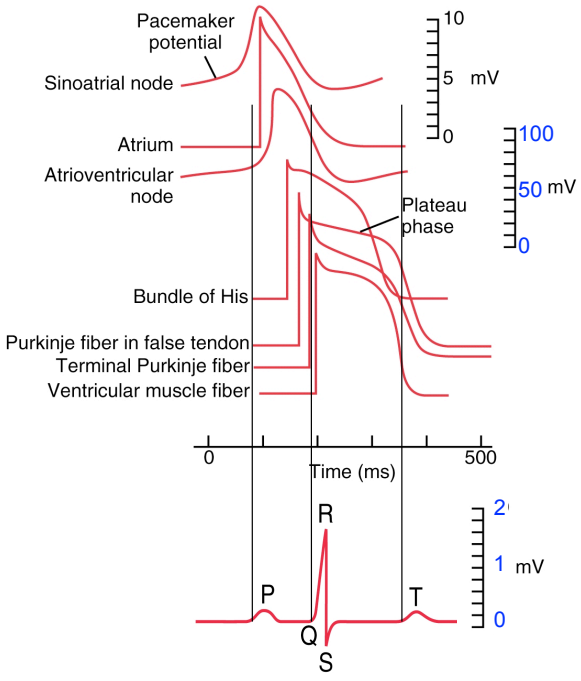
Electrocardiography

Electrophysiology Overview

- Pacemaker cells
  - Neurogenic vs. myogenic
  - SA Node
  - AV Node
  - Purkinje Fibers
- Conduction system
- Ventricular myocytes
- The Electrocardiogram (ECG

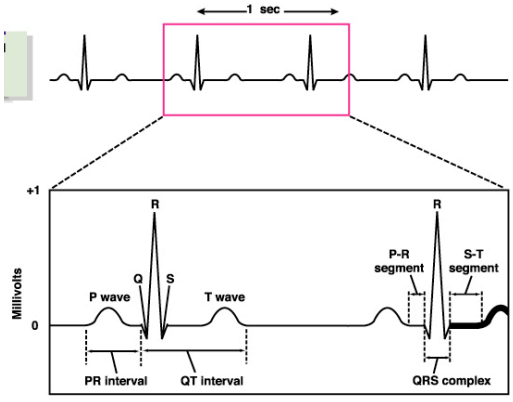


Components of the Electrocardiogram (ECG)

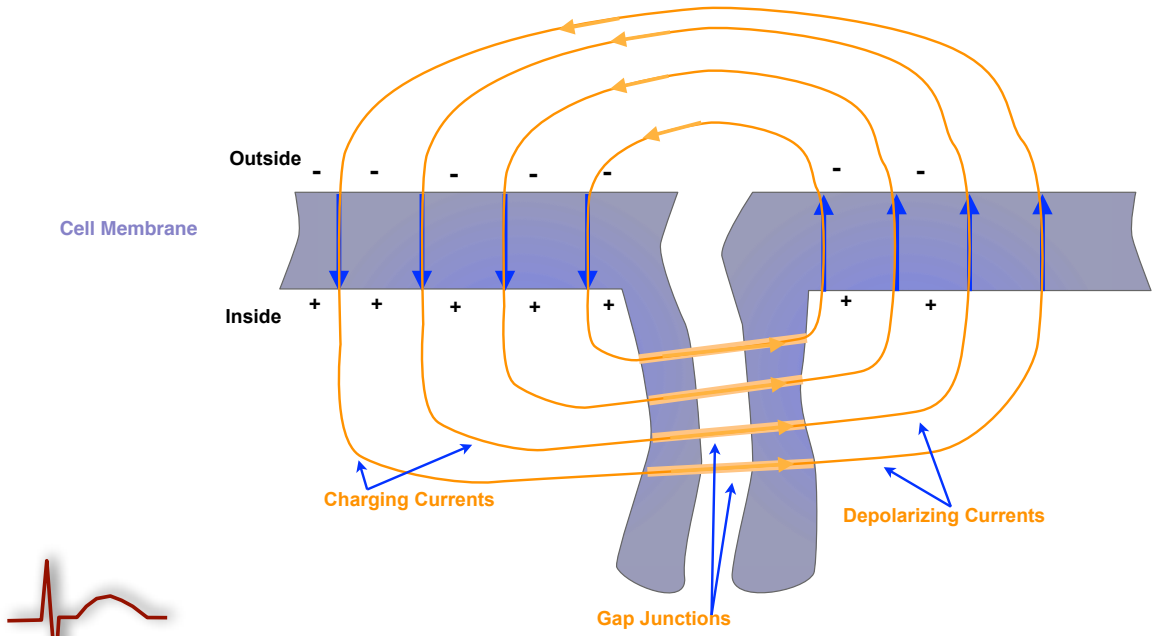
- Source
  - potential differences within the heart
  - spatially distributed and time varying
- Volume conductor
  - inhomogeneous and anisotropic
  - unique to each individual
  - boundary effects
- ECG measurement
  - body surface potentials
  - bipolar versus unipolar measurements
  - Mapping procedures
- Analysis
  - signal analysis
  - simulation and modeling approaches

