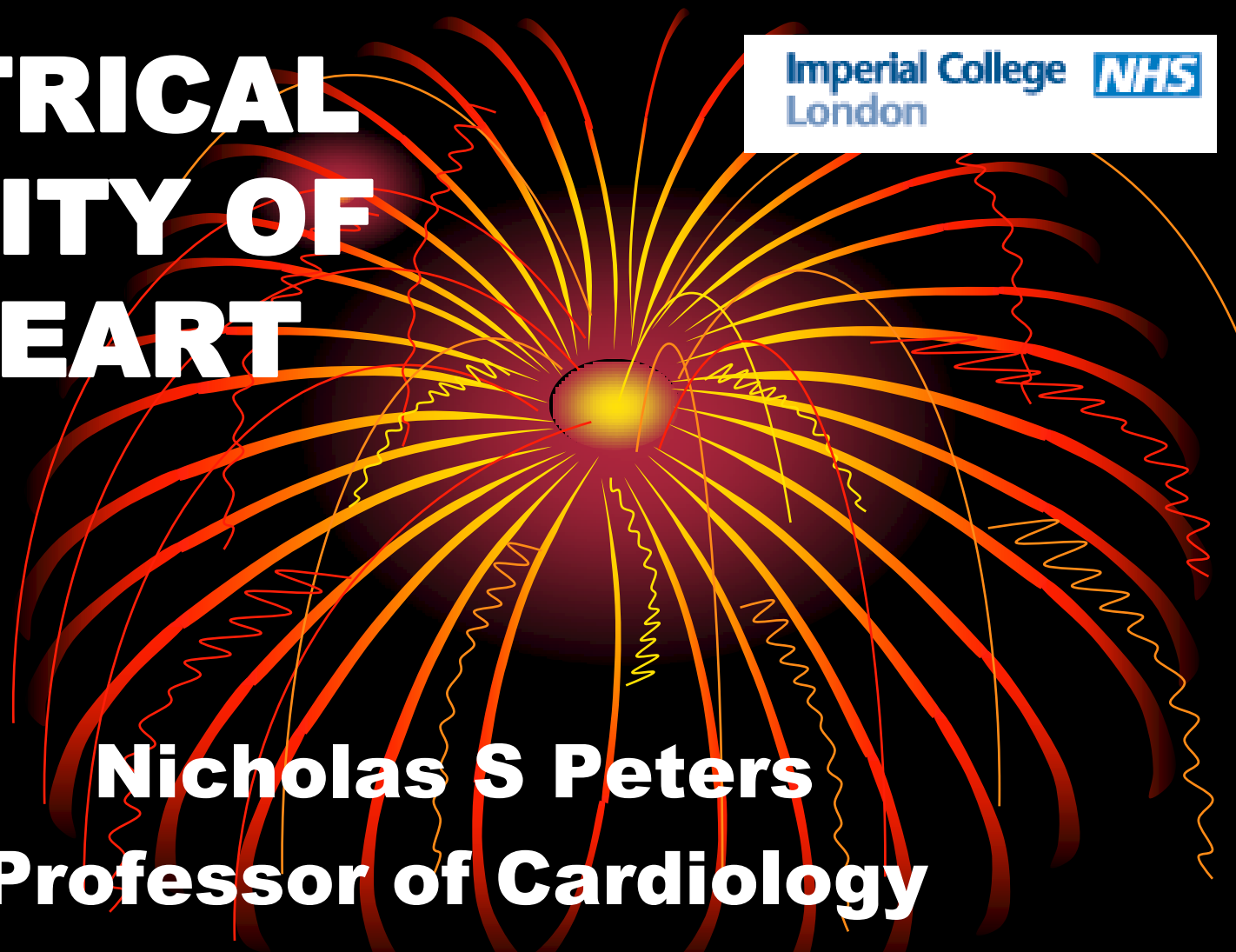


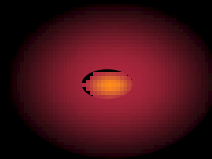
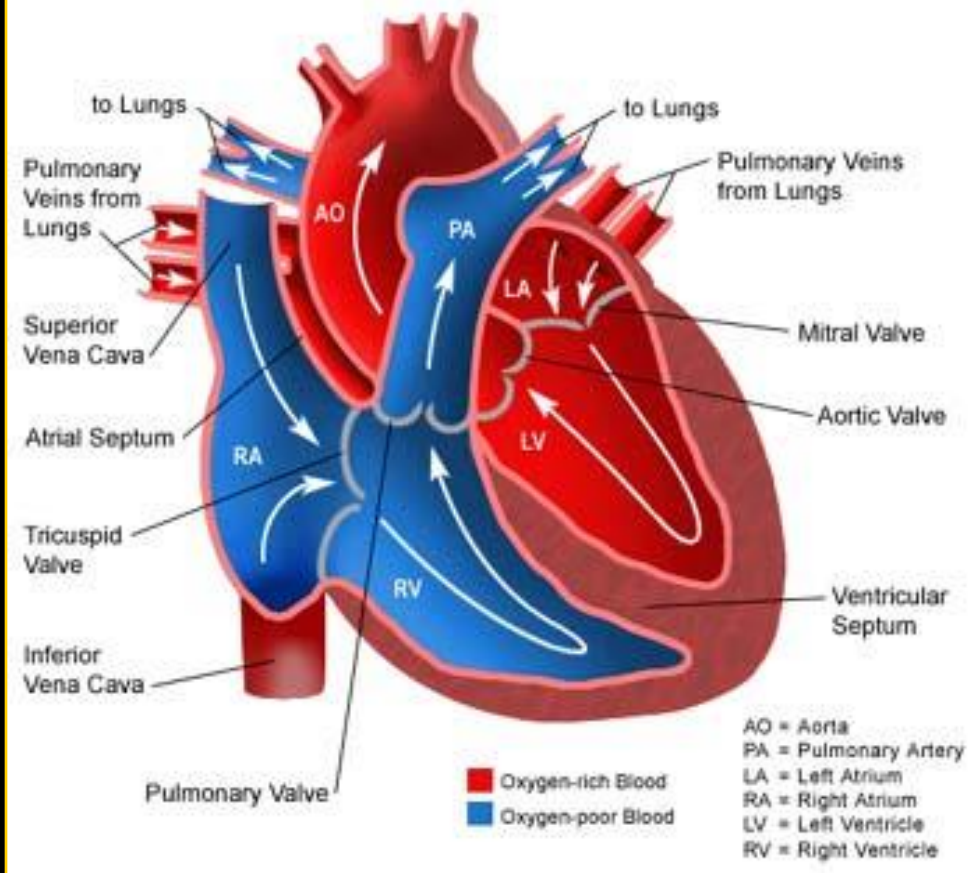
ELECTRICAL ACTIVITY OF THE HEART

