

Bioelectric Dipole Sources

January 30, 2019

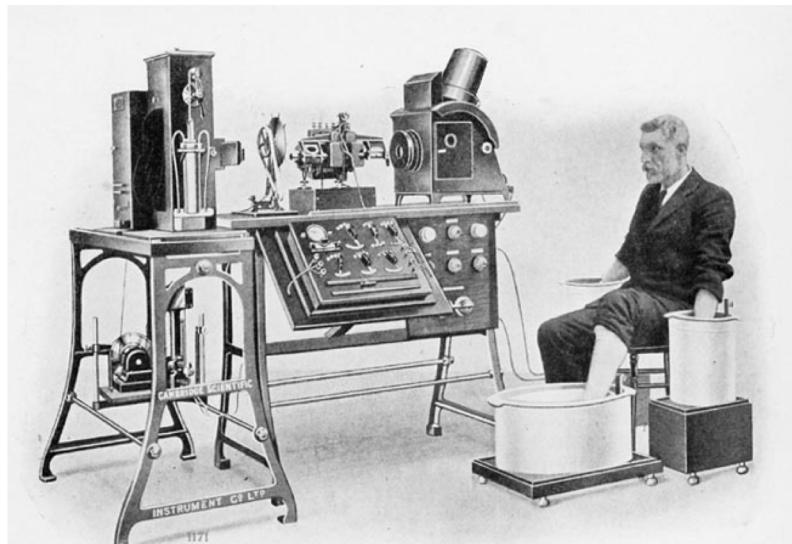
580.435/635 Applied Bioelectrical Engineering
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Johns Hopkins University

What you can expect to learn today

- Action potentials and action currents as bioelectrical sources
- Concept of source-load
- Concept of the excitatory current dipole
- Potentials in a volume conductor arising from a current dipole
- Dependence of ECG recordings on lead position
- Standard 12-lead ECG system

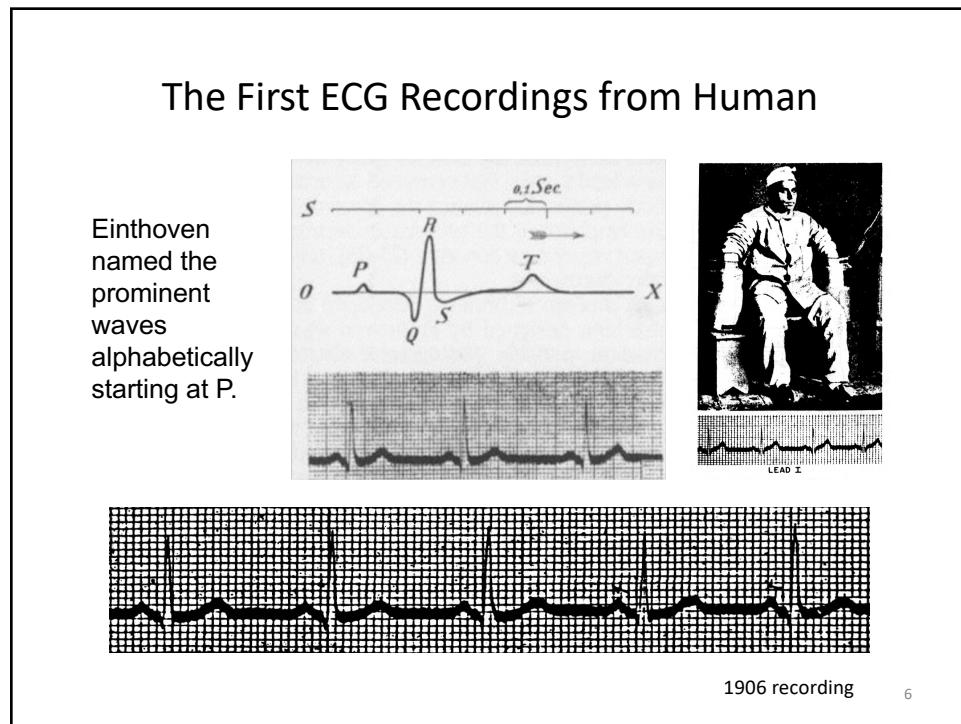
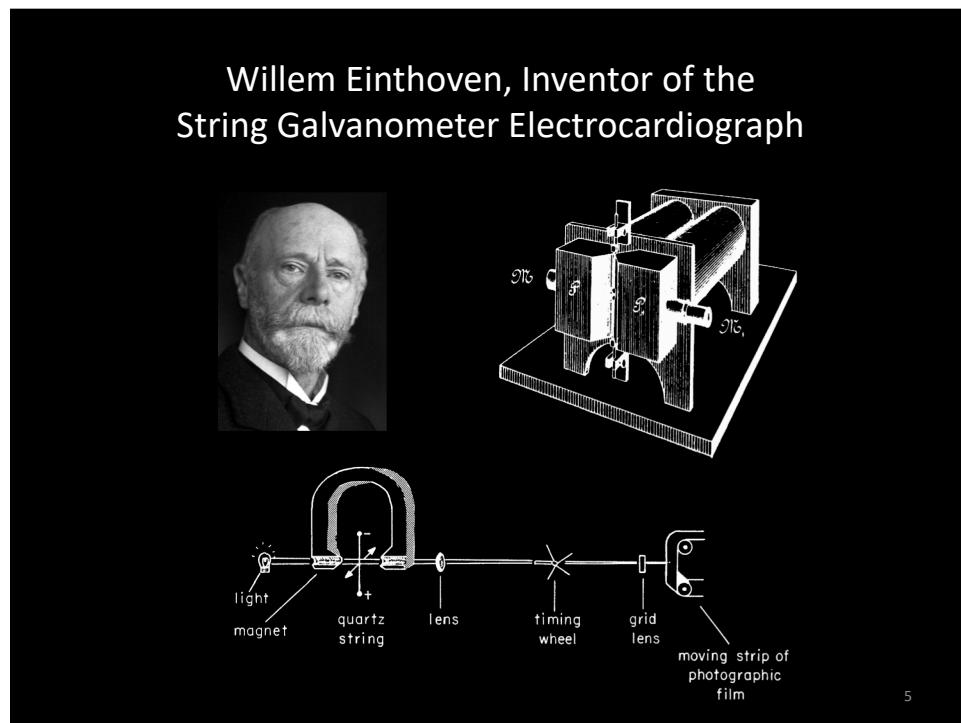
The Electrocardiogram (ECG)