ECG History and Basics

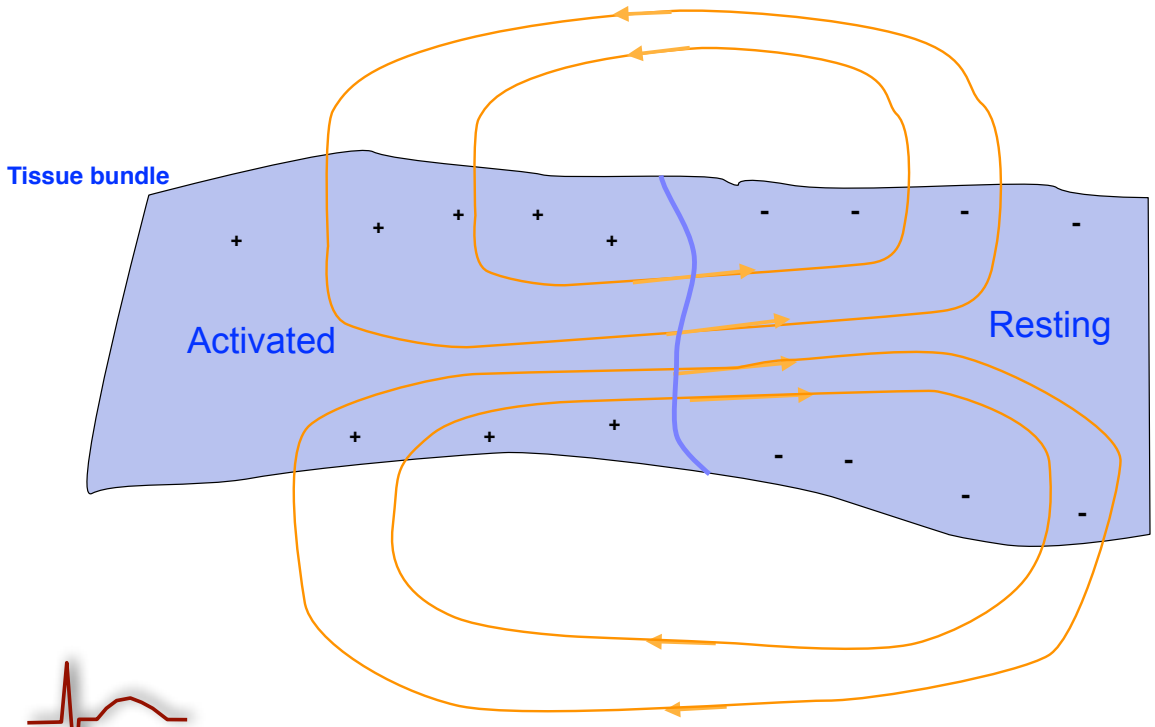
- Represents electrical activity (not contraction)
- Marey, 1867, first electrical measurement from the heart.
- Waller, 1887, first human ECG published.
- Einthoven, 1895, names waves, 1912 invents triangle, 1924, wins Nobel Prize.
- Goldberger, 1924, adds precordial leads



ECG Source Basics

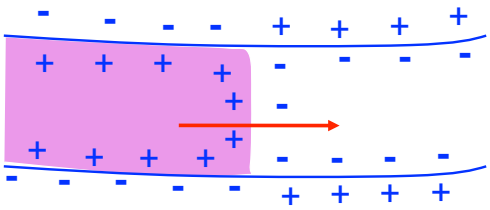


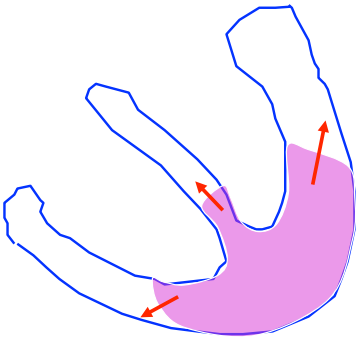
ECG Source Basics

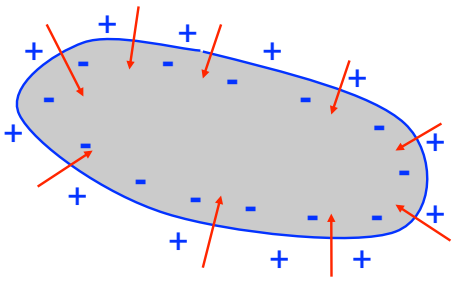


Dipole(s) Source

- Represent bioelectric sources
  - Membrane currents
  - Coupled cells
  - Activation wavefront
  - Whole heart