Imperial College
London 



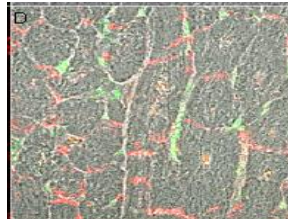
Nicholas S Peters
Professor of Cardiology
Head of Cardiac
Electrophysiology

Normal Heart

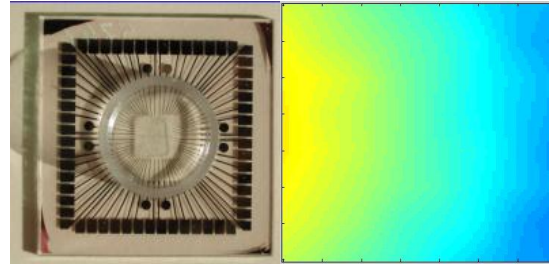
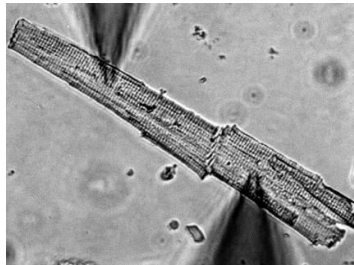


Multiscale Cardiac Electrophysiology

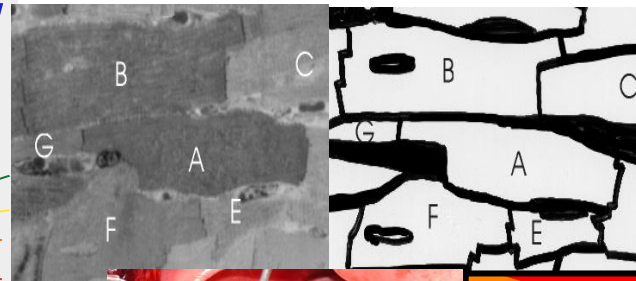
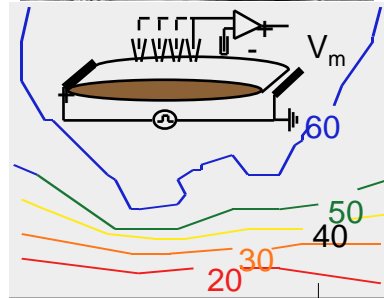
SUBCELLULAR



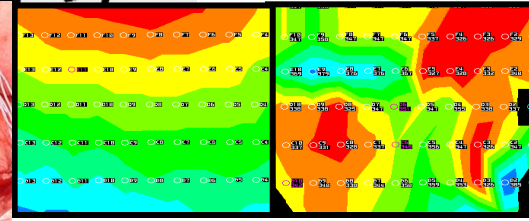
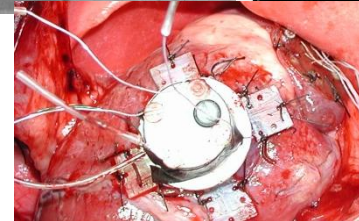
CELLS & CULTURE



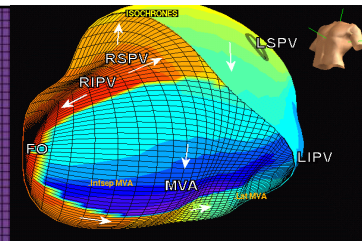
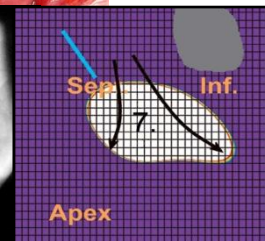
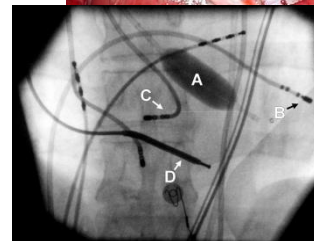
INTACT MYOCARDIUM



