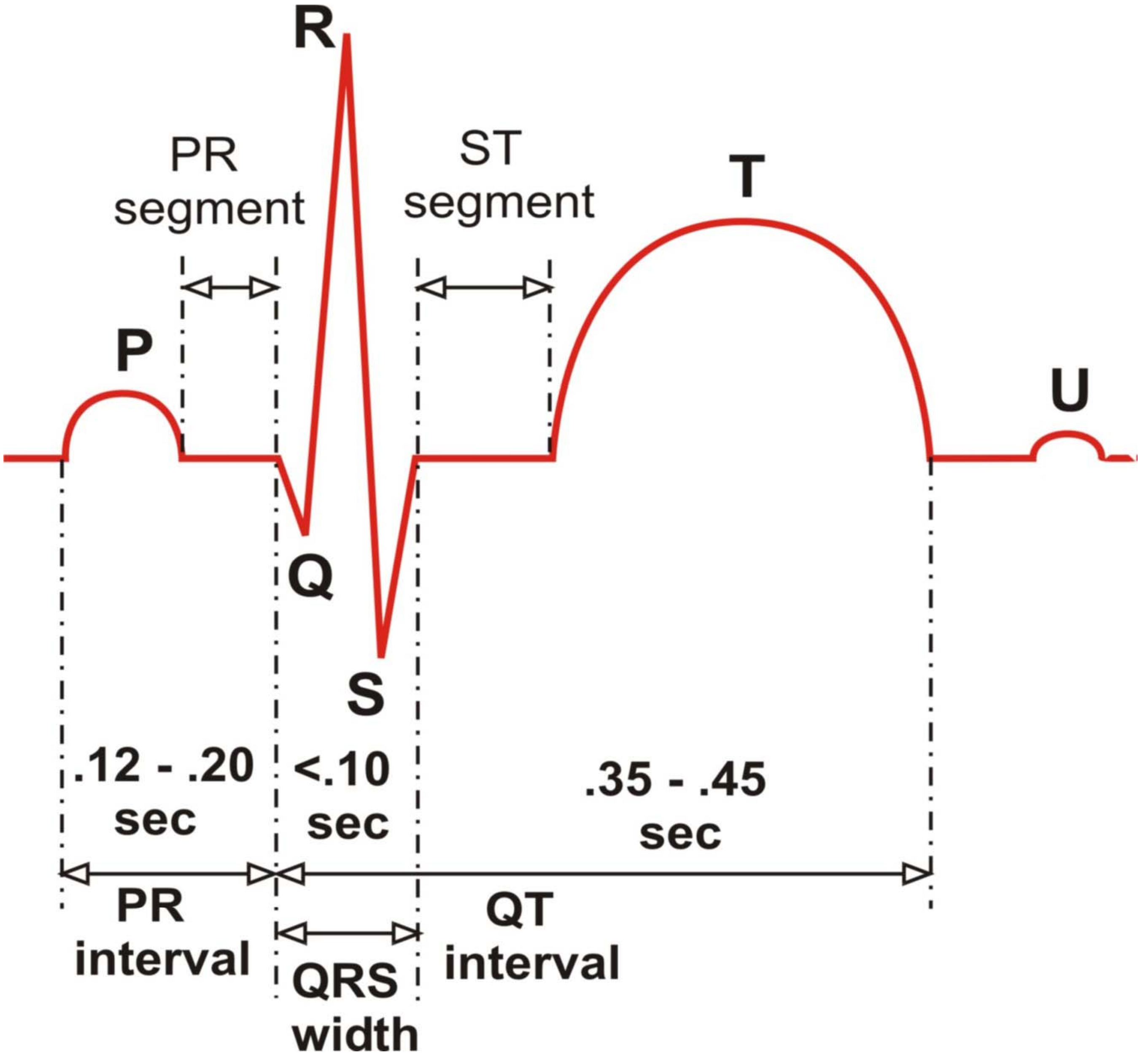
3. Repolarization can be thought of as beginning where depolarization left off and proceeding clockwise from the lateral wall back to the septum..

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

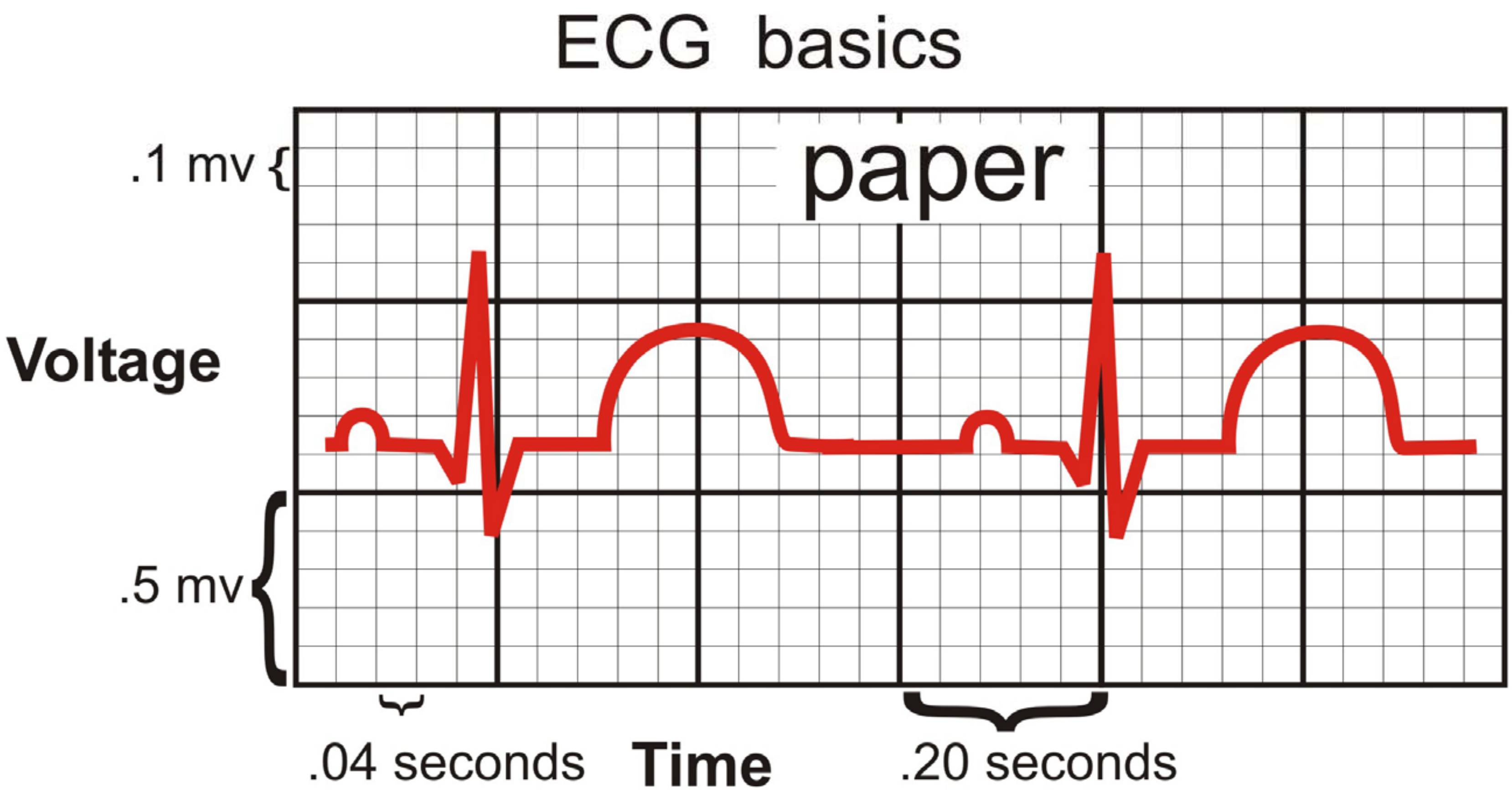


5. Putting the P-wave with the ventricular generated complex yields the entire ECG complex, representing atrial depolarization, atrial repolarization (hidden in ventricular depolarization), ventricular depolarization, and ventricular repolarization

The ECG Complex with Interval and Segment Measurements



ECG Paper and related Heart Rate & Voltage Computations



Paper speed = 25mm / second

Heart Rate

Memorize These 2

= 1500 divided by the number of small boxes between consecutive R-waves

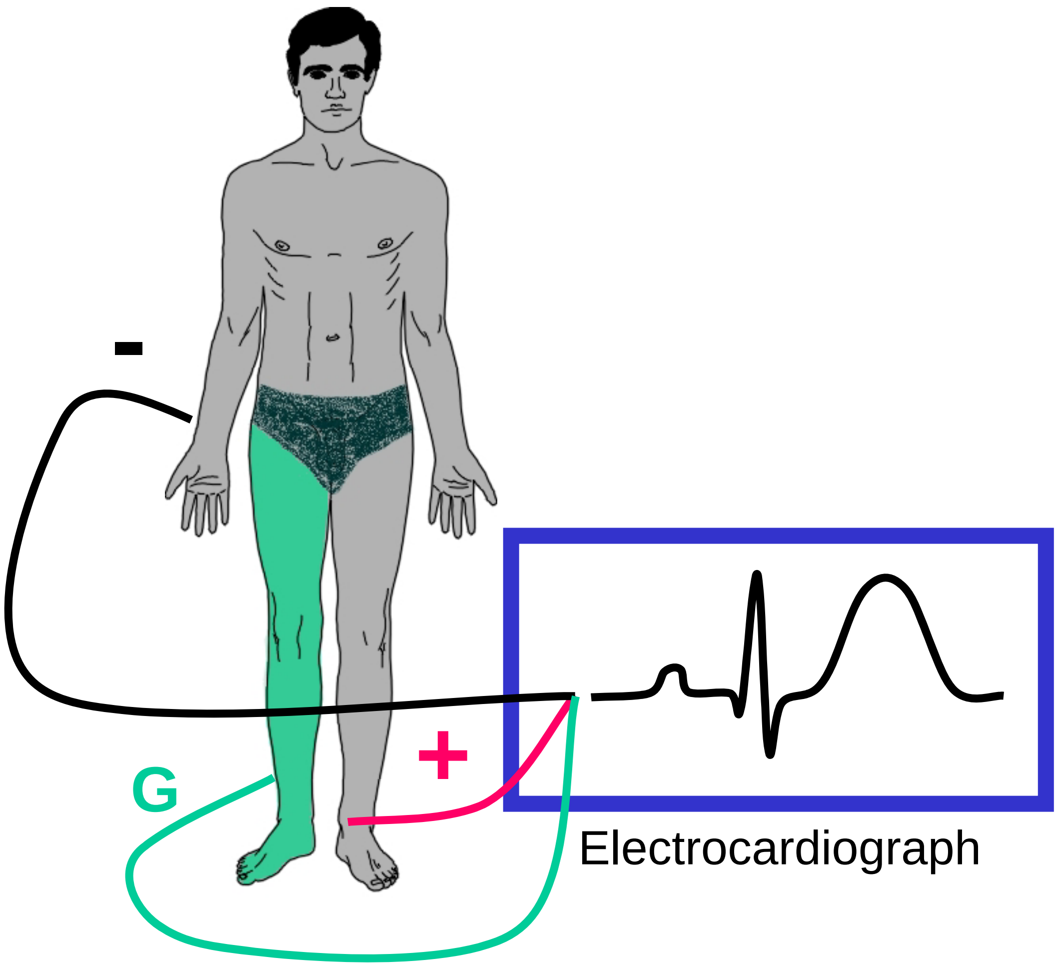
= large square estimation counts (300 - 150 - 100 - 75 - 60 - 50 - 43)