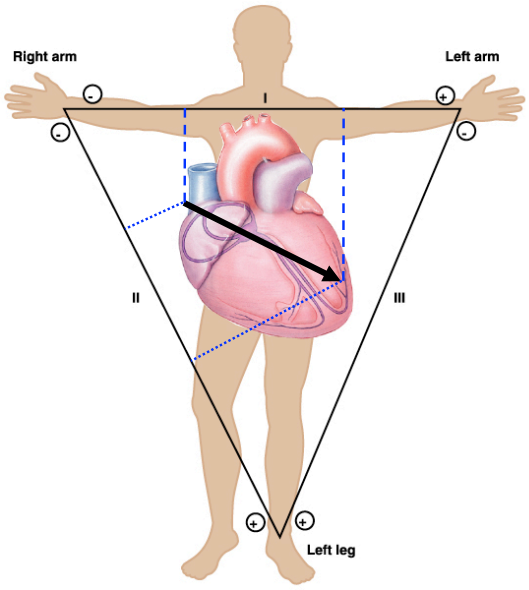




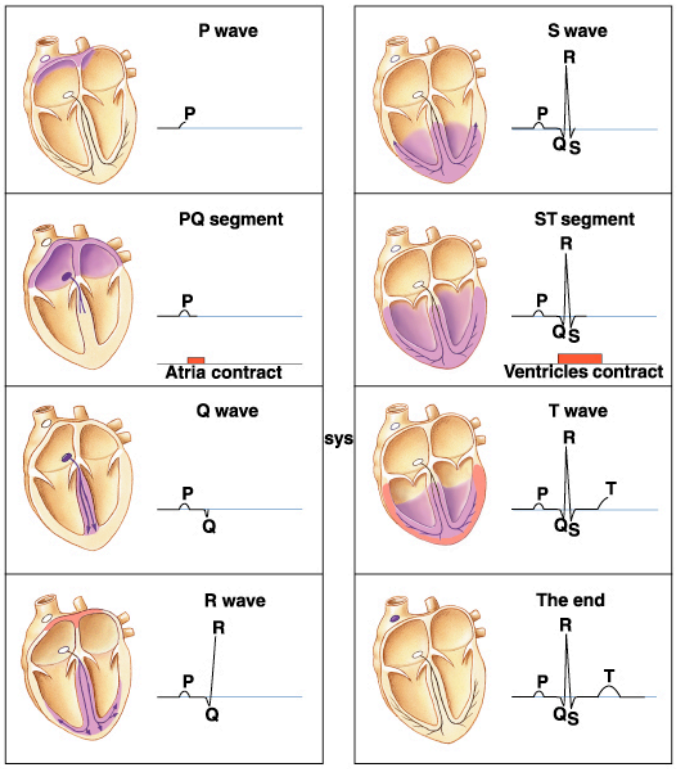


Heart Dipole and the ECG

- Represent the heart as a single moving dipole
- ECG measures projection of the dipole vector
- Why a dipole?
- Is this a good model?
- How can we tell?

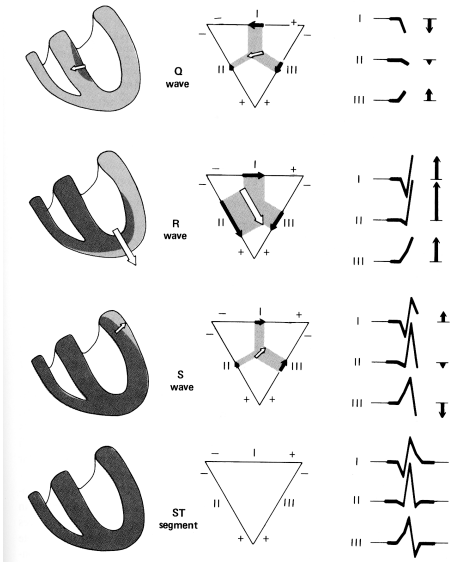


Cardiac Activation Sequence and ECG



Cardiac Activation Sequence: Moving Dipole

- Oriented from active to inactive tissue
- Changes location and magnitude
- Gross simplification

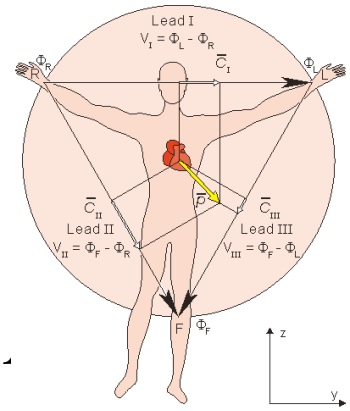


Electrocardiographic Lead Systems

- Einthoven Limb Leads (1895--1912): heart vector, Einthoven triangle, string galvanometer
- Goldberger, 1924: adds augmented and precordial leads, the standard ECG
- Wilson Central Terminal (1944): the "indifferent" reference
- Frank Lead System (1956): based on three-dimensional Dipole
- Body Surface Potential Mapping (Taccardi, 1963)

Einthoven ECG

- Bipolar limb leads
- Einthoven Triangle
- Based on heart vector

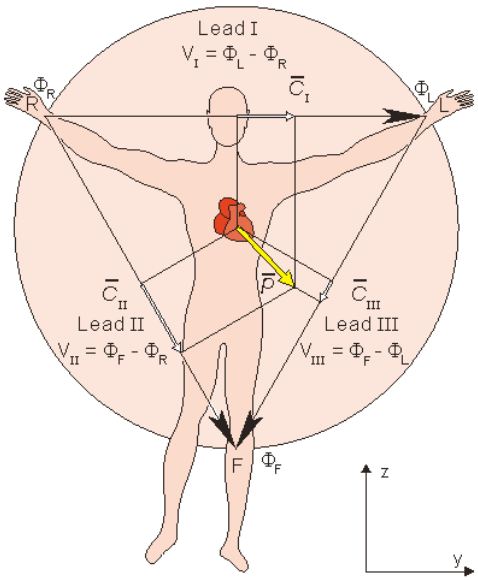


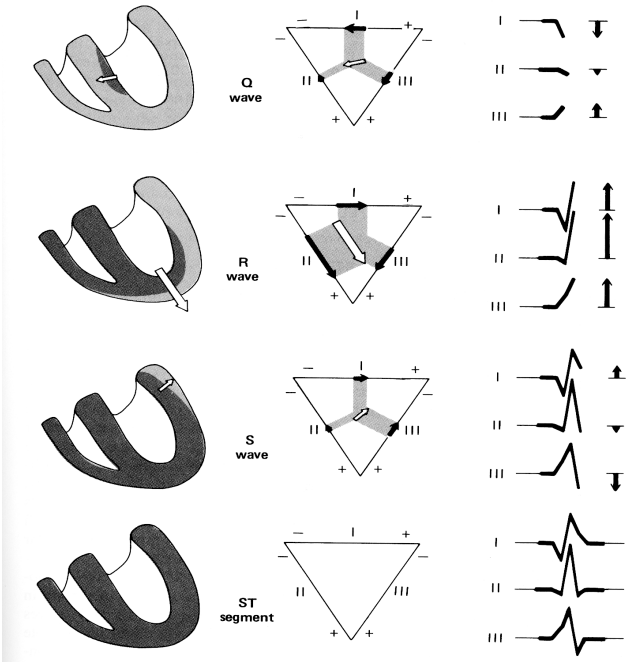
$$V_I = \Phi_{LA} - \Phi_R$$
$$V_{II} = \Phi_{LL} - \Phi_{RA}$$
$$V_{III} = \Phi_{LL} - \Phi_{LA}$$