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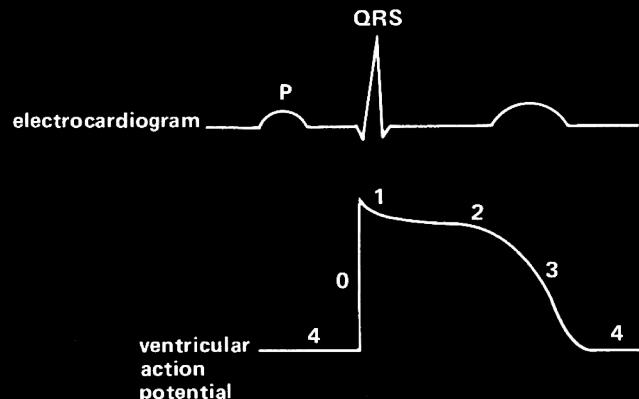


PHOTOGRAPH OF A COMPLETE ELECTROCARDIOGRAPH, SHOWING THE MANNER IN WHICH THE ELECTRODES ARE ATTACHED TO THE PATIENT, IN THIS CASE THE HANDS AND ONE FOOT BEING IMMERSSED IN JARS OF SALT SOLUTION

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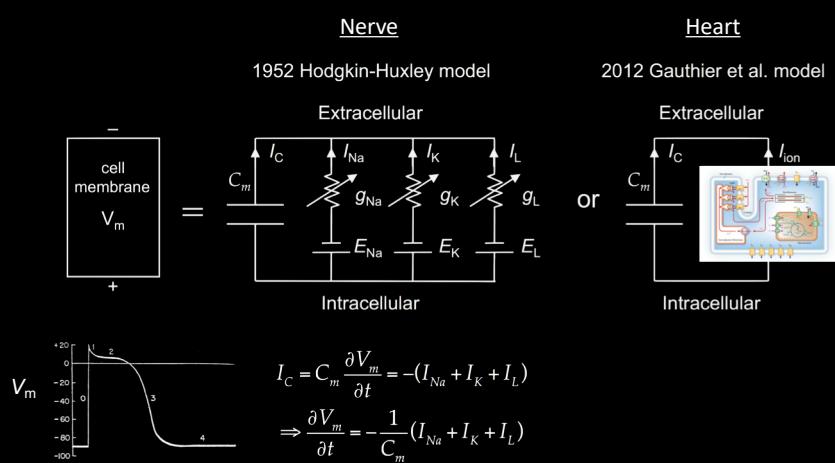


What is the intrinsic relationship between the (organismal) electrocardiogram (ECG) and the (cellular) cardiac action potential?



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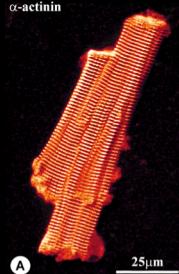
Ionic Currents Give Rise to the Action Potential



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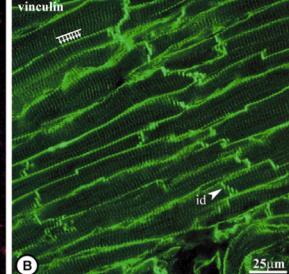
Cellular Arrangement in Cardiac Muscle

- Orderly arrangement of cells.
- Each cell is ~10-20 μm wide and ~100-200 μm long.
- Cells form fiber-like and sheet-like arrays.
- Space between cells is called “interstitium.”
- Cell-to-cell connections are called “intercalated disks.”
- The myocardium is a “functional syncytium.”