The Concept of a "Lead"

Lead II

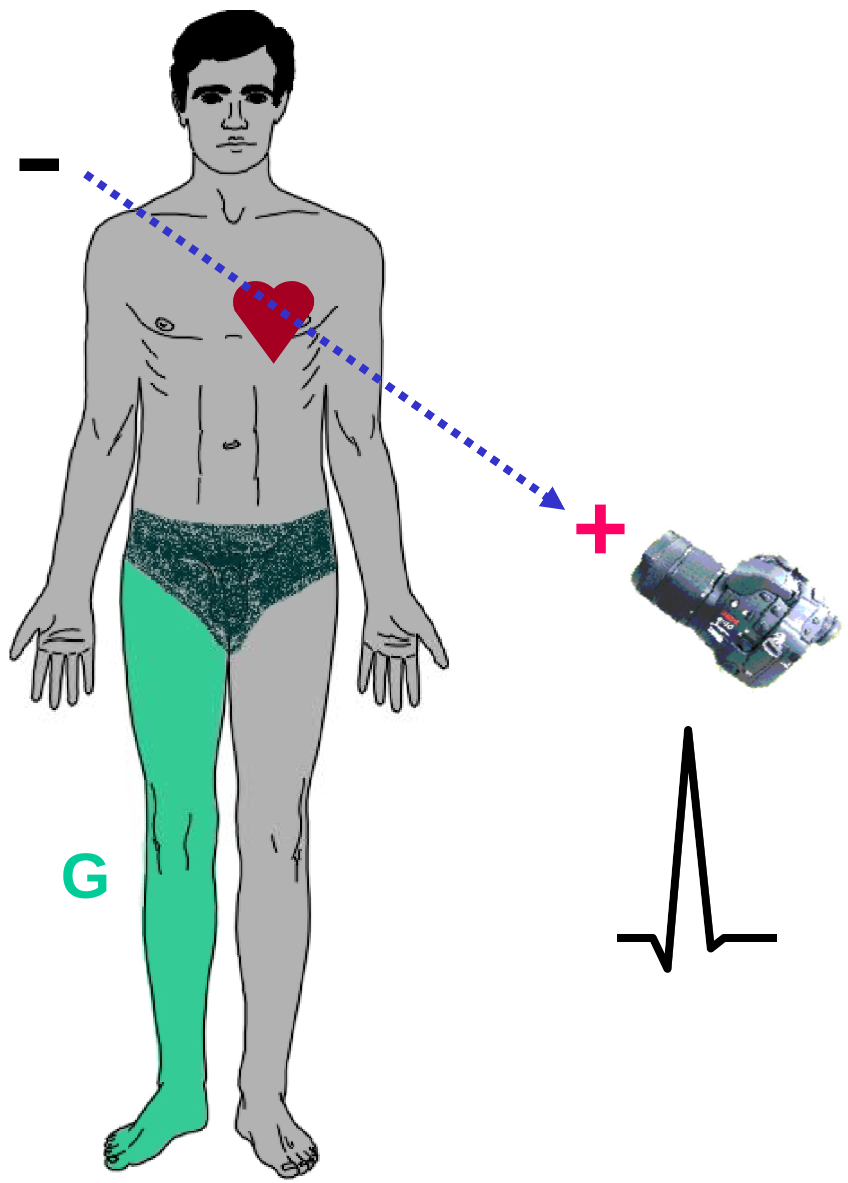
• Right arm (RA) negative, left leg (LL) positive, right leg (RL) is always the ground.

•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 II

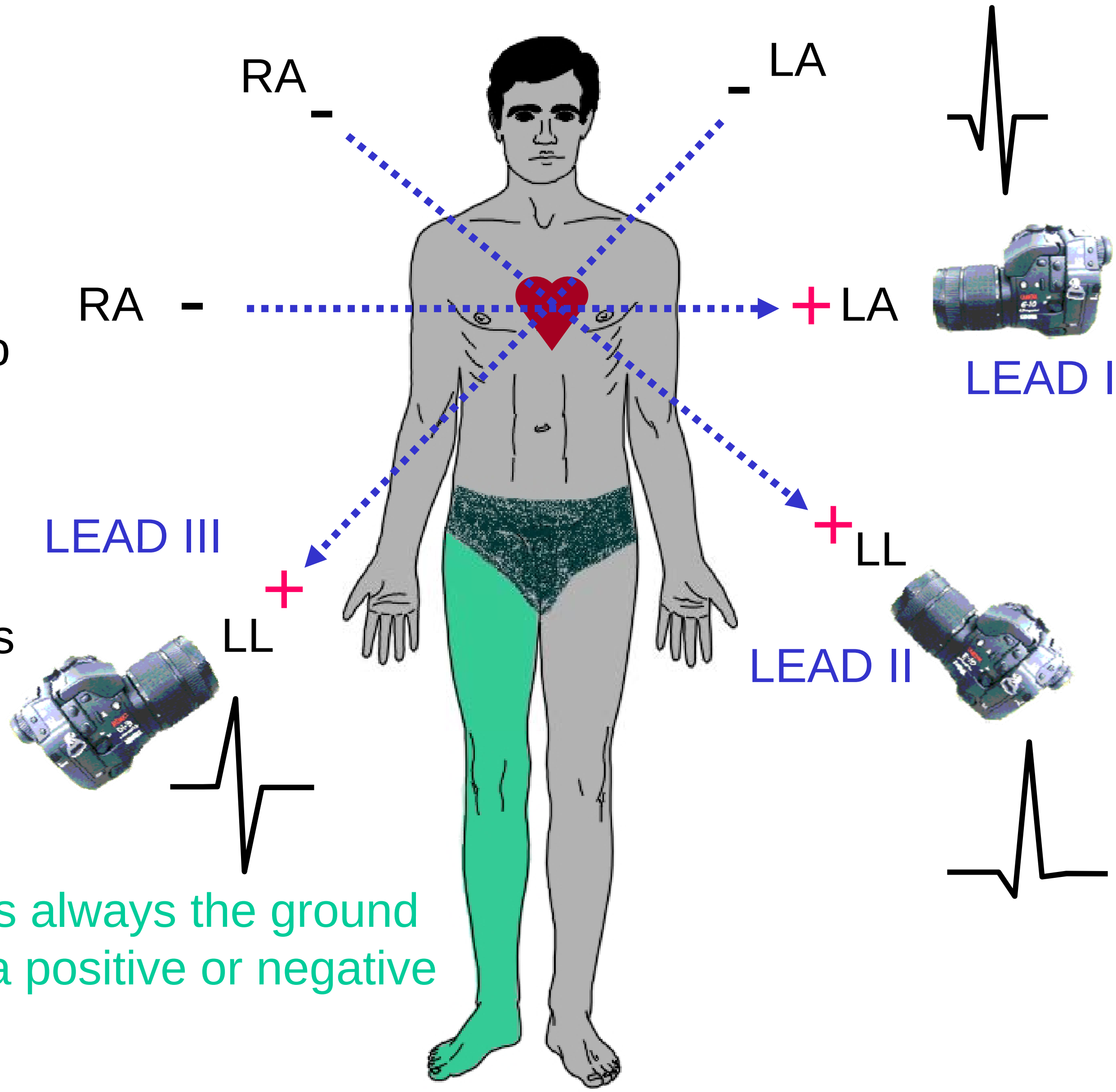


- The directional flow of electricity from Lead II can be viewed as flowing from the RA toward the LL and passing through the heart (RA is negative LL is positive. Also, it is useful to imagine a camera lens taking an "electrical picture" of the heart with the lead as its line of sight

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 (I & III) can be created and we have two more "pictures" of the heart's electrical activity from different angles. Lead I: RA is neg. and LA is pos. Lead III: LA is neg. and LL is pos.