Applying Kirchoff's Laws to these definitions yields:

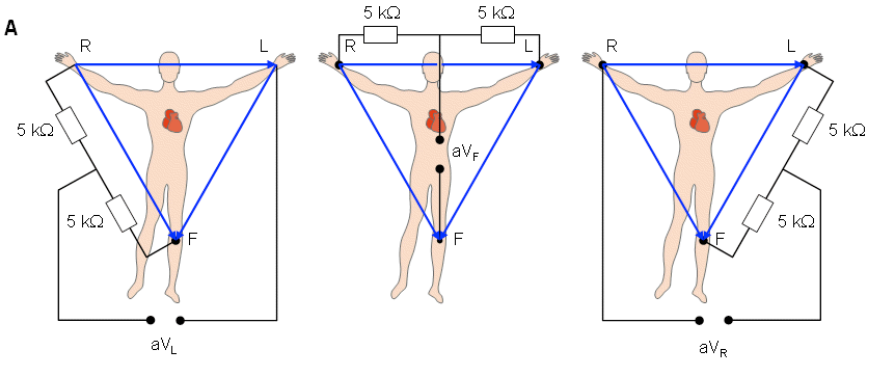
$$V_I + V_{III} = V_{II}$$

Einthoven/Limb Leads



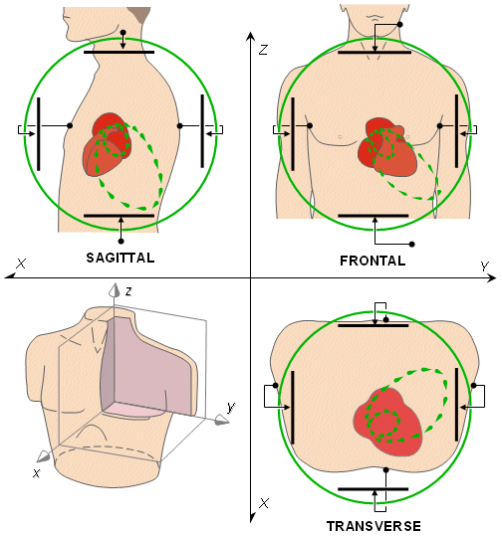


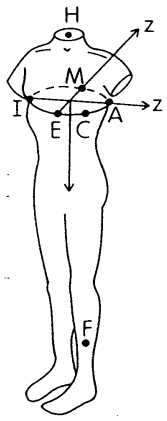
Augmented Leads

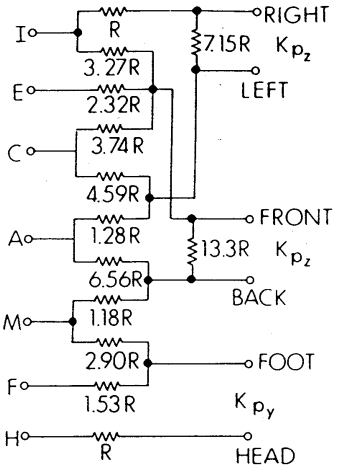


Vectorcardiographic Lead Systems

Frank Lead System

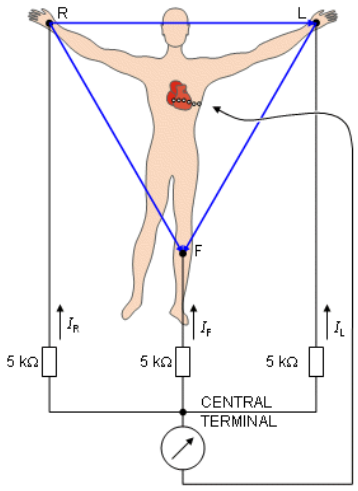






Wilson Central Terminal

- Goldberger (1924) and Wilson (1944)
- “Invariant” reference
- “Unipolar” leads
- Standard in clinical applications
- Driven right leg circuit



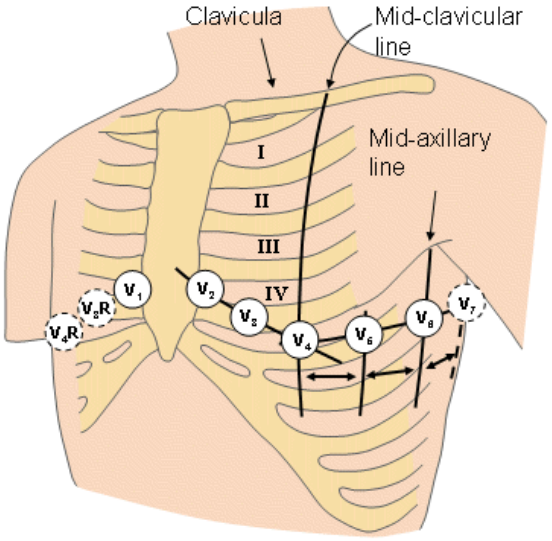
$$I_R + I_F + I_L = 0$$

$$\frac{\Phi_{CT} - \Phi_{RA}}{5000} + \frac{\Phi_{CT} - \Phi_{LA}}{5000} + \frac{\Phi_{CT} - \Phi_{LL}}{5000} = 0$$