α -actinin

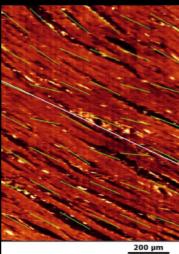
A



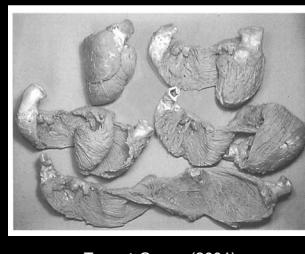
vinculin

B

Severs (2000)



200 μm

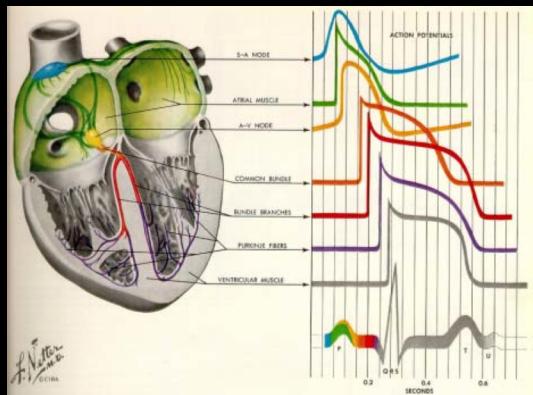


Sands (2008)

Torrent-Guasp (2001)

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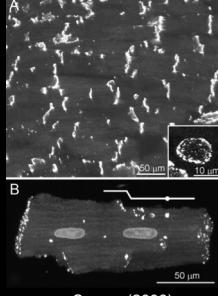
Components of the ECG Arise from Activation and Propagation of Action Potentials



ACTION POTENTIALS

0.2 0.4 0.6 SECONDS

Tissue stained for Cx43



A

B

50 μm

10 μm

Severs (2008)

Activation of different parts of the heart relative to the ECG →



A-V NODE ATRIUM B-P VENTRICLES

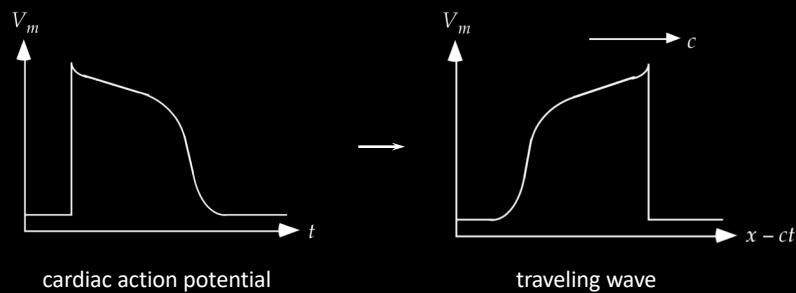
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Propagated Electrical Activity

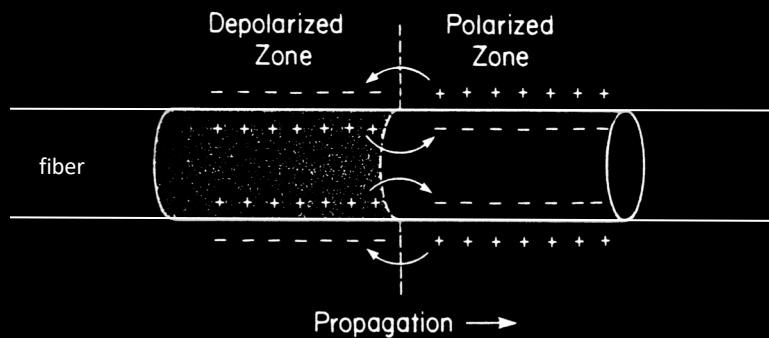
the wave equation

$$\frac{\partial^2 V_m}{\partial x^2} = \frac{1}{c^2} \frac{\partial^2 V_m}{\partial t^2} \Rightarrow V_m = f(ct - x) \text{ or } f(t - \frac{x}{c})$$