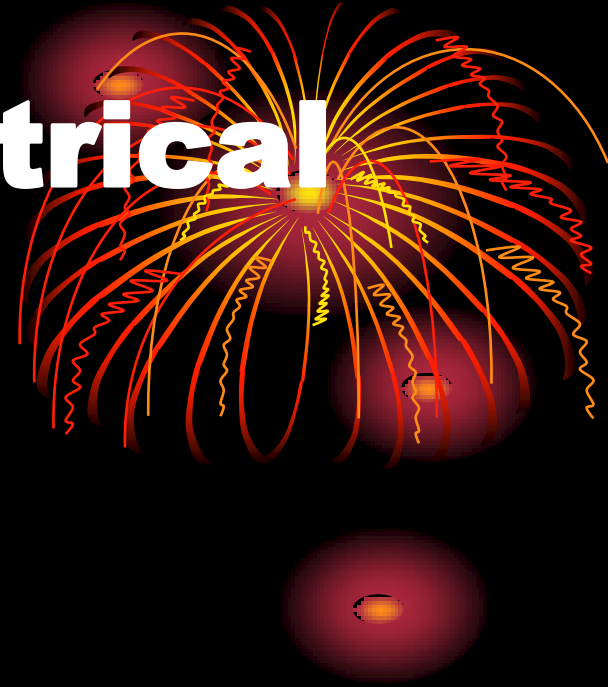
HUMAN HEART



CLINICAL ARRHYTH

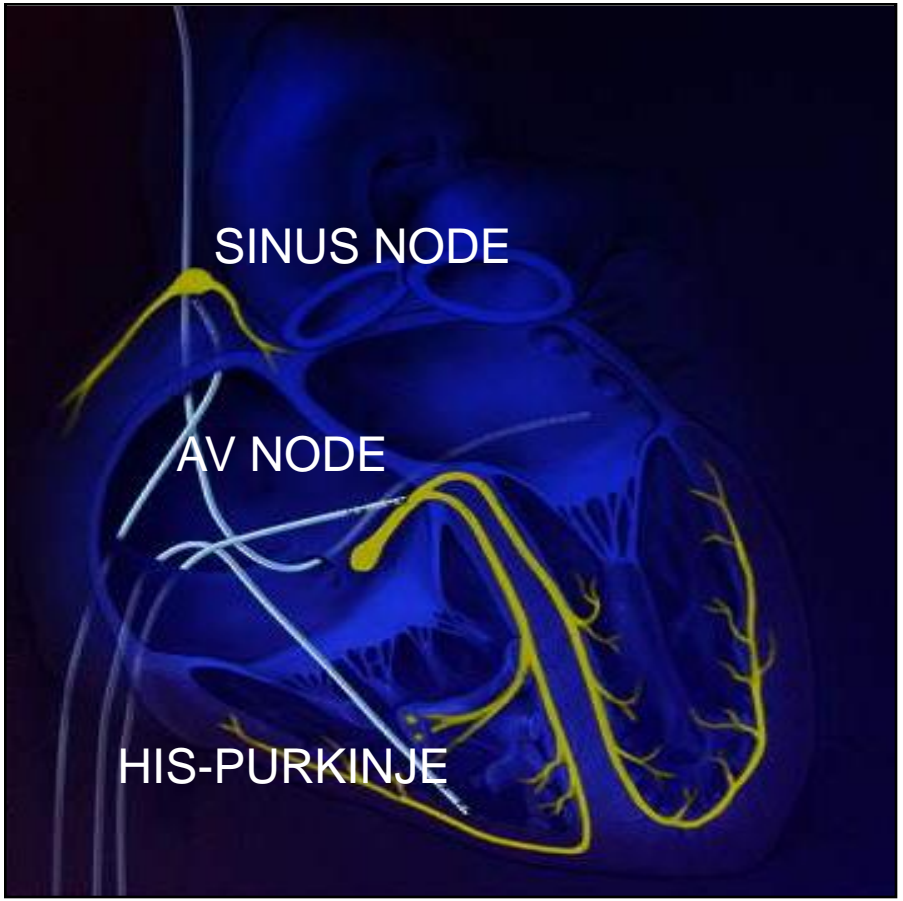
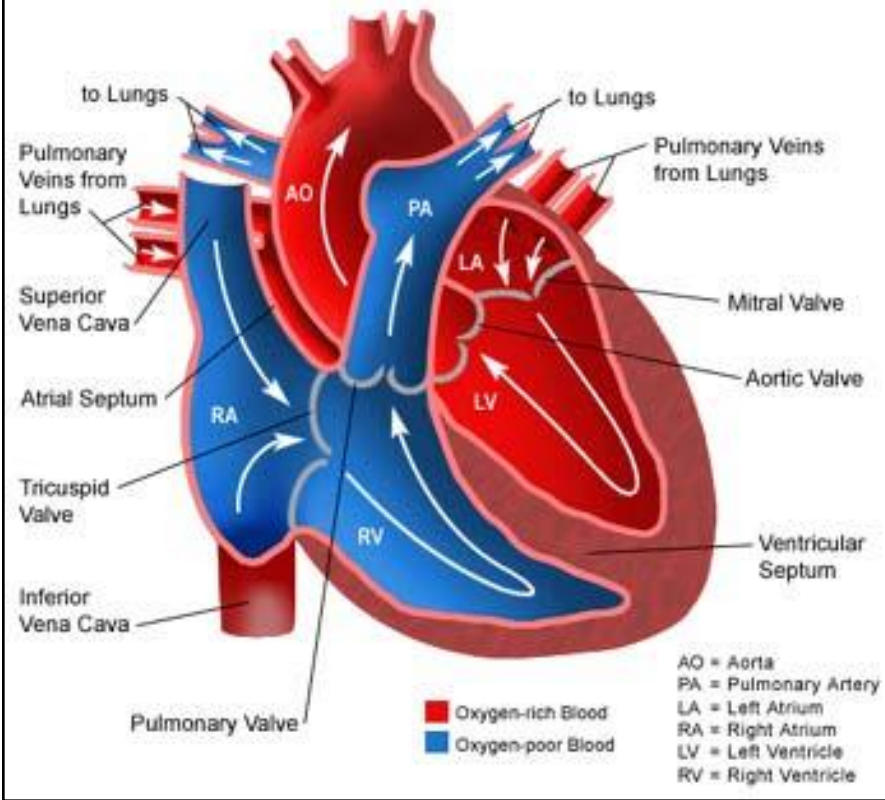