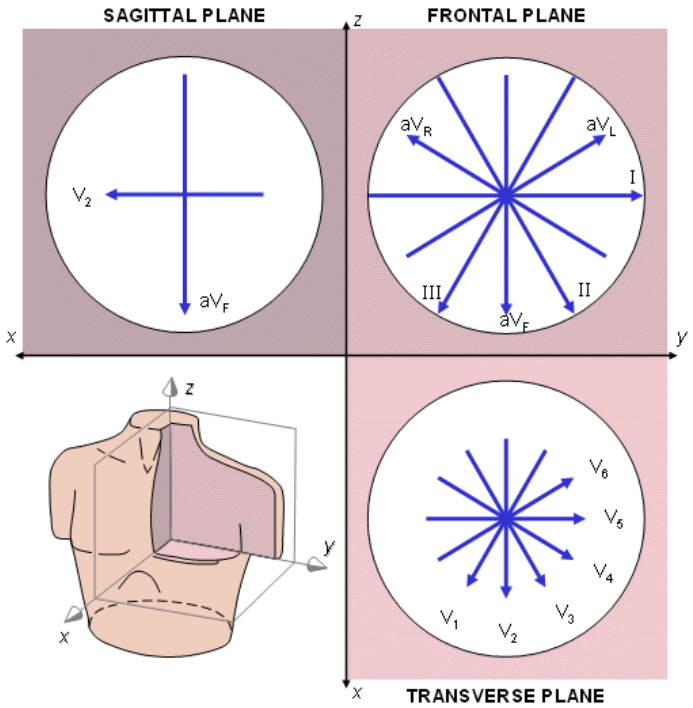
$$\Phi_{CT} = \frac{\Phi_{RA} + \Phi_{LA} + \Phi_{LL}}{3}$$

Precordial Leads

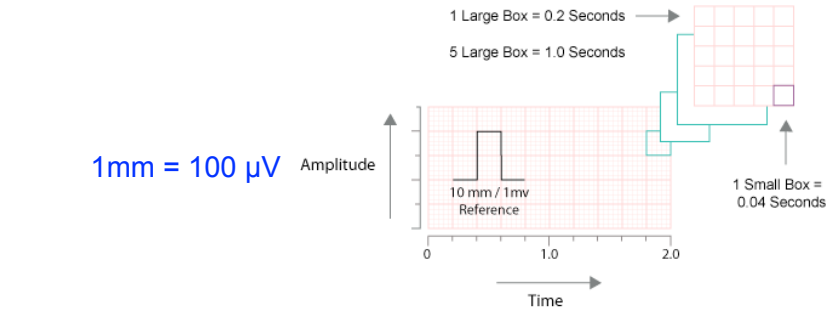
- Modern clinical standard (V1-V6)
- Note enhanced precordials on right side of chest and V7