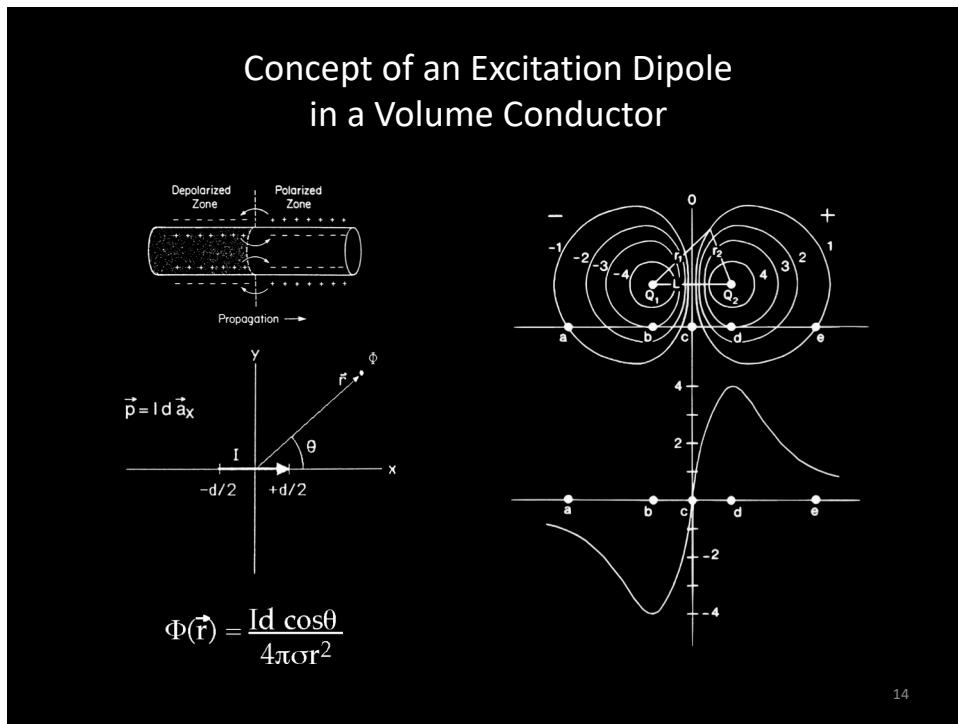
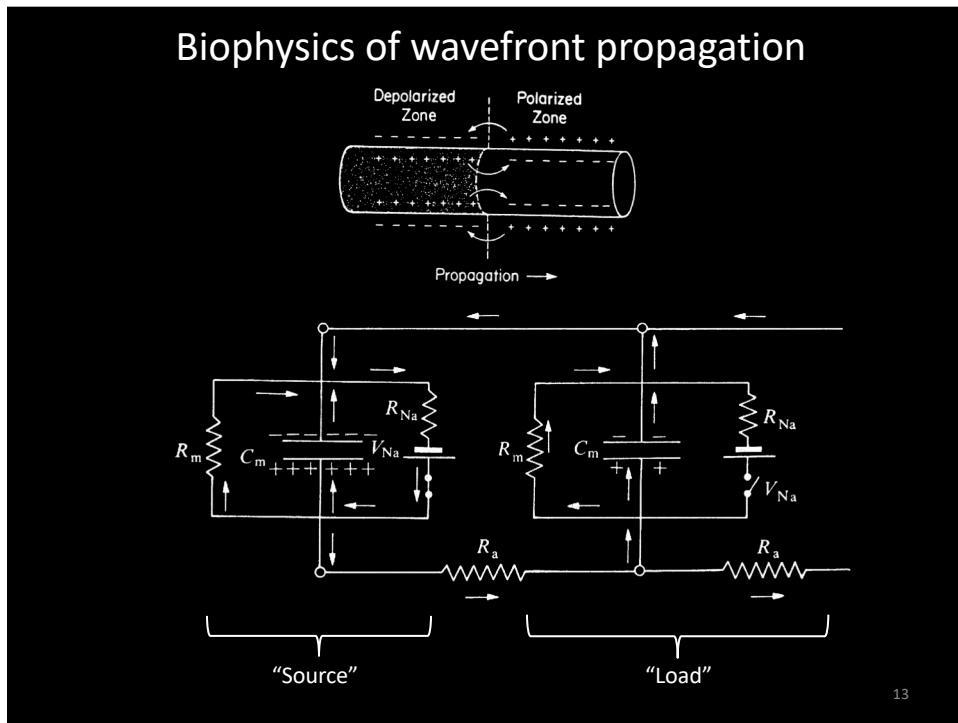


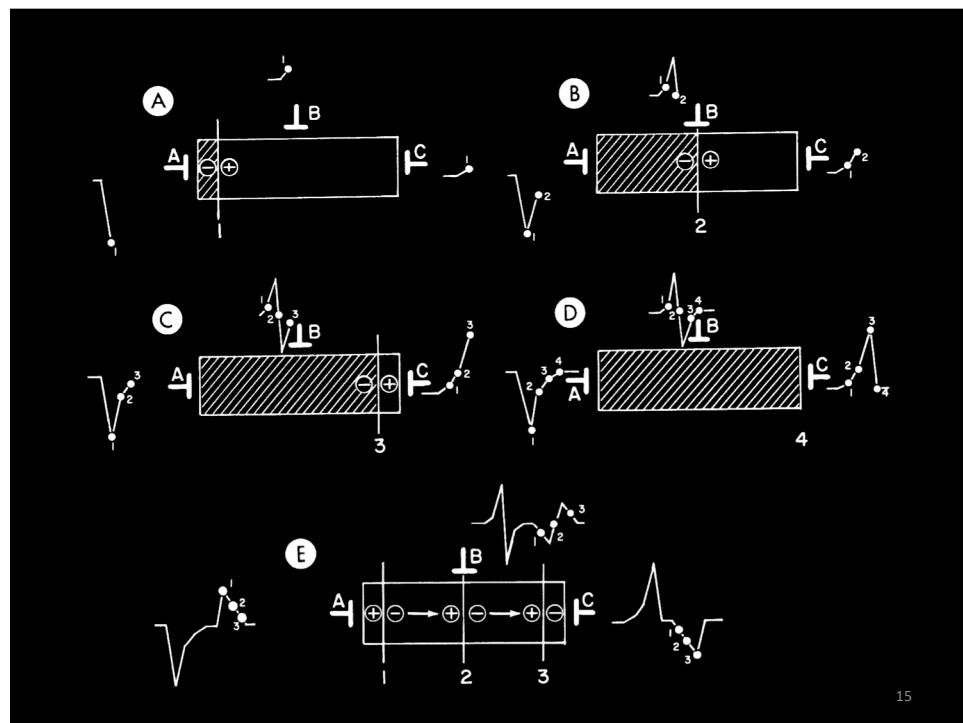
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Propagation of a wave of electrical activity down a linear fiber (nerve fiber, cardiac muscle fiber, skeletal muscle fiber)