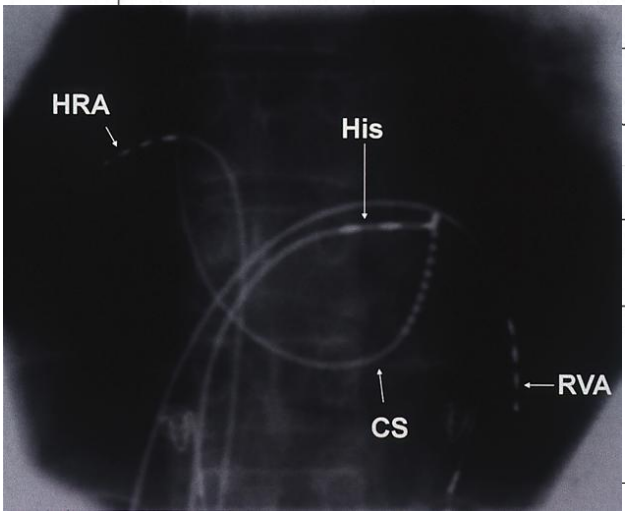
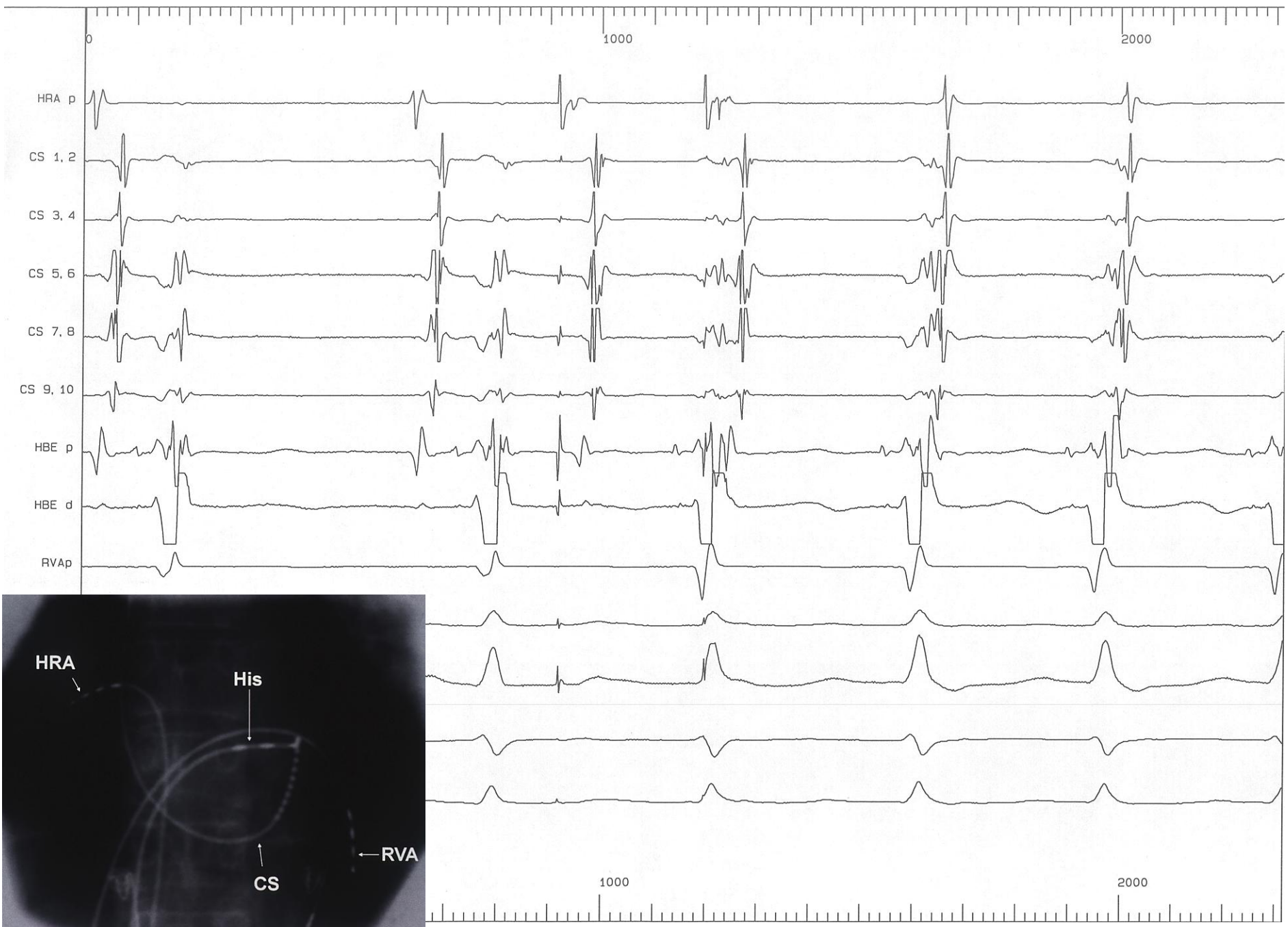
Macroscopic Electrical Activity



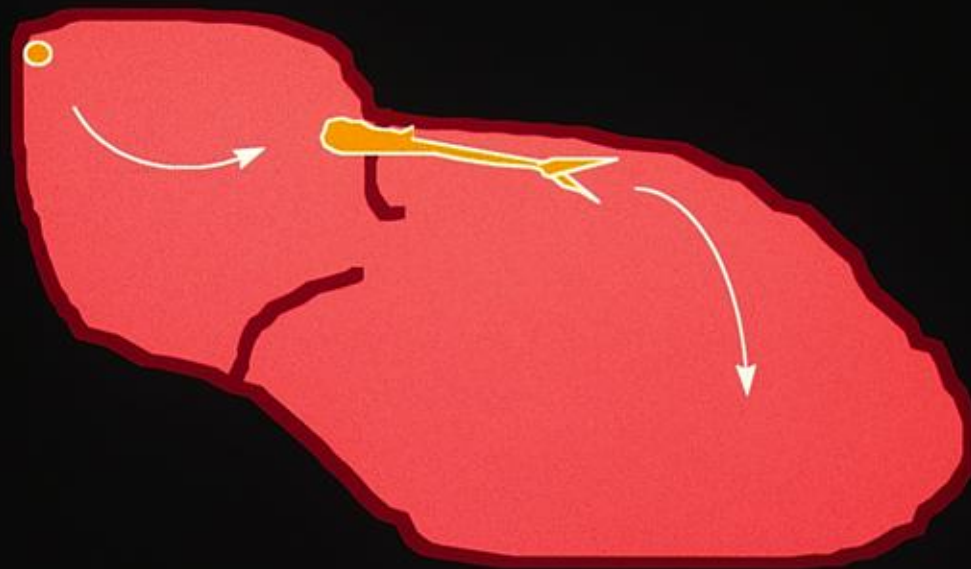
**Whole-Heart Cardiac
Electrocardiology/Electrophysiology**