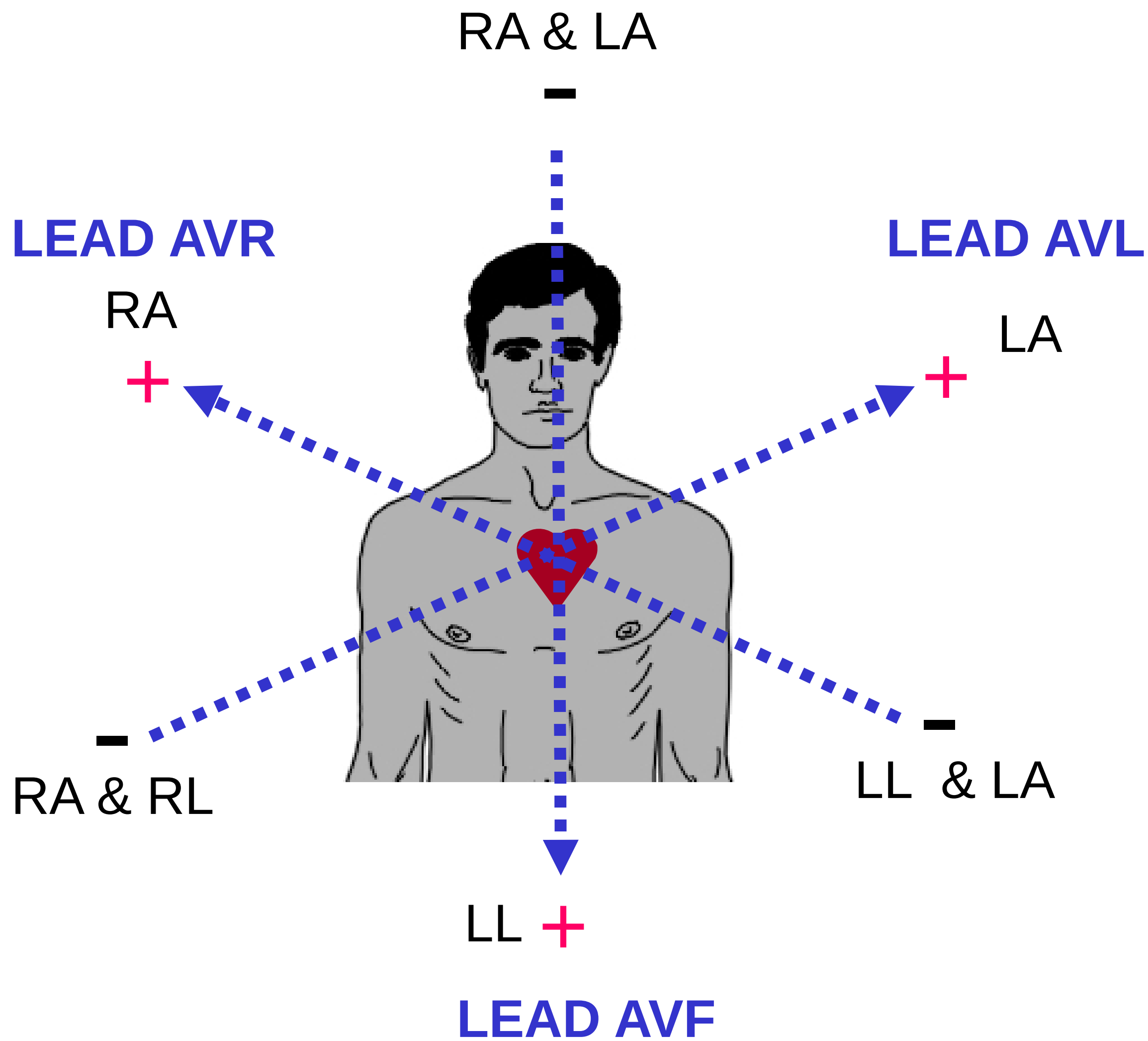


Remember, the **RL** is always the ground and never takes on a positive or negative charge.

The Concept of a "Lead"

Augmented Voltage Leads
AVR, AVL, and AVF

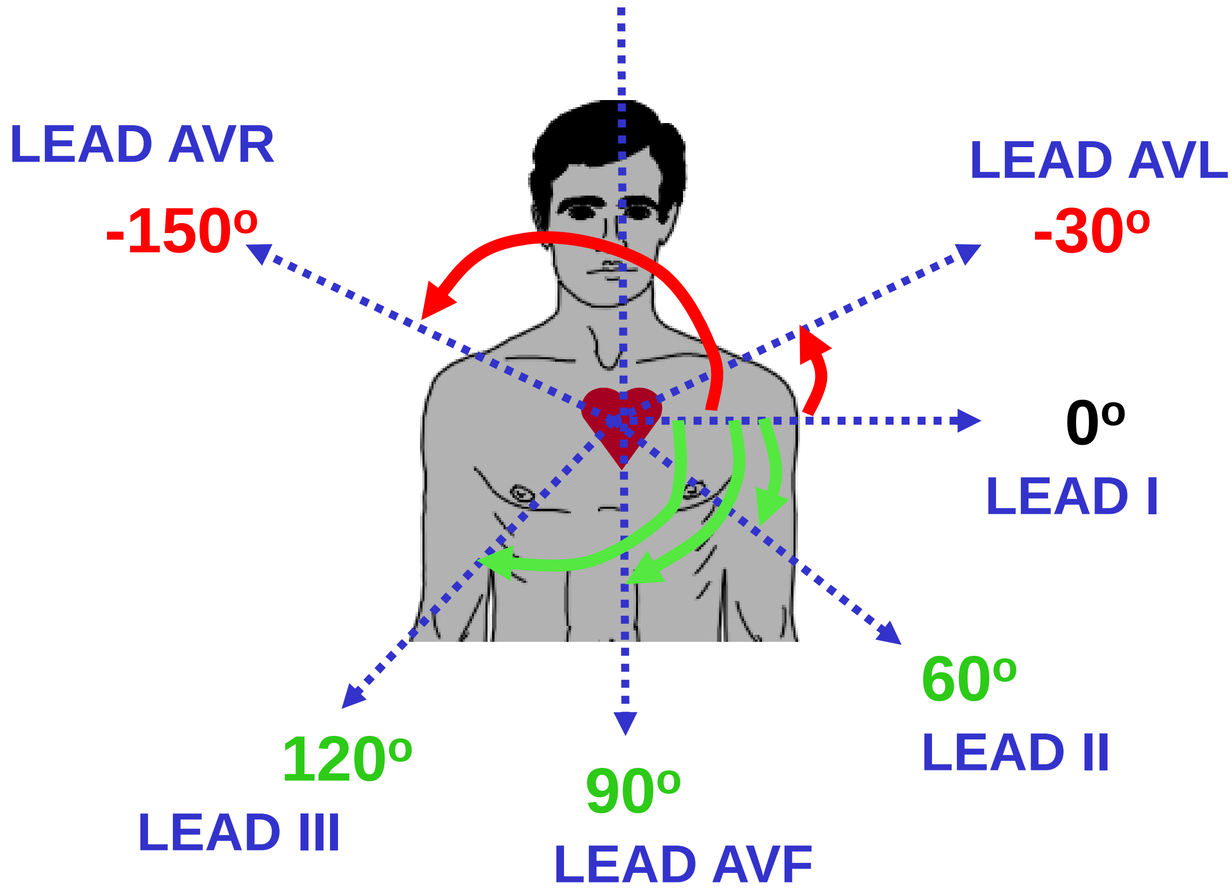
By combining certain limb leads into a **central terminal**, which serves as the negative electrode, other leads could be formed to "fill in the gaps" in terms of the angles of directional recording. These leads required **augmentation of voltage** to be read and are thus labeled.



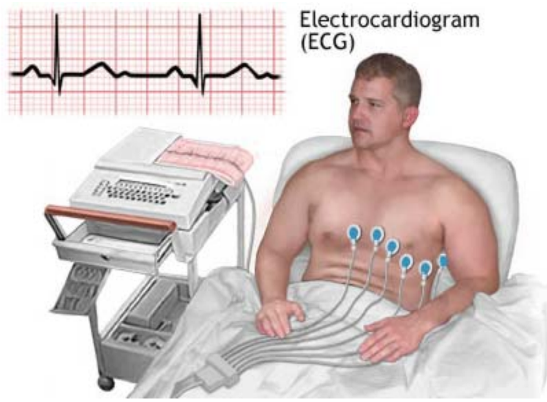
The Concept of a “Lead”

Summary of the “Limb Leads”

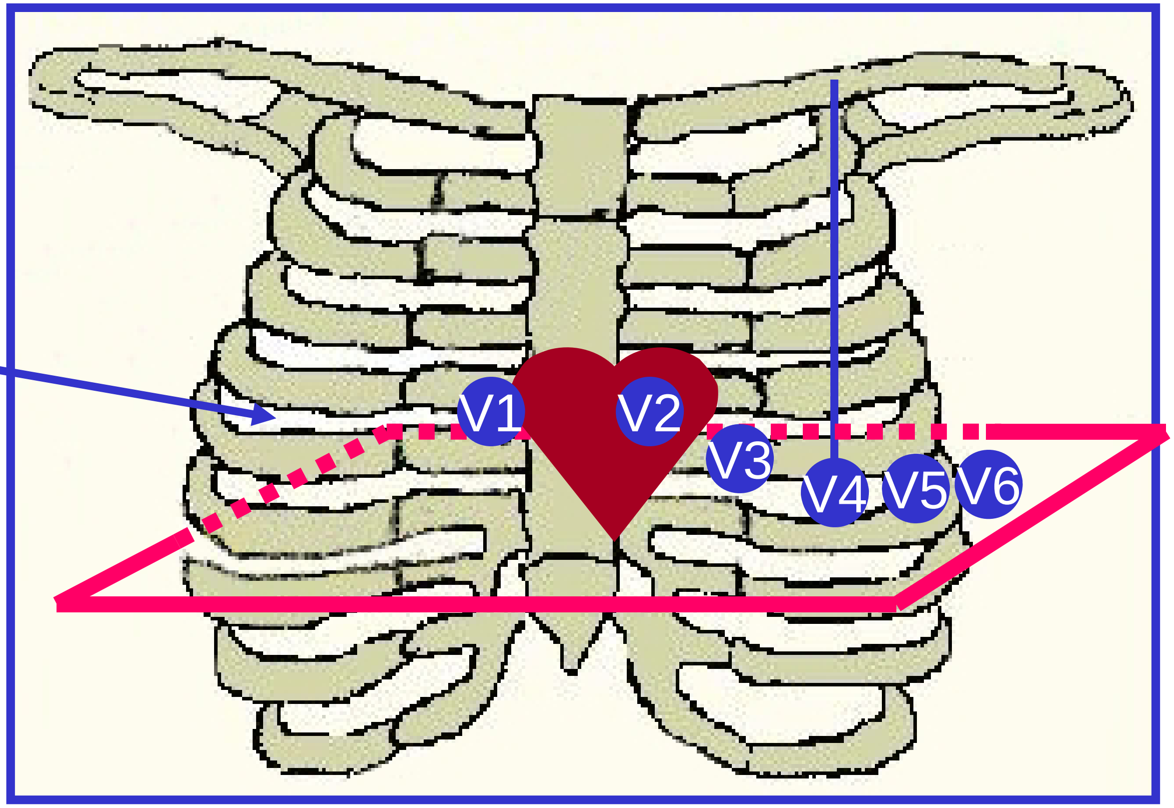
Each of the limb leads (I, II, III, AVR, AVL, AVF) can be assigned an angle of **clockwise** or **counterclockwise** rotation to describe its position in the frontal plane. Downward rotation from 0 is positive and upward rotation from 0 is negative.