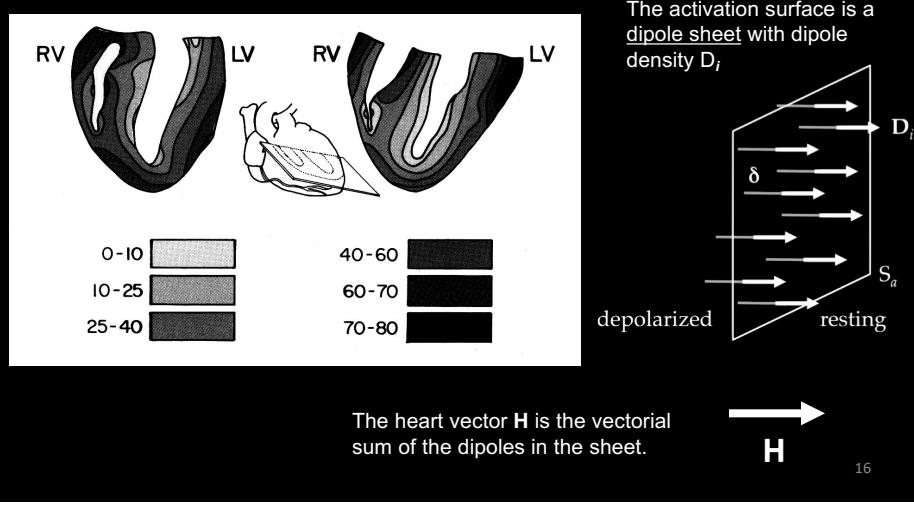
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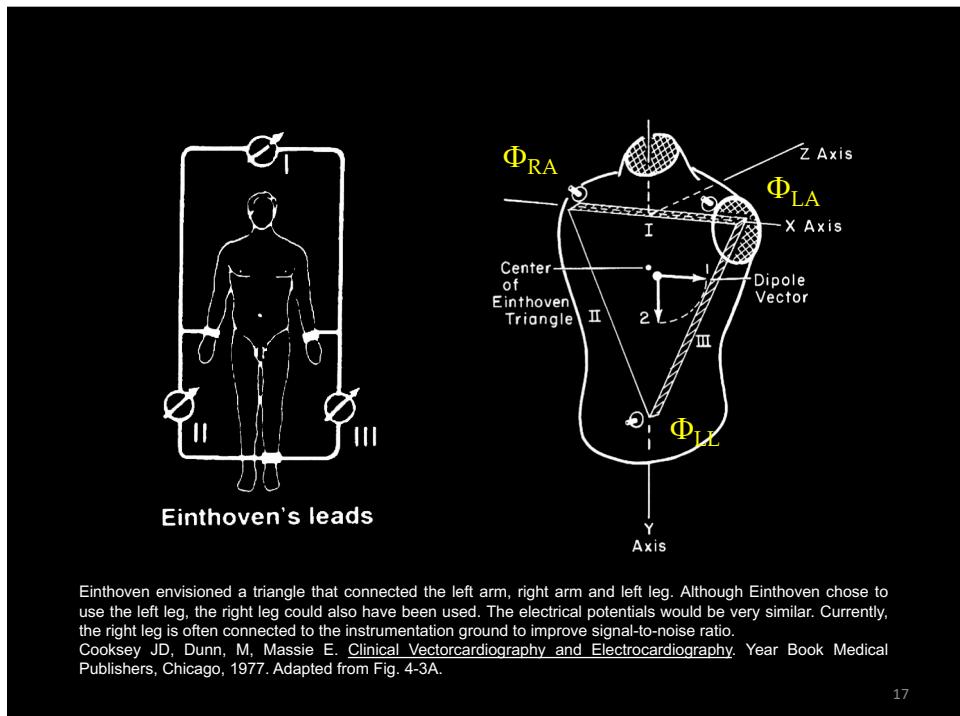