Normal Heart

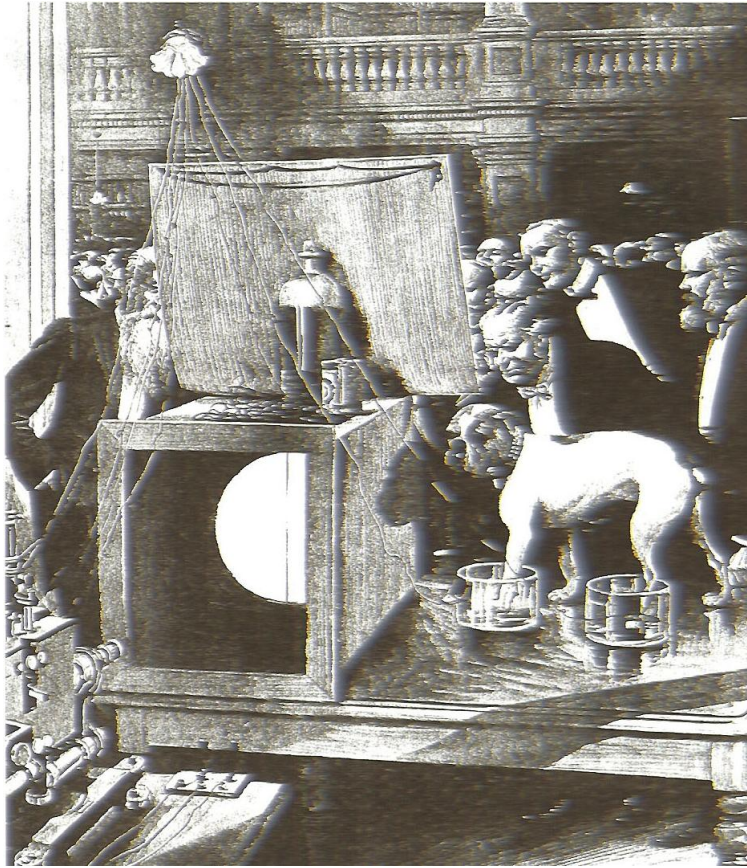




SINUS RHYTHM



A Century of Imperial Cardiac EP



Augustus D Waller & Jimmie
St Mary's Hospital Medical School

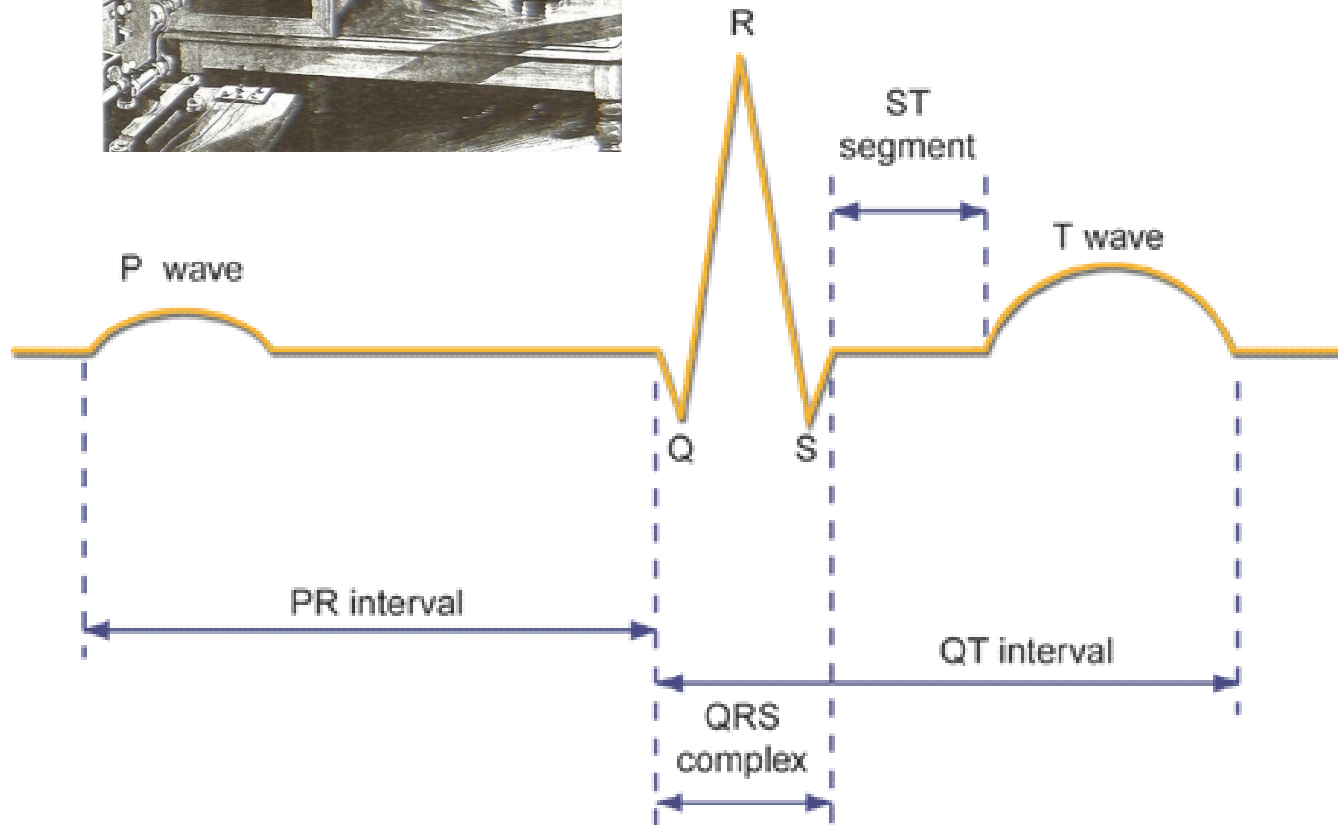
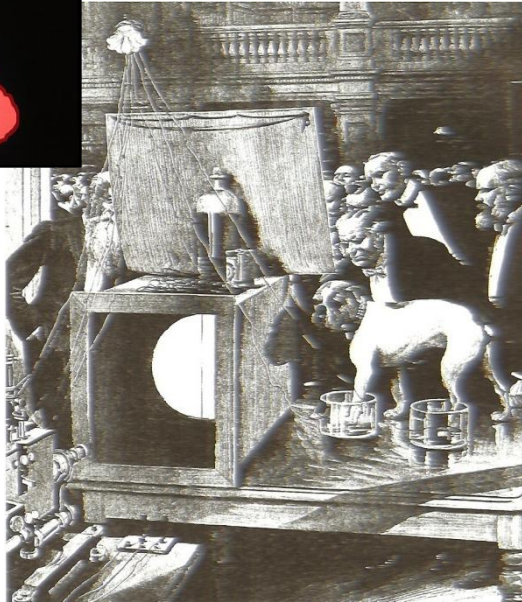
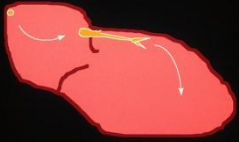
The Times newspaper of July 9, 1909 reported that Mr Ellis Griffith (MP for Anglesey) questioned the Secretary of State in Parliament over Waller's 'public experiment'. Had the Cruelty to Animals Act (1876) been contravened?