The Concept of a "Lead"



The "Precordial Leads"

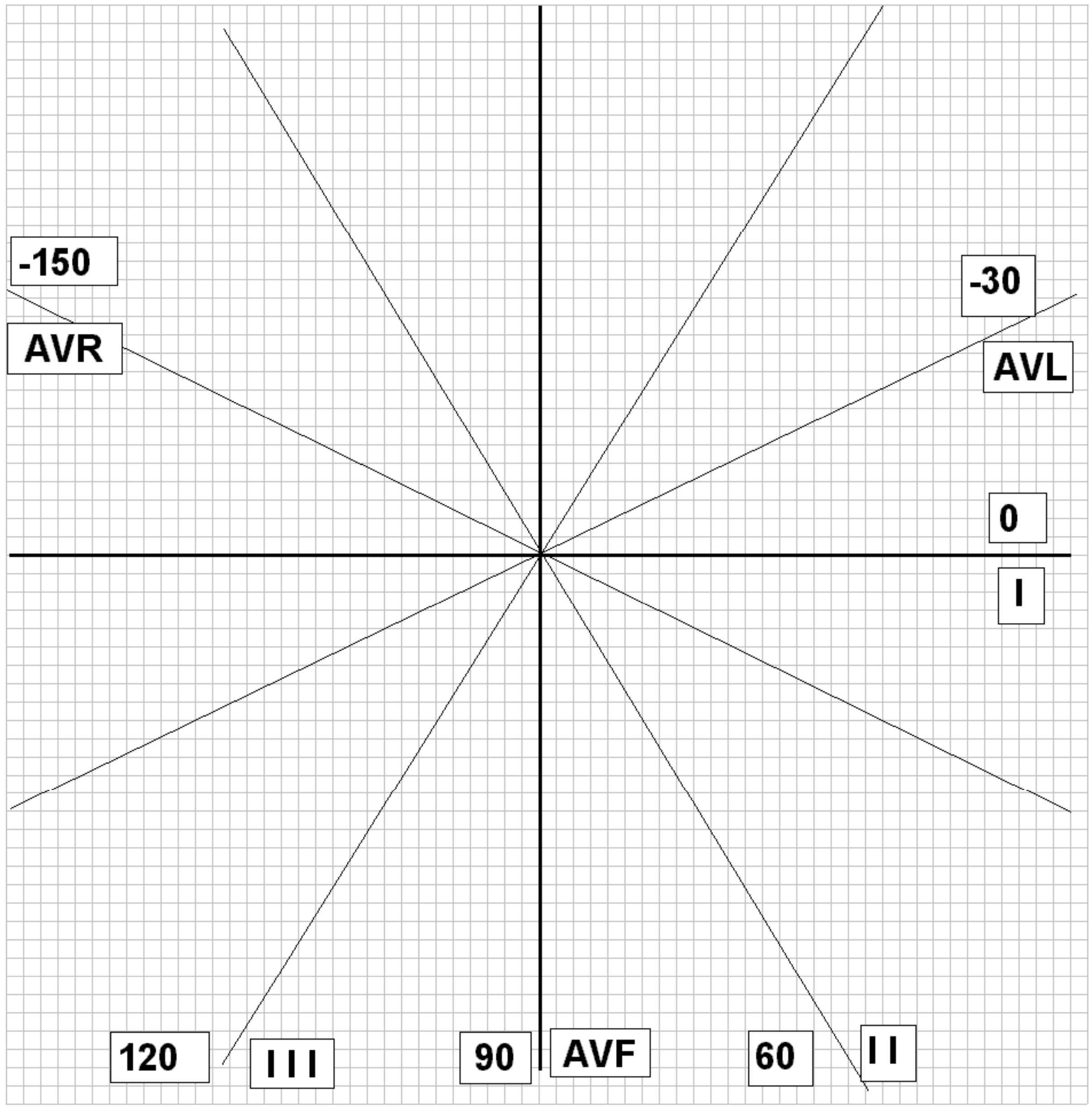


Each of the 6 precordial leads is unipolar (1 electrode constitutes a lead) and is designed to view the electrical activity of the heart in the **horizontal** or **transverse plane**

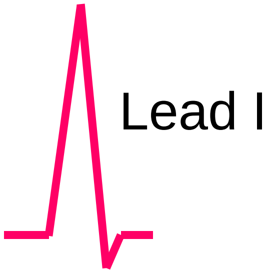
V1 - 4th intercostal space - right margin of sternum
V2 - 4th intercostal space - left margin of sternum
V3 - linear midpoint between V2 and V4
V4 - 5th intercostal space at the mid clavicular line
V5 - horizontally adjacent to V4 at anterior axillary line
V6 - horizontally adjacent to V5 at mid-axillary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

Hexaxial Array for Axis Determination

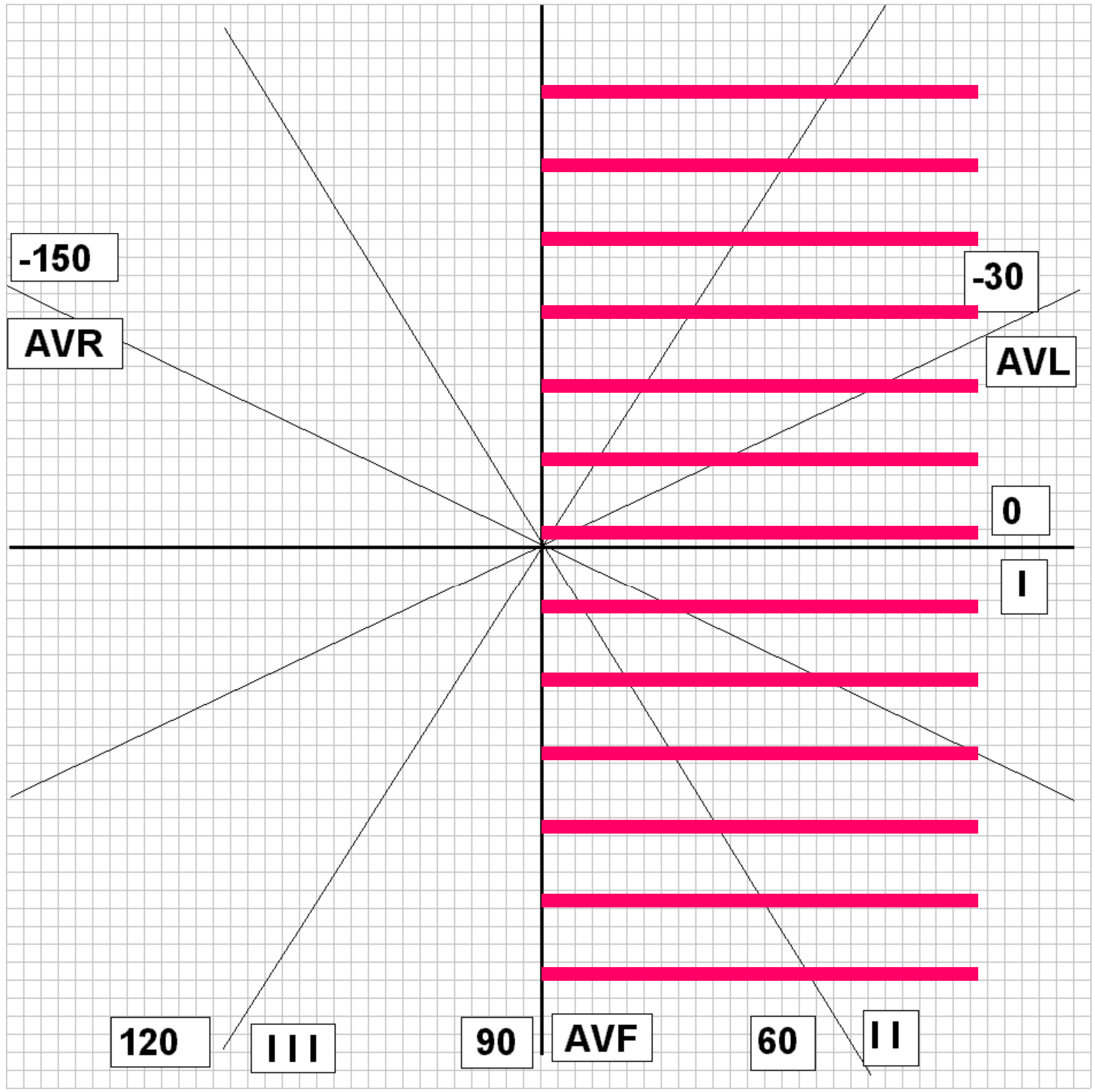
determination of the angle of the **HEART AXIS** in the frontal plain



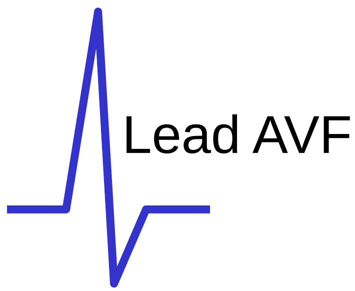
Hexaxial Array for Axis Determination – Example 1