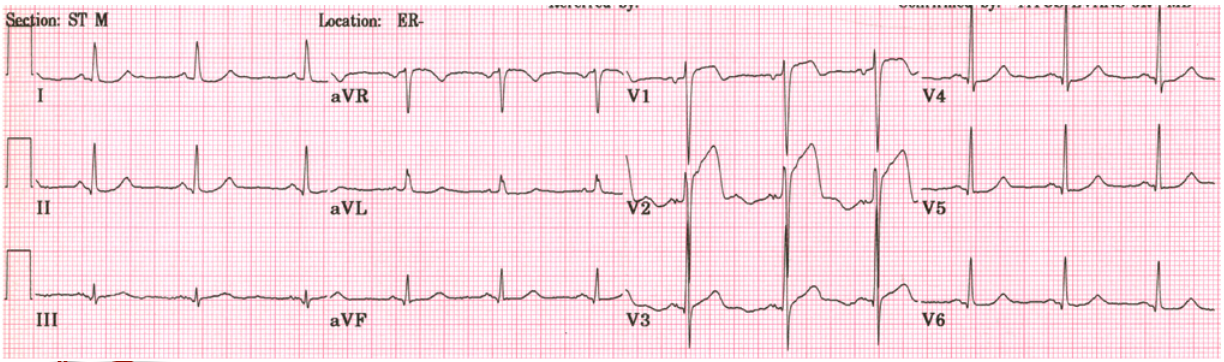
Projection Summary



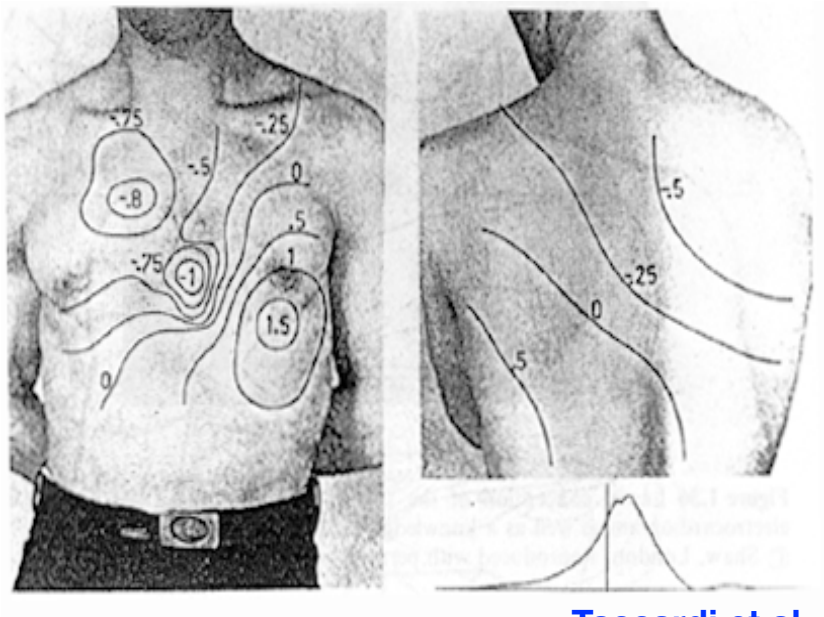
Standard (12-lead) ECG



50 mm = 1 s 1 mm = 40 ms

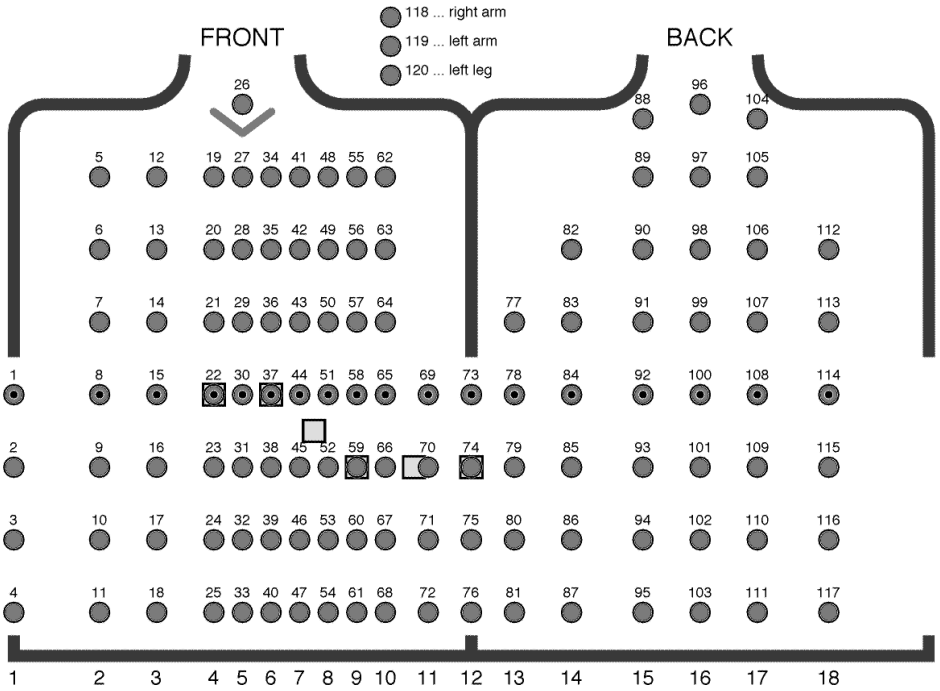


Body Surface Potential Mapping

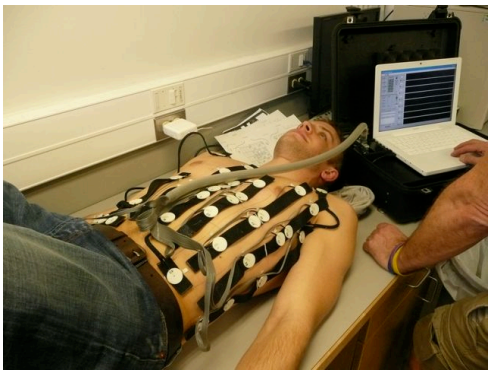


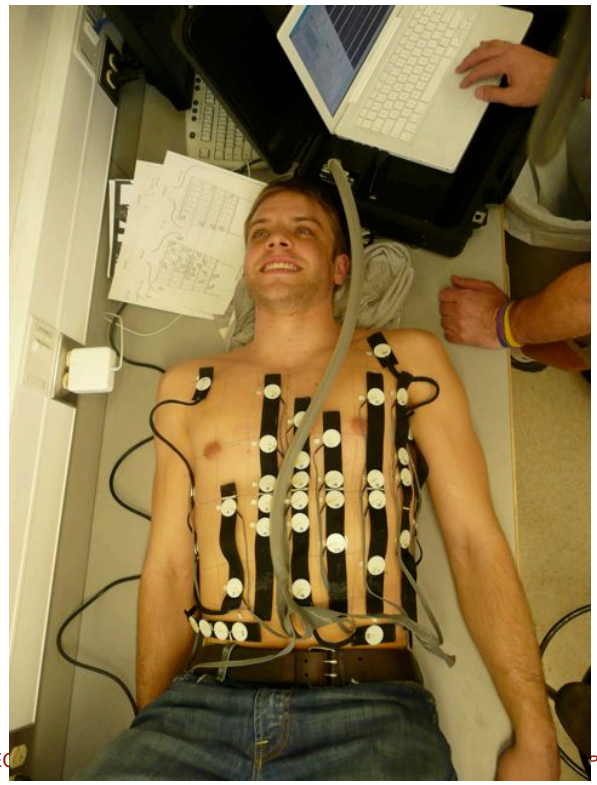
Taccardi et al, Circ., 1963

Body Surface Potential Mapping



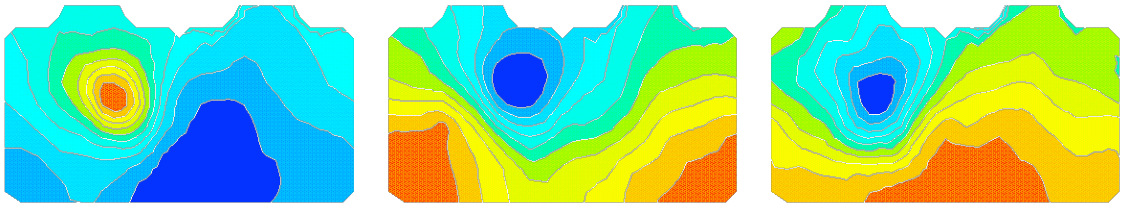