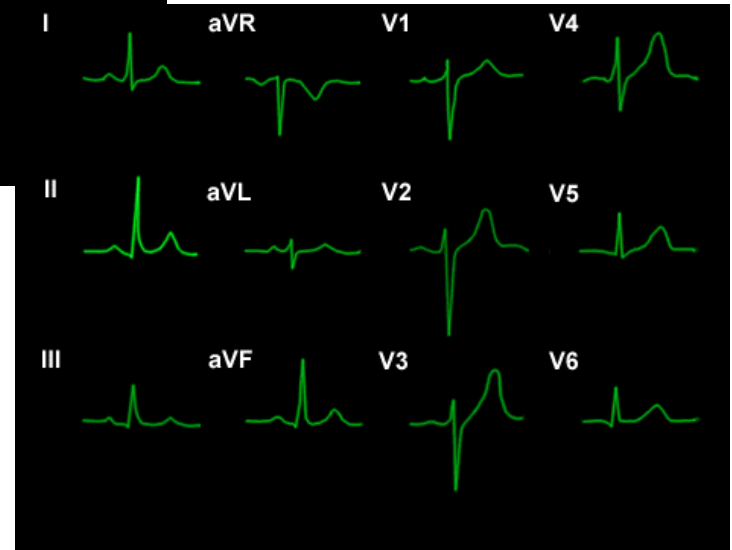
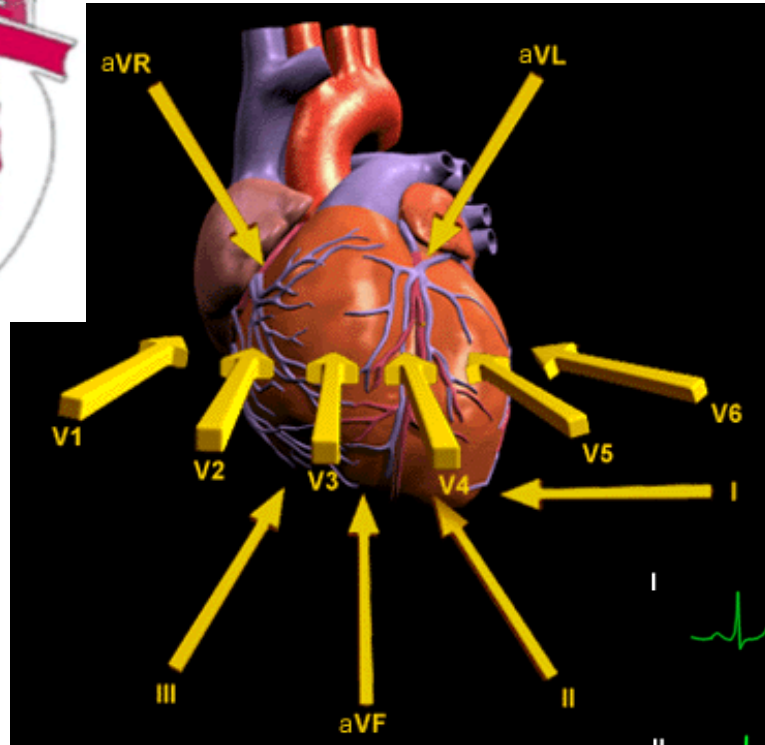
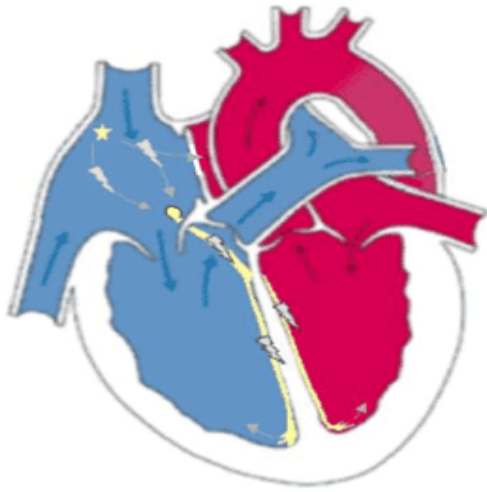
Mr Gladstone: 'I understand the dog stood for some time in water to which sodium chloride had been added or in other words a little common salt. If my honourable friend has ever paddled in the sea he will understand the sensation. (Laughter) The dog – a finely developed bulldog – was neither tied nor muzzled.'



Jimmie – born 1st April 2009

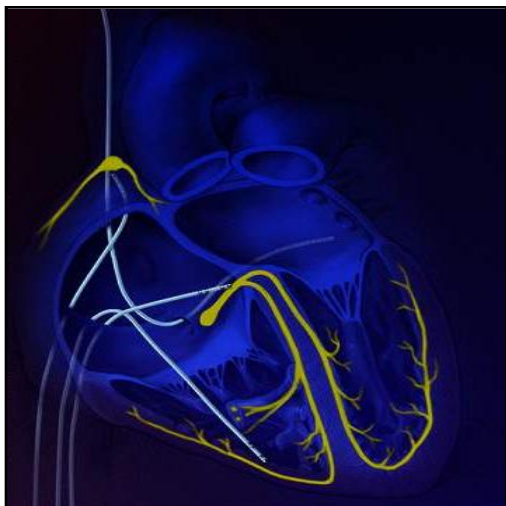
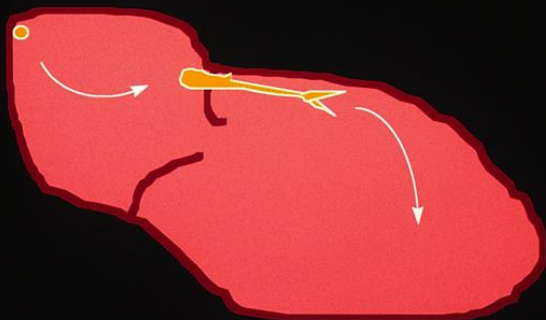
SINUS RHYTHM