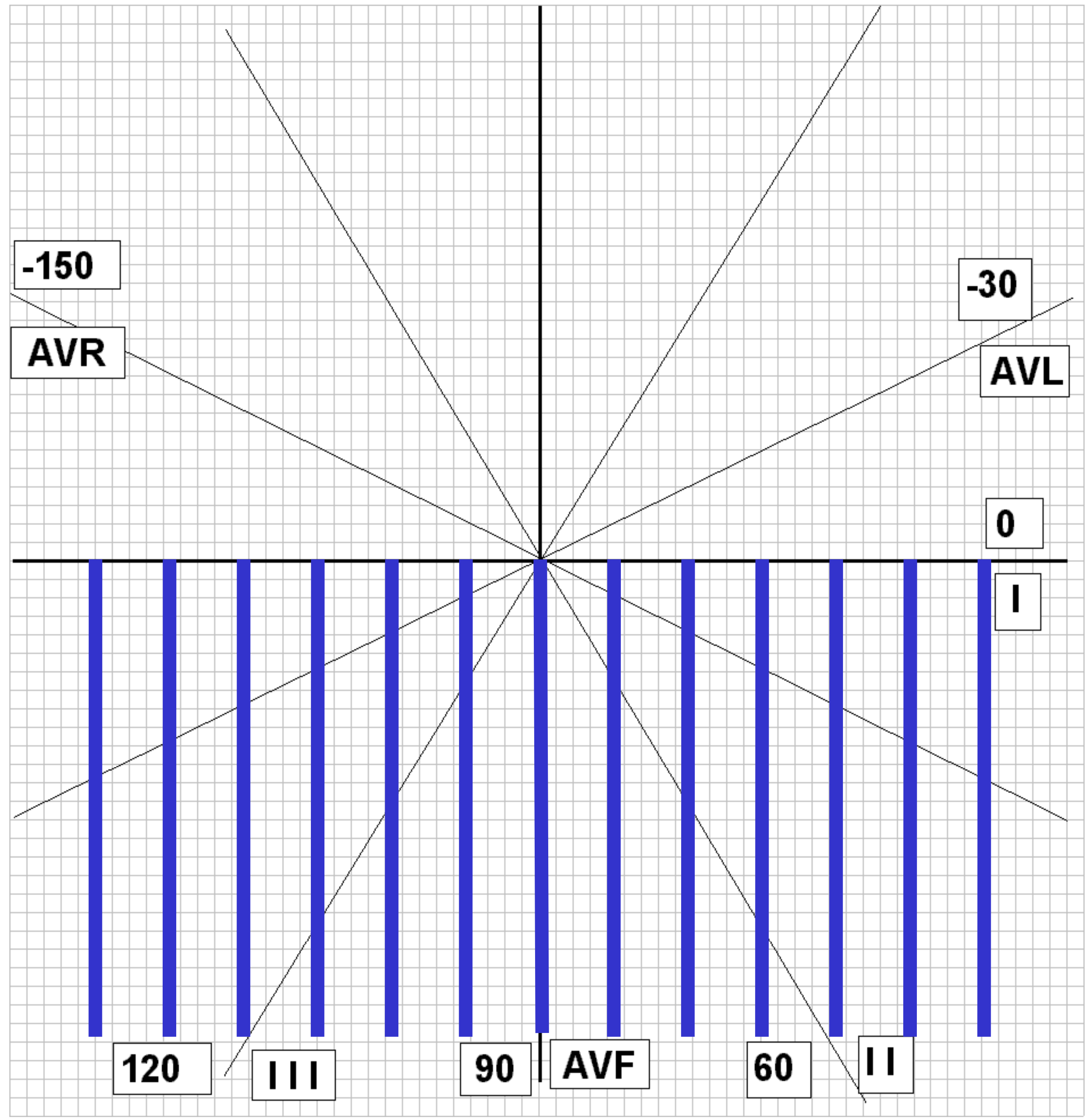
If lead I is mostly positive, the axis must lie in the right half of of the coordinate system (the main vector is moving mostly toward the lead's positive electrode)



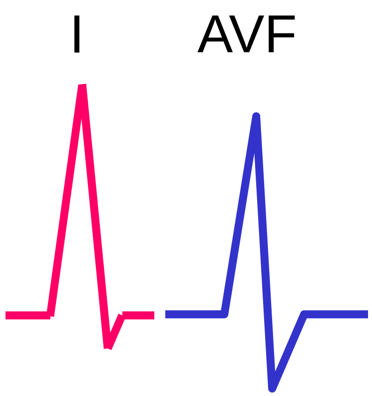
Hexaxial Array for Axis Determination – Example 1



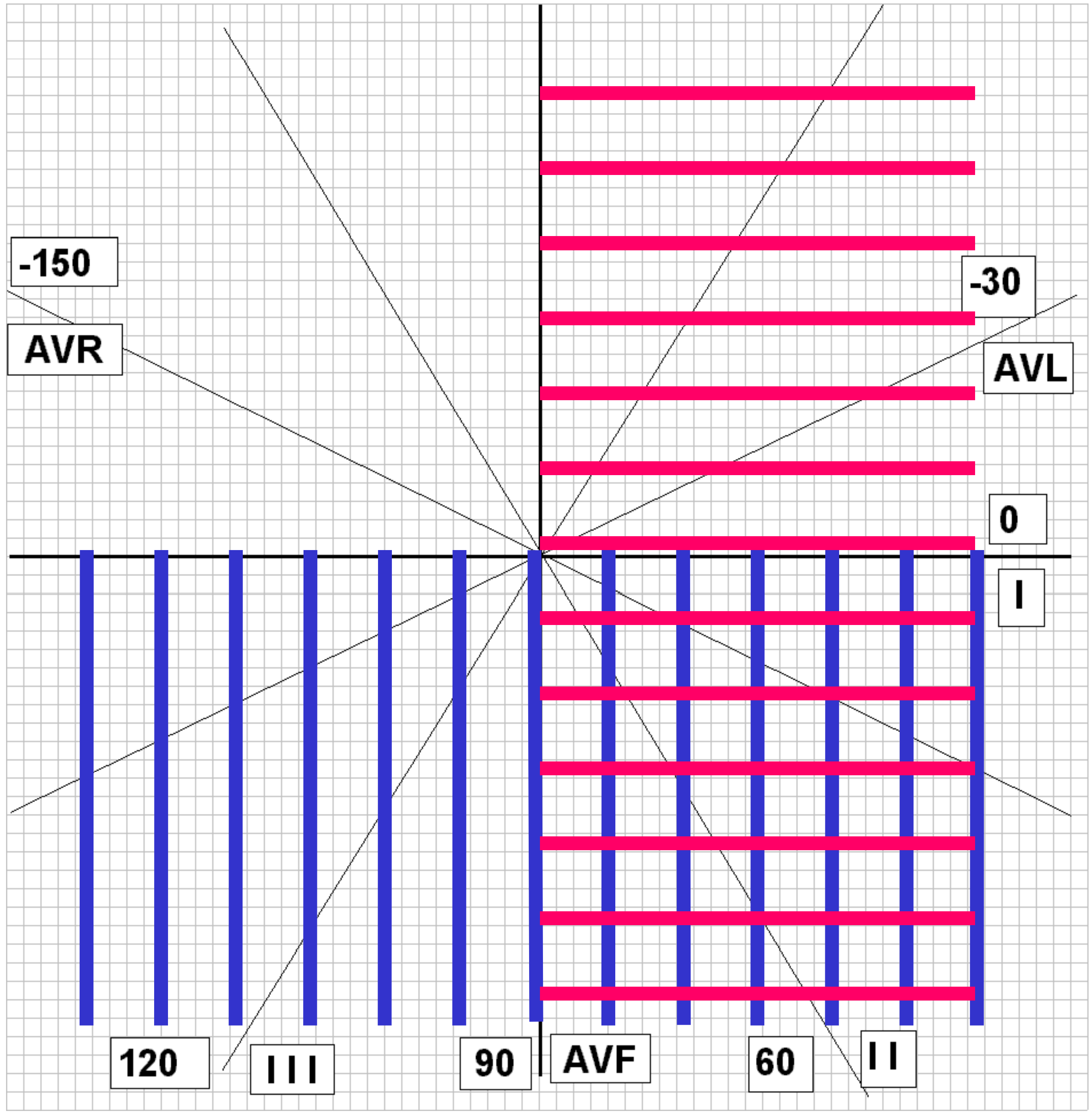
If lead AVF is mostly positive, the axis must lie in the bottom half of of the coordinate system (again, the main vector is moving mostly toward the lead's positive electrode



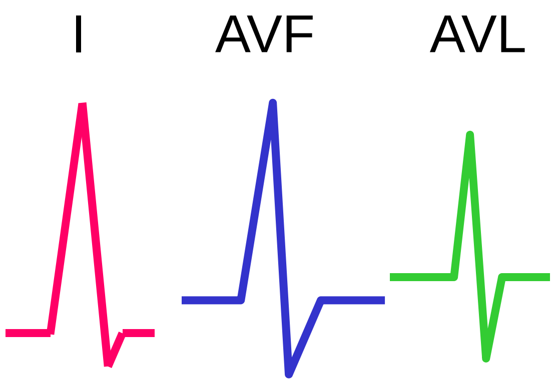
Hexaxial Array for Axis Determination – Example 1