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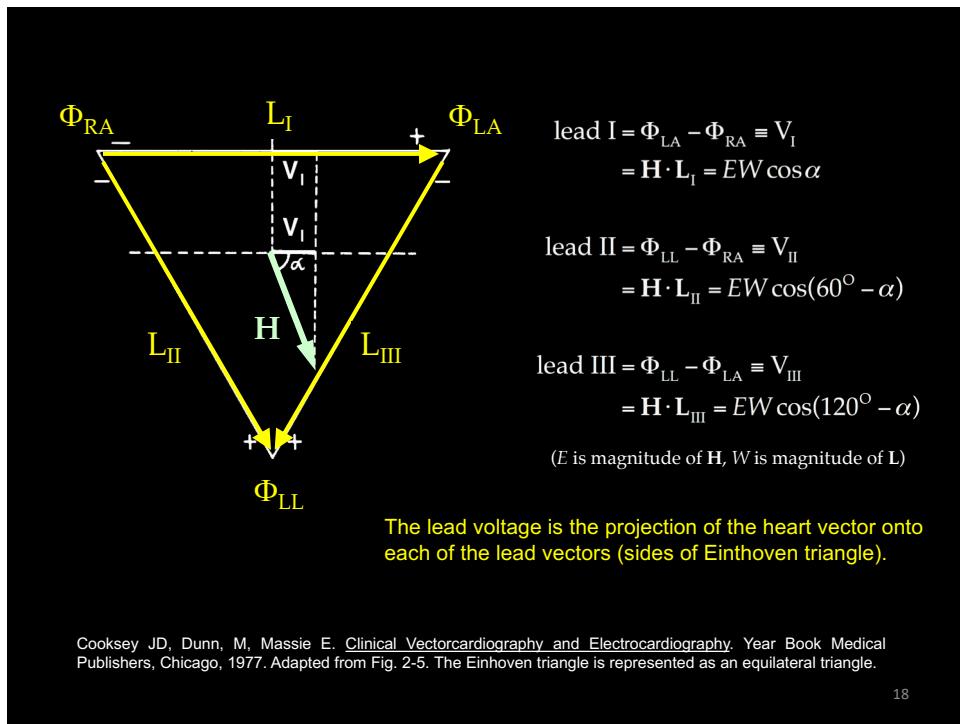
Transmural Activation in the Ventricles Occurs from Endocardium to Epicardium