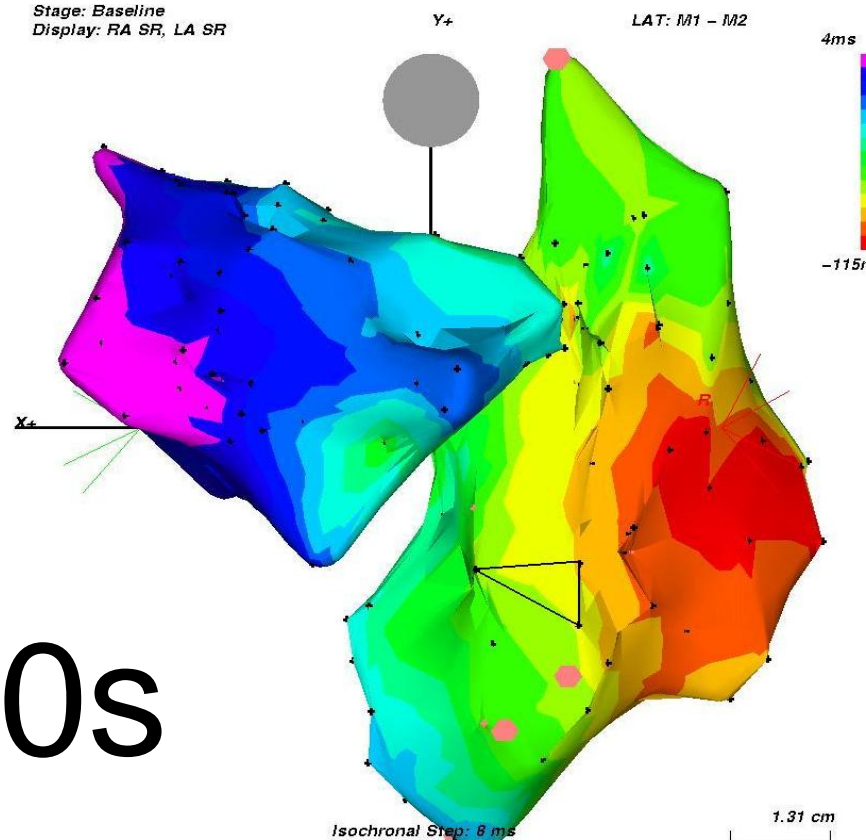


1890s

SINUS RHYTHM



Stage: Baseline
Display: RA SR, LA SR



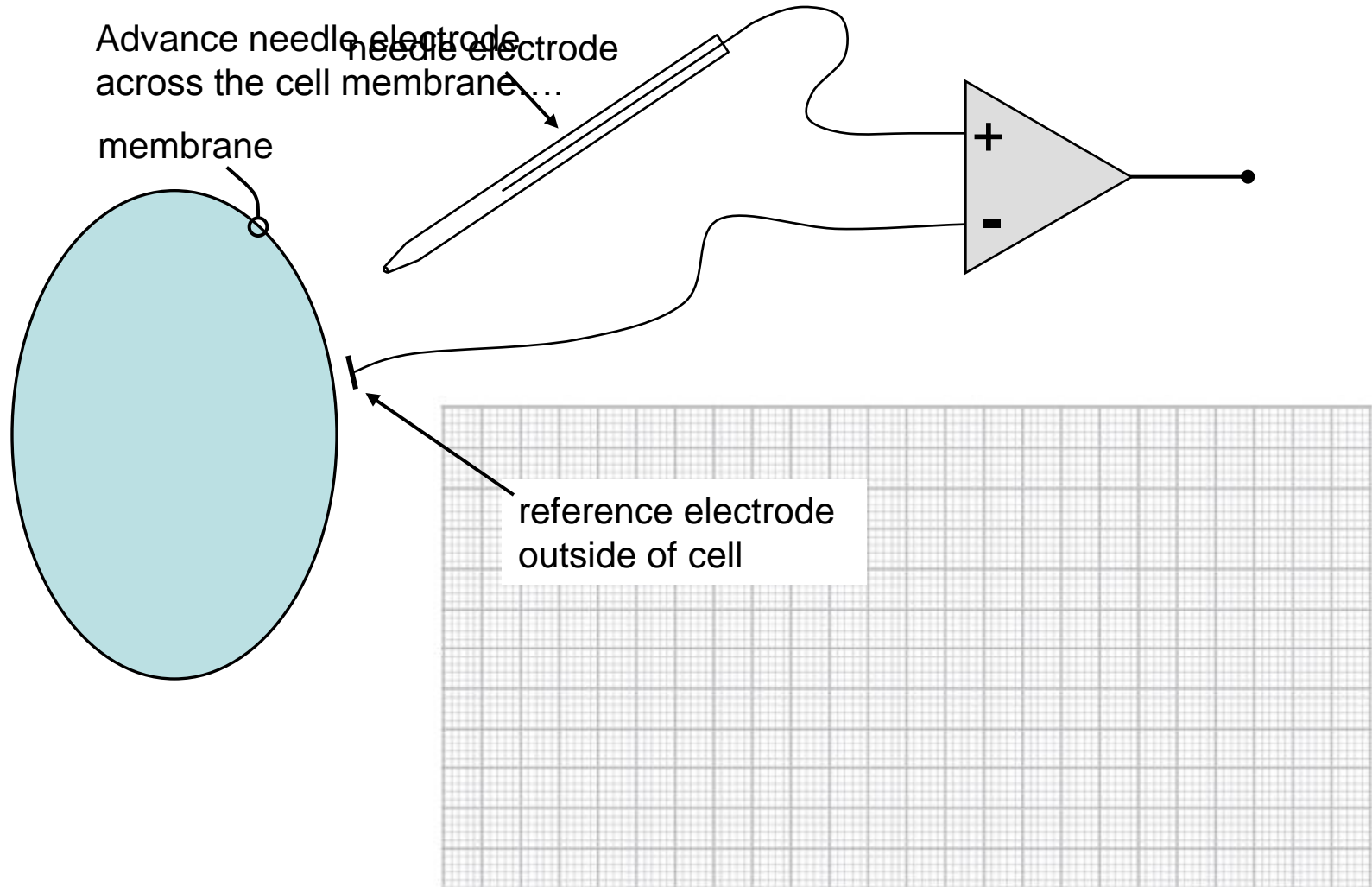
2000s

Origin of Biopotentials



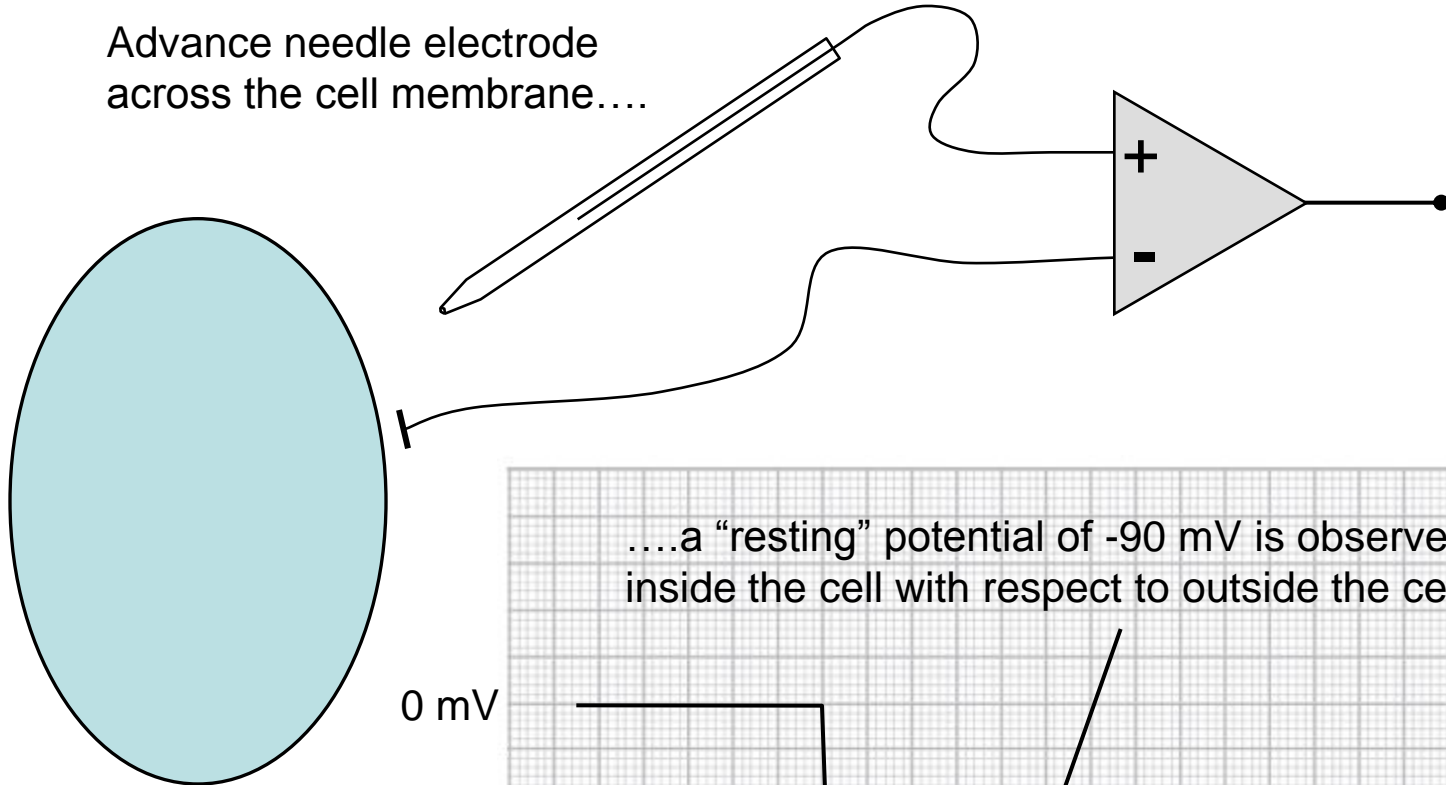
Transmembrane, Unipolar, and
Bipolar Electrograms

Cell-Membrane Resting Potential