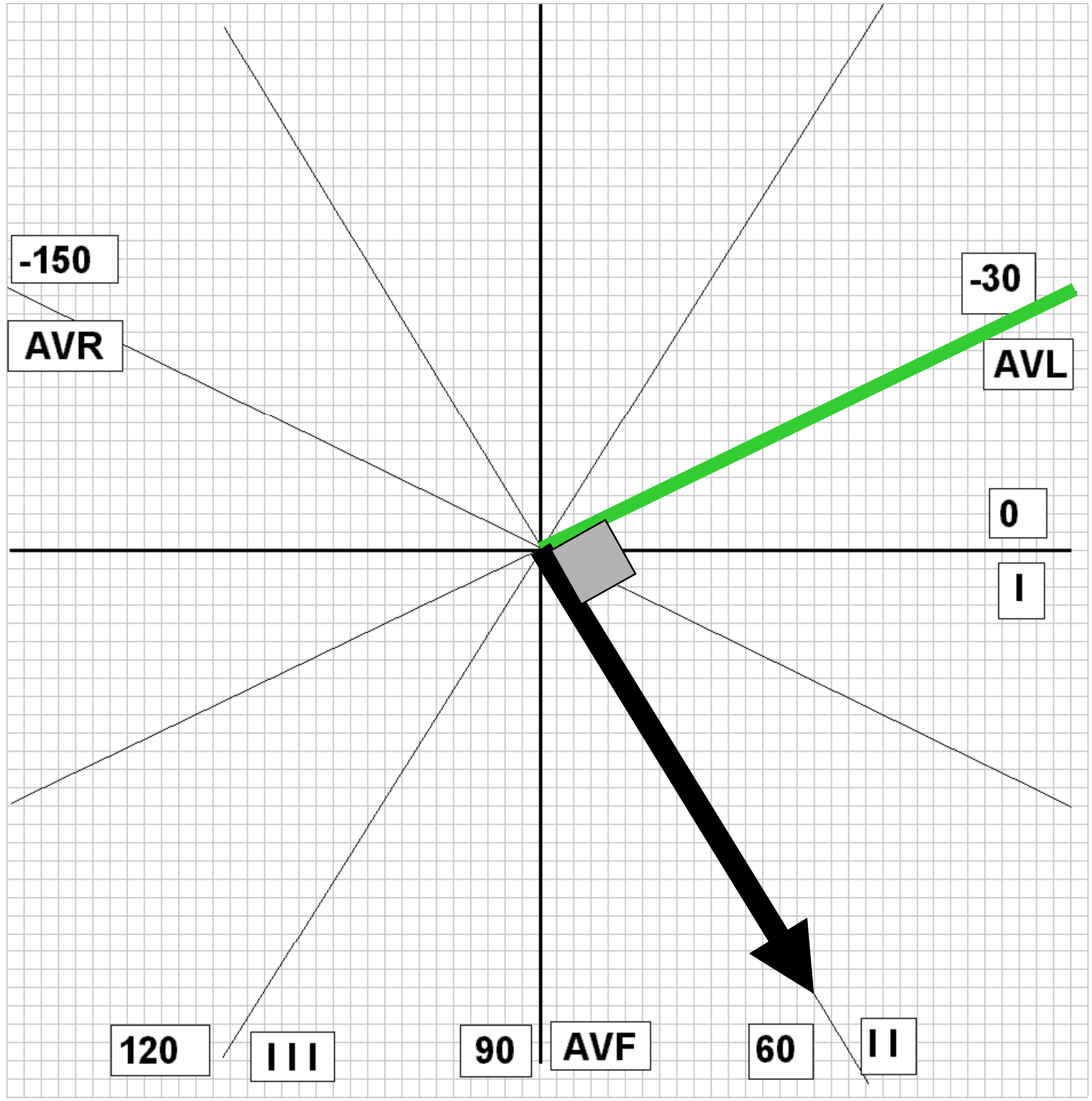
Combining the two plots, we see that the axis must lie in the bottom right hand quadrant



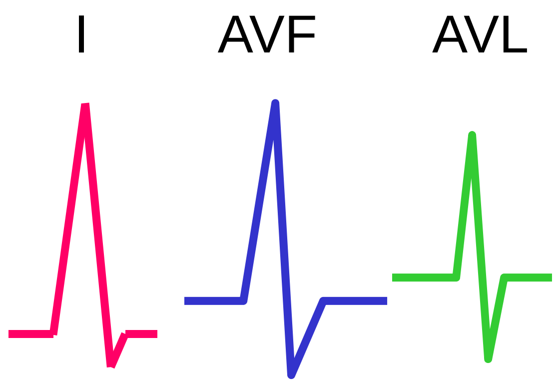
Hexaxial Array for Axis Determination – Example 1



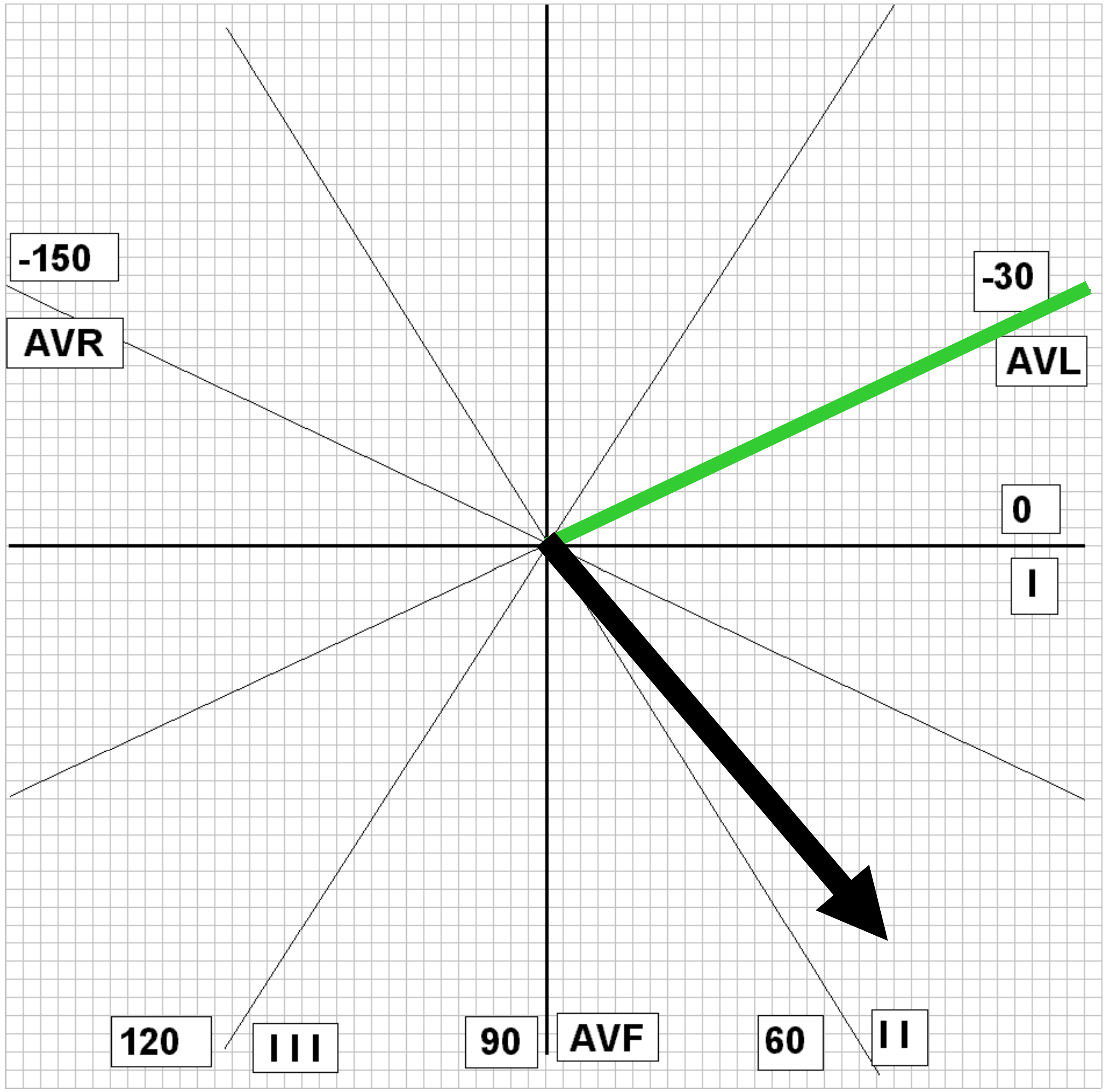
Once the quadrant has been determined, find the most equiphasic or smallest limb lead. The axis will lie about 90º away from this lead. Given that AVL is the most equiphasic lead, the axis here is at approximately 60º.



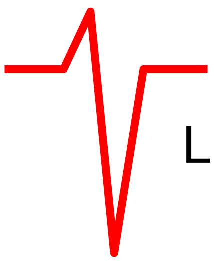
Hexaxial Array for Axis Determination – Example 1