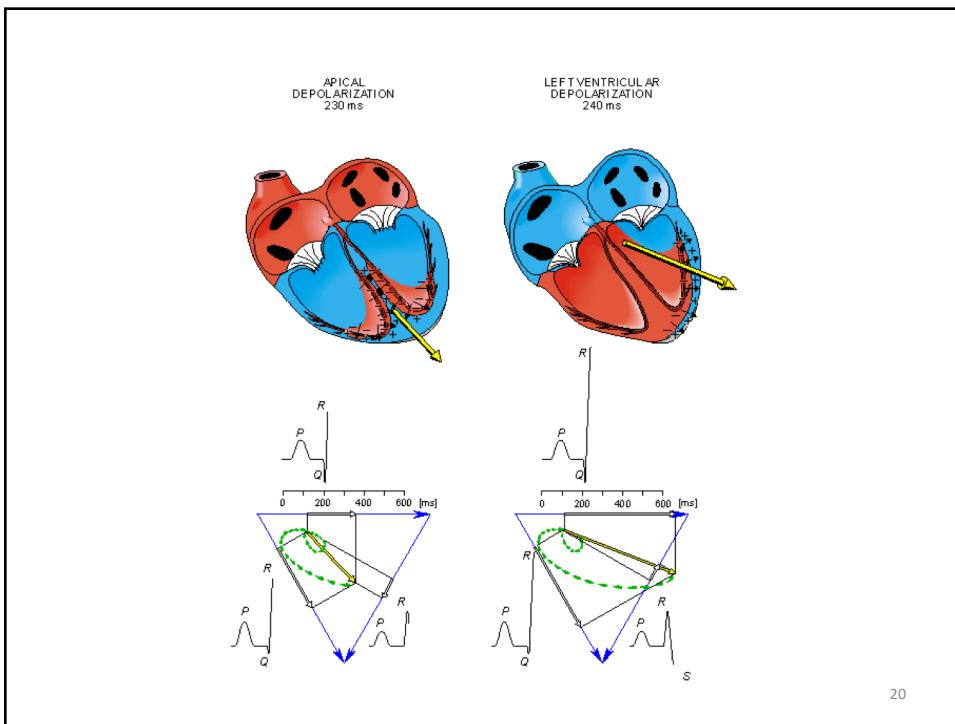
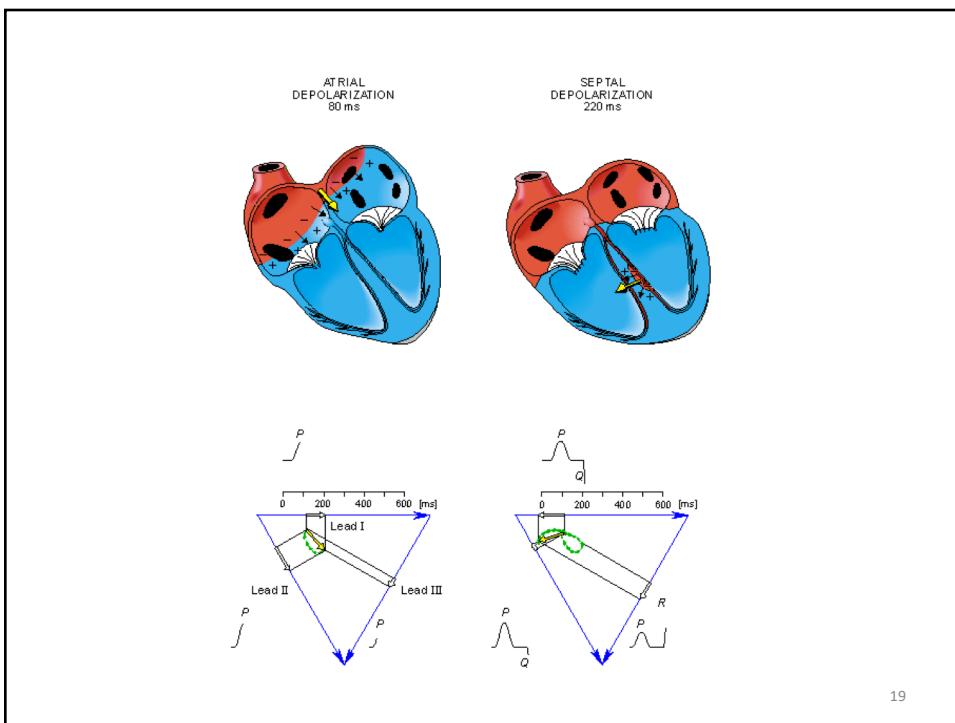
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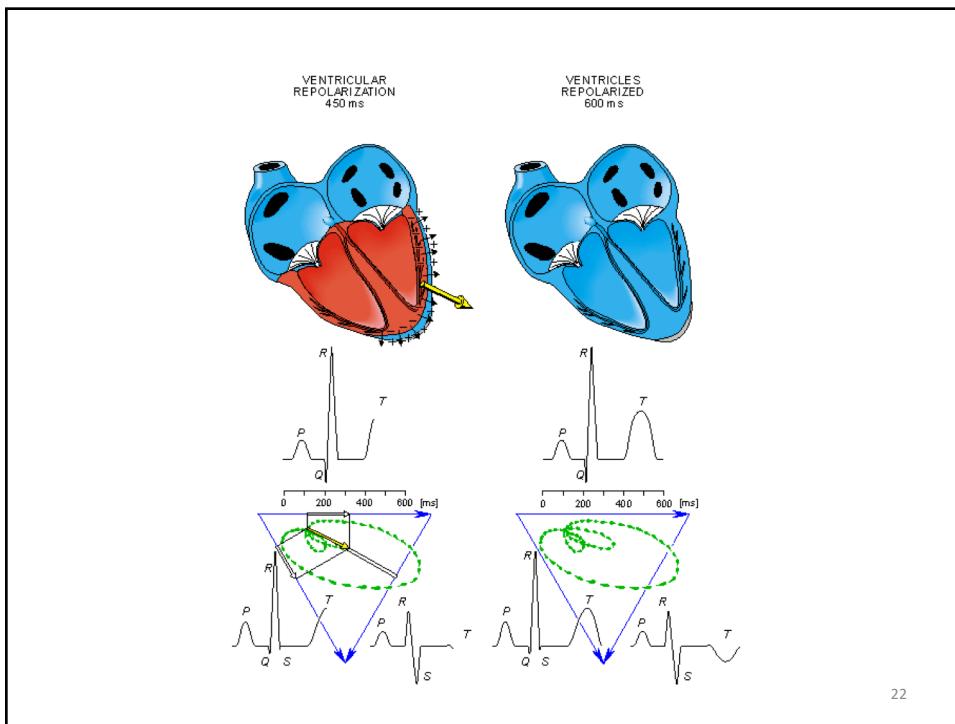
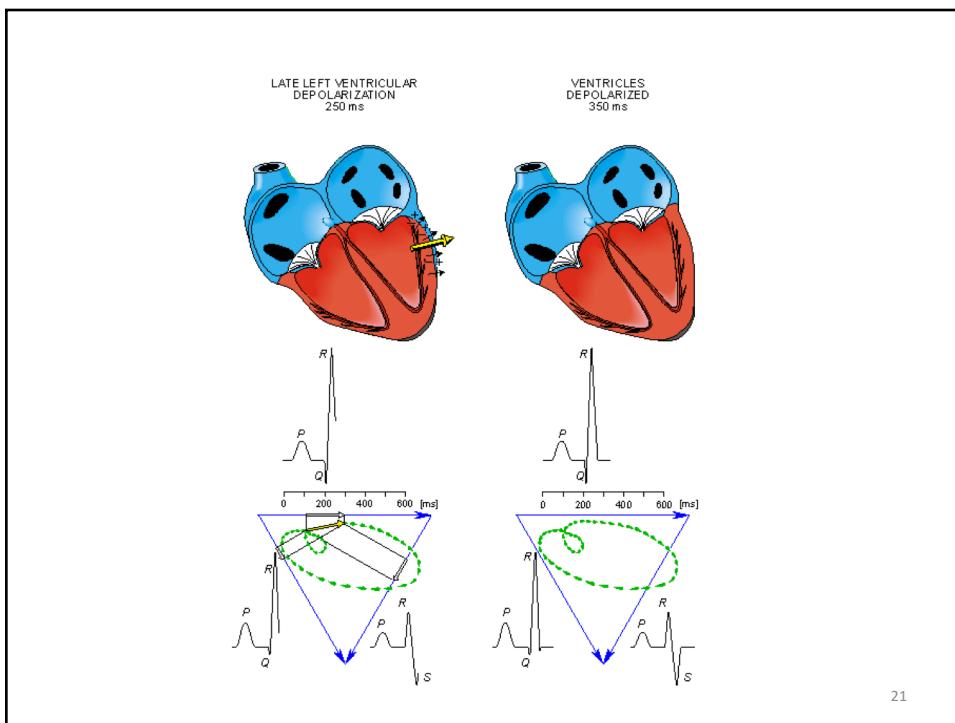