Body Surface Potential Mapping





Feature/Pattern Analysis

Angioplasty Mapping

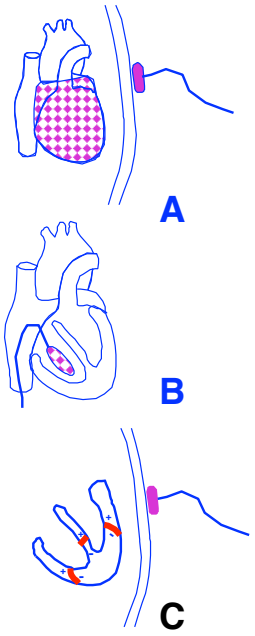


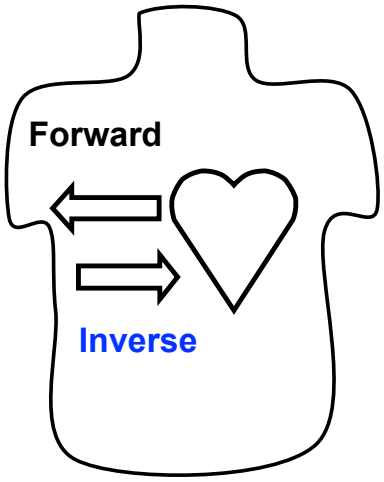
LAD RCA LCx

Taccardi Video

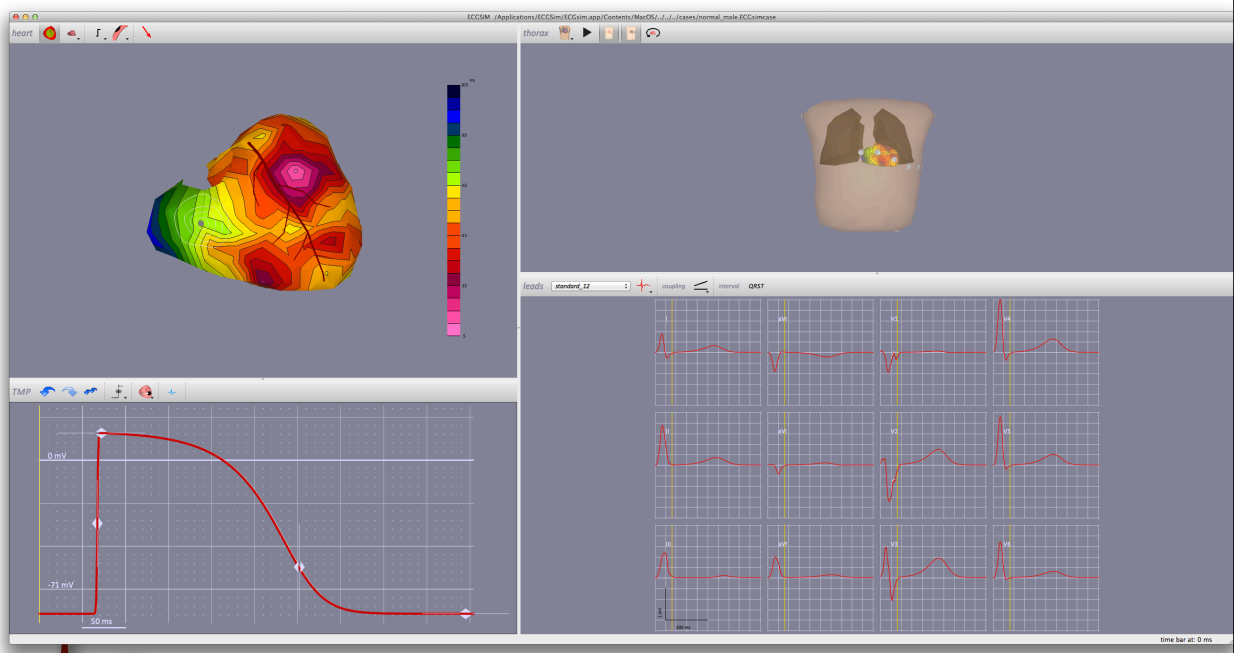
http://www.sci.utah.edu/gallery2/v/cibc/video/taccardi_lg.html

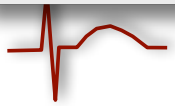
Forward/Inverse Problems in Electrocardiography