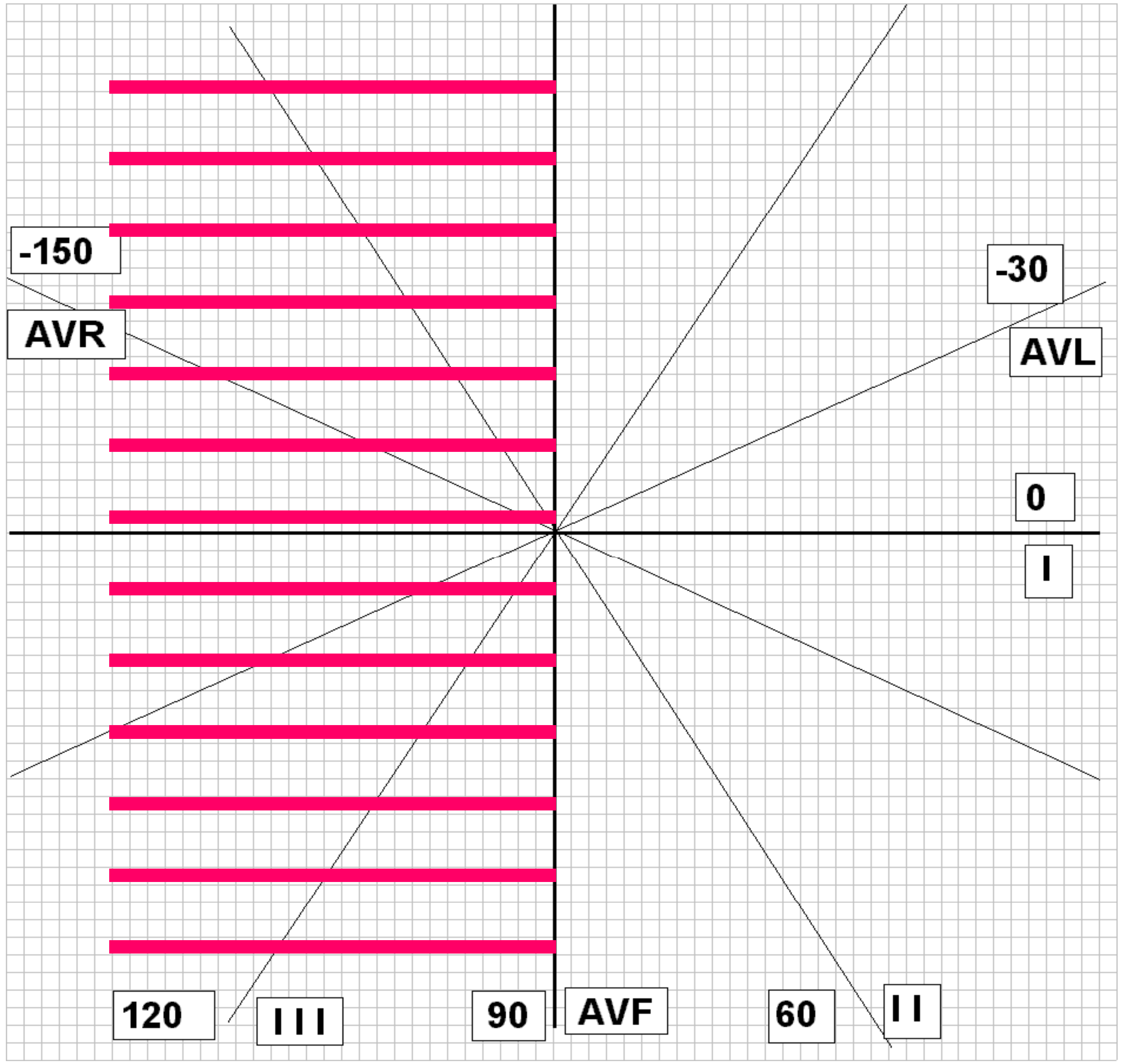


Since QRS complex in AVL is a slightly more positive, the true axis will lie a little closer to AVL (the depolarization vector is moving a little more towards AVL than away from it). A better estimate would be about 50º (normal axis).



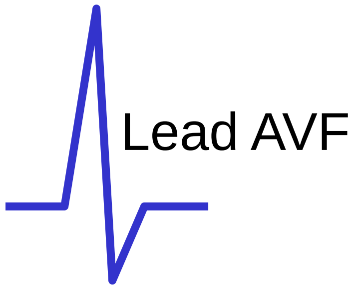
Hexaxial Array for Axis Determination – Example 2



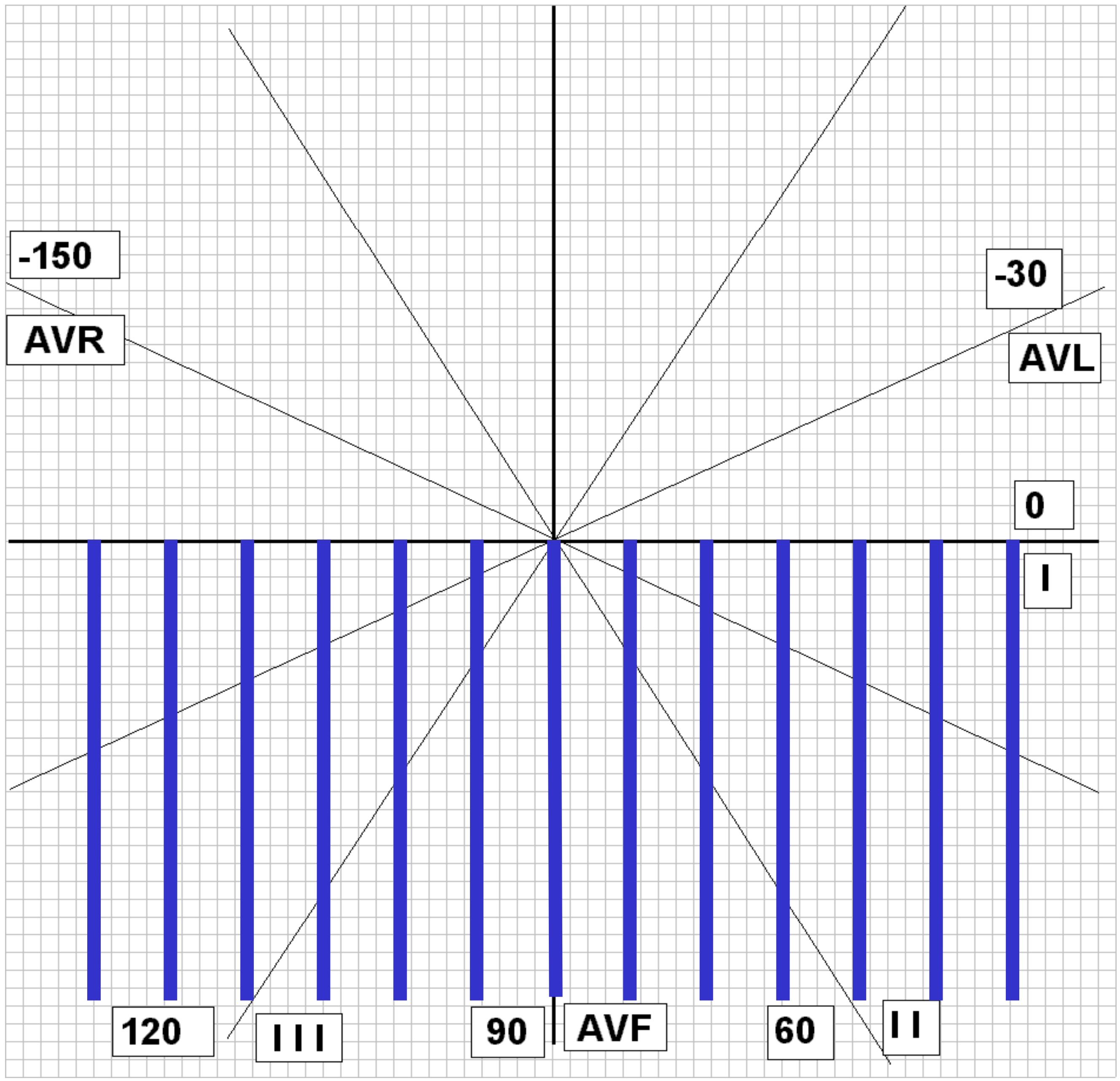


If lead I is mostly negative, the axis must lie in the left half of of the coordinate system.

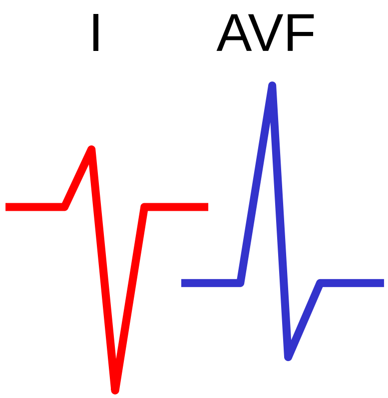
Hexaxial Array for Axis Determination – Example 2



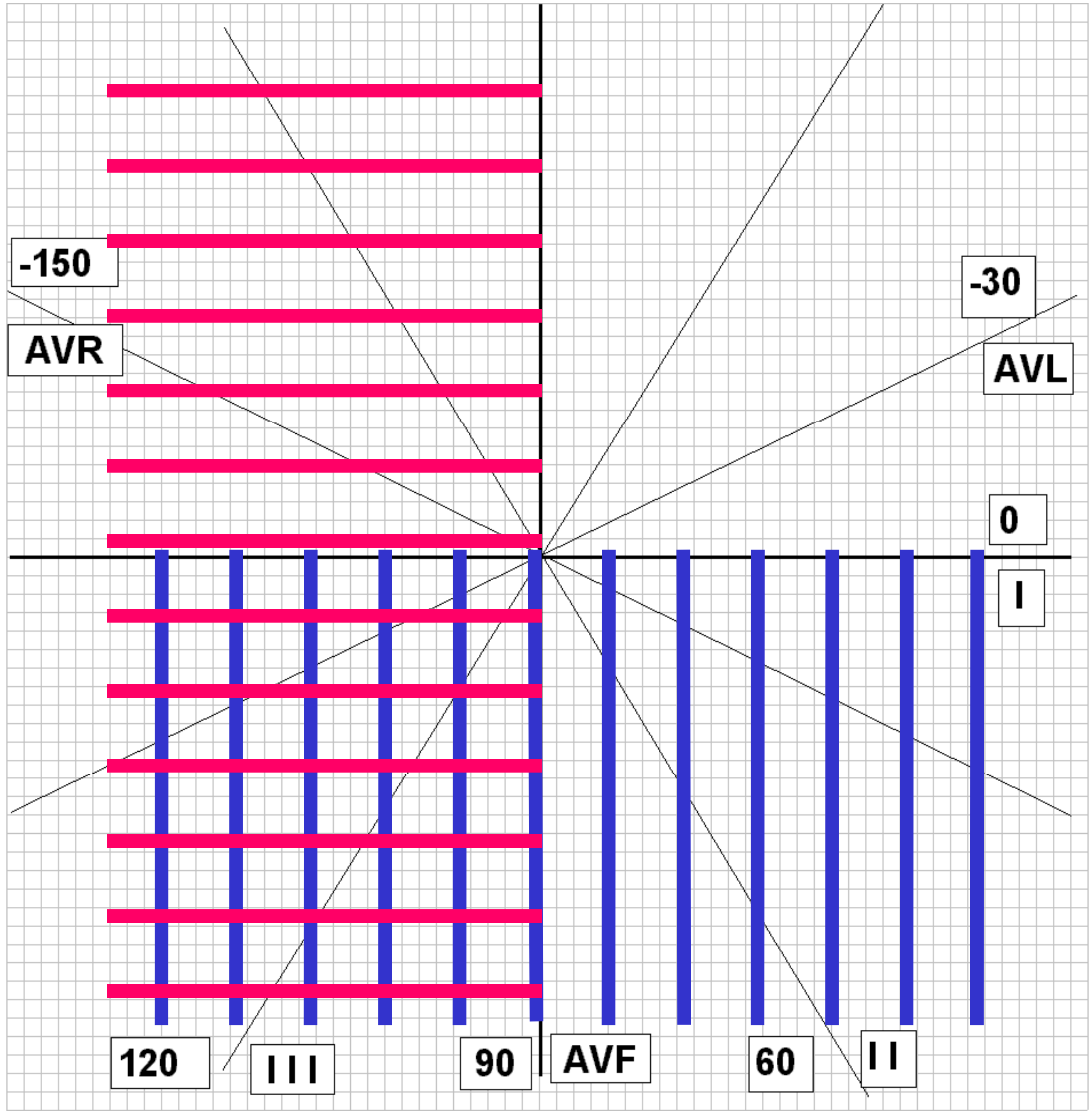
If lead AVF is mostly positive, the axis must lie in the bottom half of of the coordinate system