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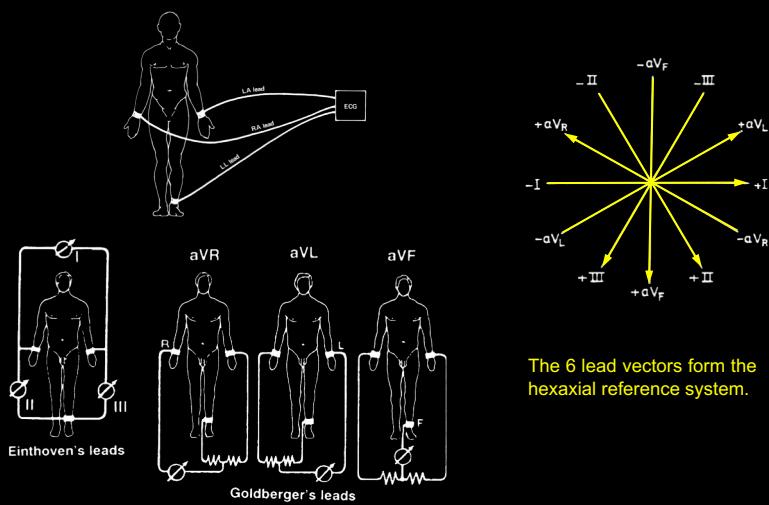




The Standard Leads of the ECG

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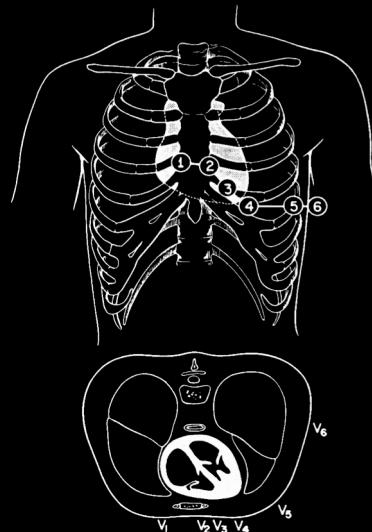
Six Leads in the Frontal Plane
(3 bipolar, 3 augmented unipolar leads)



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Six Unipolar “Precordial” Leads in the Horizontal Plane

- Introduced by Wilson in 1944
- The points V₁ and V₂ are located at the fourth intercostal space on the right and left side of the sternum; V₄ is located in the fifth intercostal space at the midclavicular line; V₃ is located between the points V₂ and V₄; V₅ is at the same horizontal level as V₄ but on the anterior axillary line; V₆ is at the same horizontal level as V₄ but at the midline.
- The lead voltages are measured with respect to the Wilson Central Terminal (average of LA, RA and LL potentials).



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Display of Leads on Standard ECG

I	aVR	V ₁	V ₄
II	aVL	V ₂	V ₅
III	aVF	V ₃	V ₆

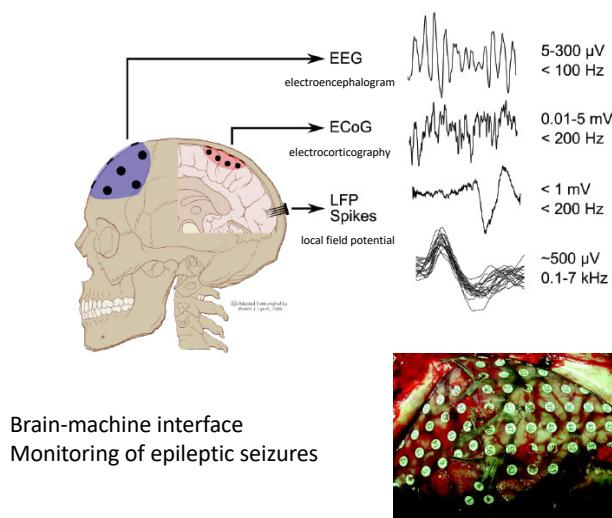


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Electrocorticography (ECoG)

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Brain Signals (EEG & ECoG)



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