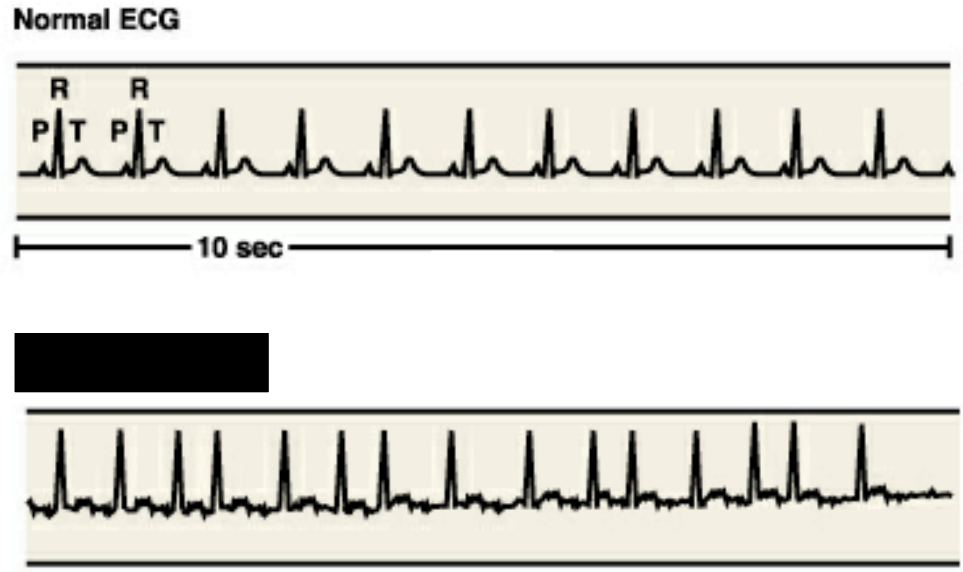
Forward Simulation with ECGSim



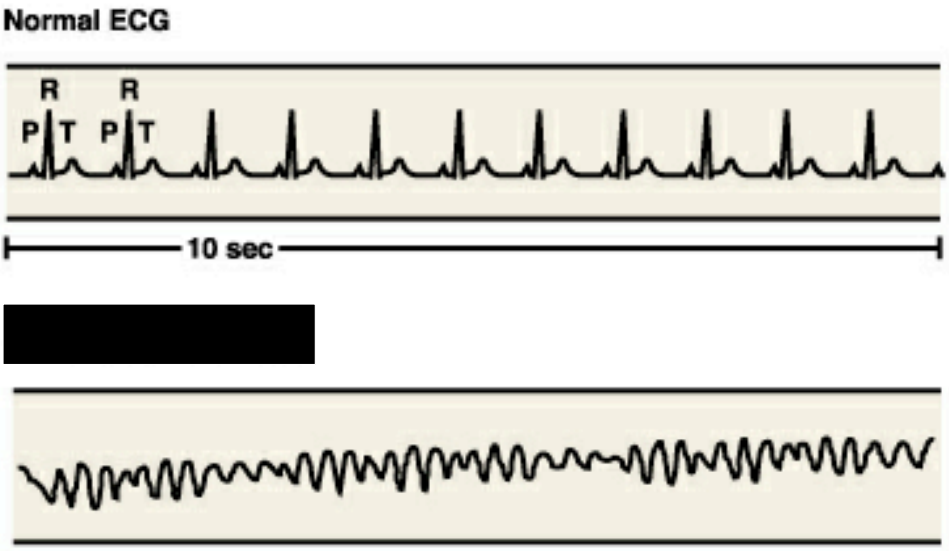


ECG Example 1

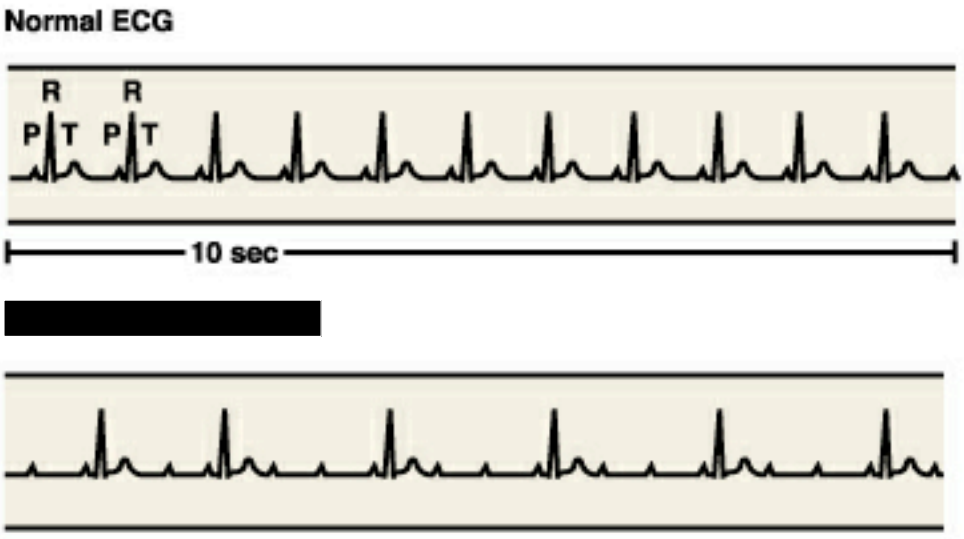
ECG Example 2



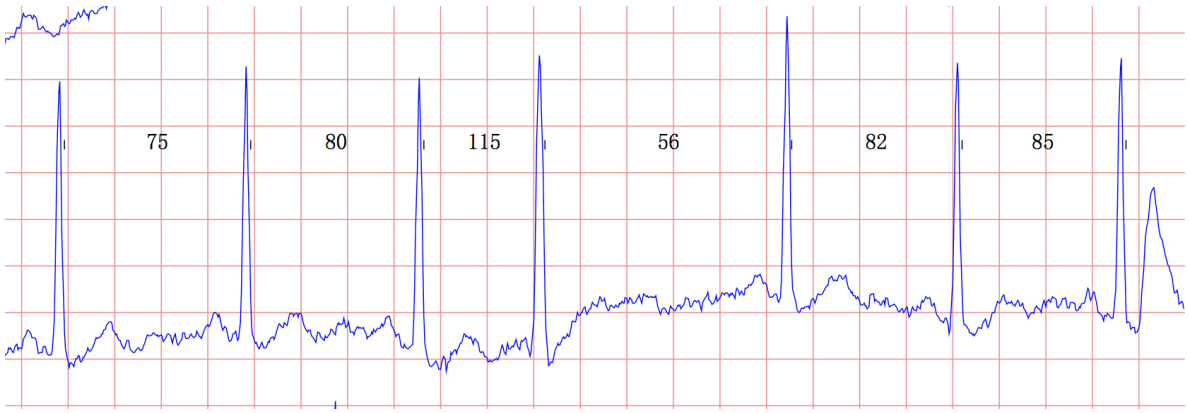
ECG Example 3



ECG Example 4



Some Real Examples



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