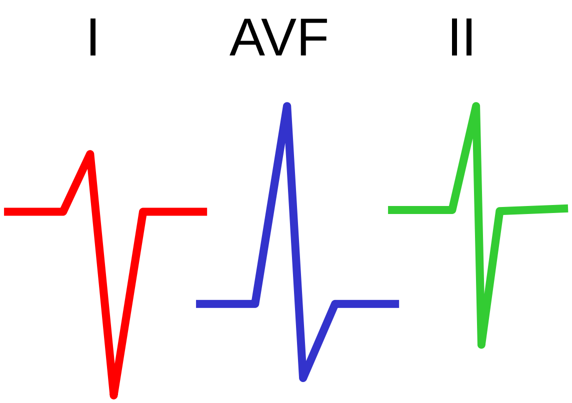
Hexaxial Array for Axis Determination – Example 2



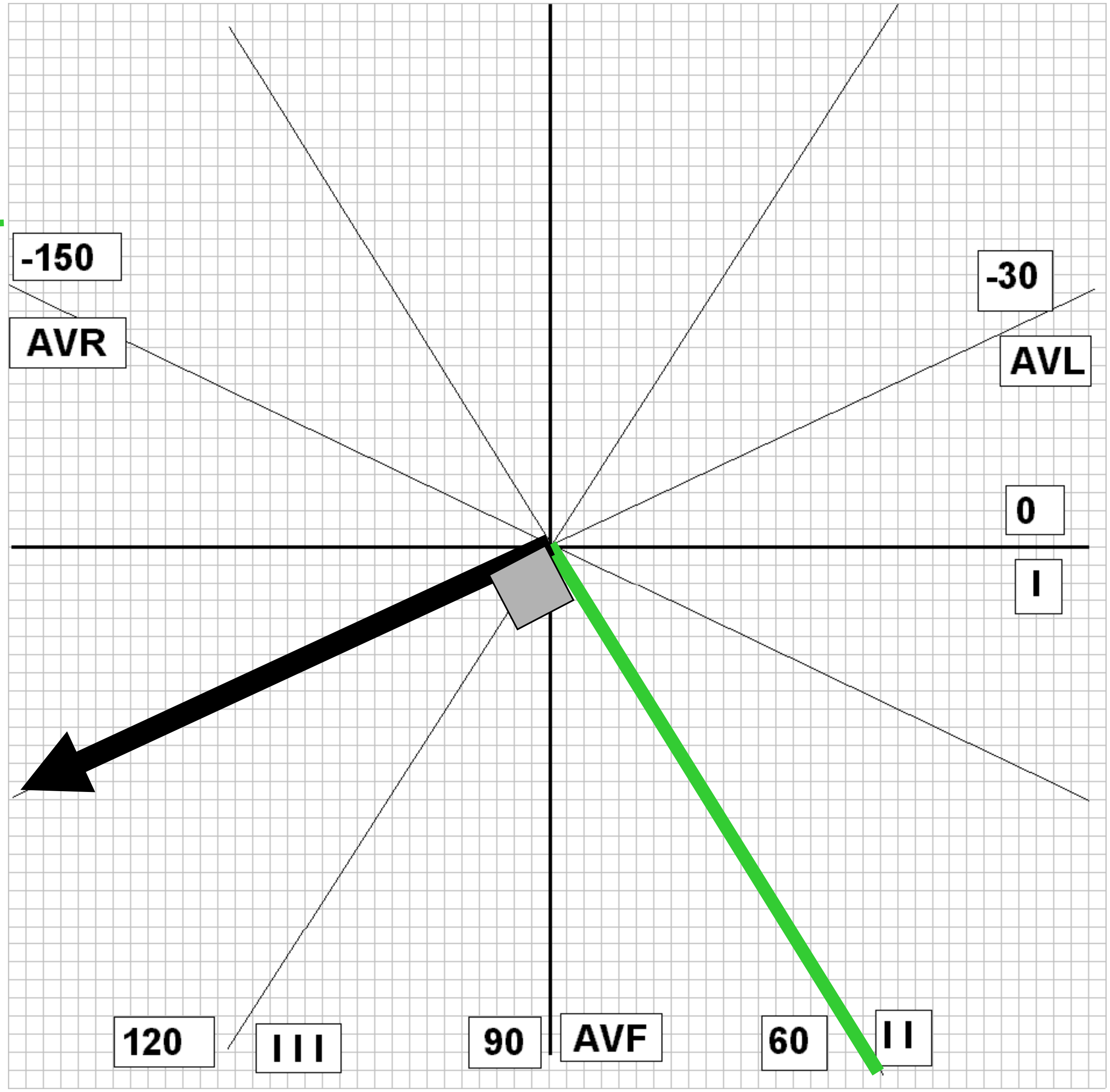
Combining the two plots, we see that the axis must lie in the bottom left hand quadrant (Right Axis Deviation)



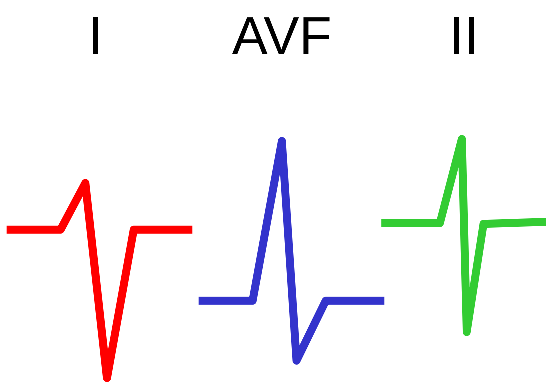
Hexaxial Array for Axis Determination – Example 2



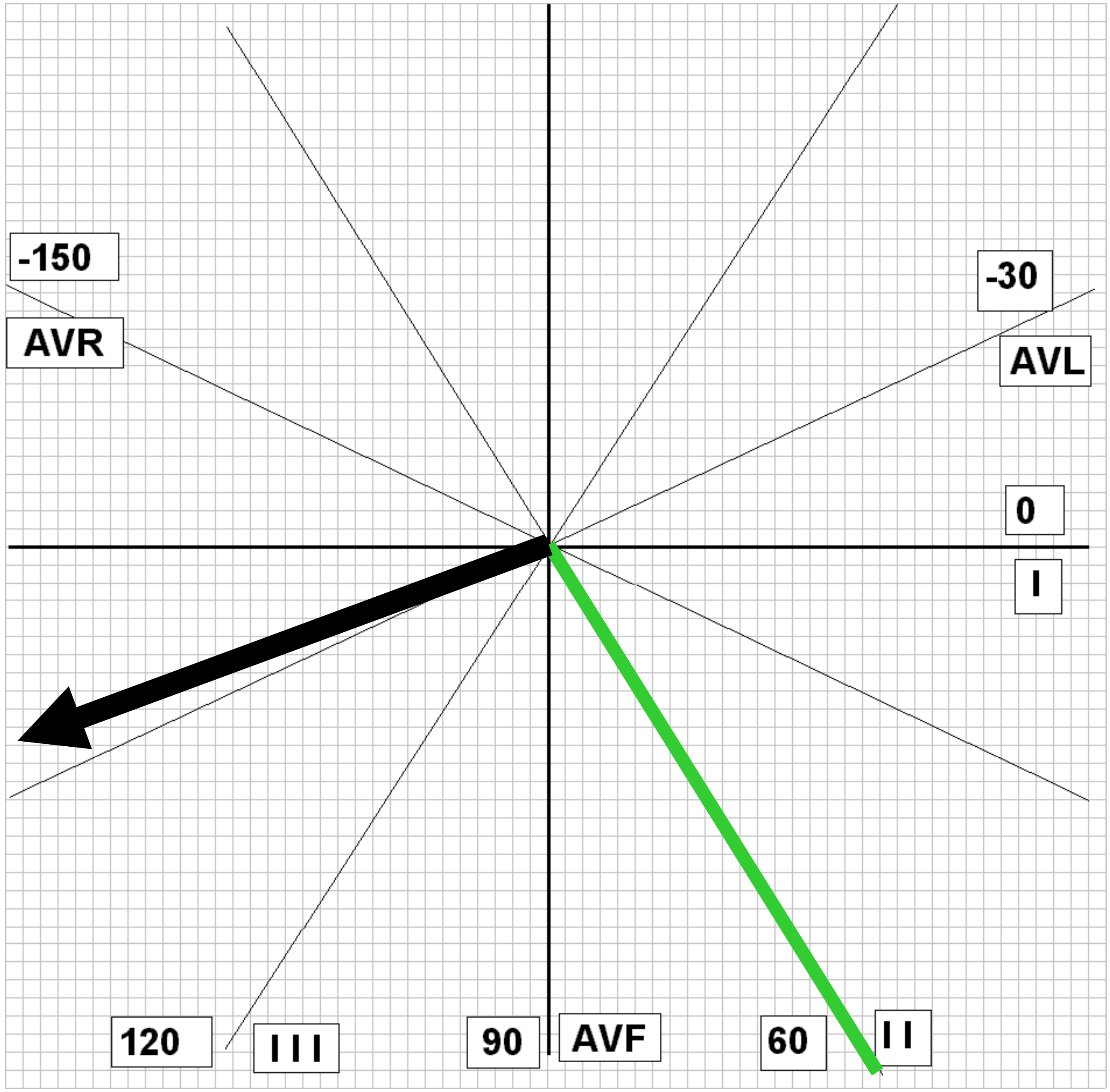
Once the quadrant has been determined, find the most equiphasic or smallest limb lead. The axis will lie about 90º away from this lead. Given that II is the most equiphasic lead, the axis here is at approximately 150º.



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.