Cell-Membrane Resting Potential

Advance needle electrode
across the cell membrane....



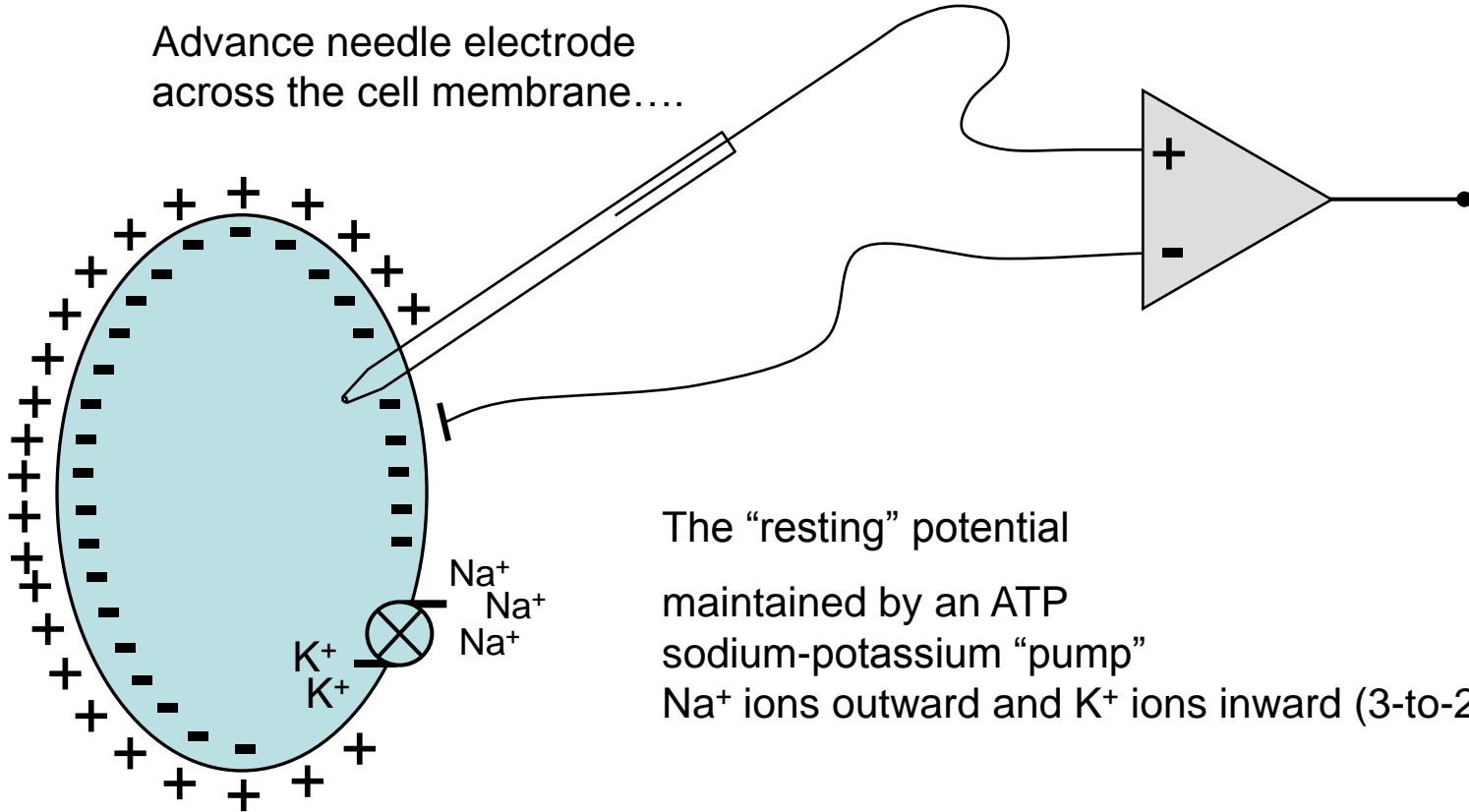
....a "resting" potential of -90 mV is observed
inside the cell with respect to outside the cell

0 mV



Cell-Membrane Resting Potential

Advance needle electrode
across the cell membrane....

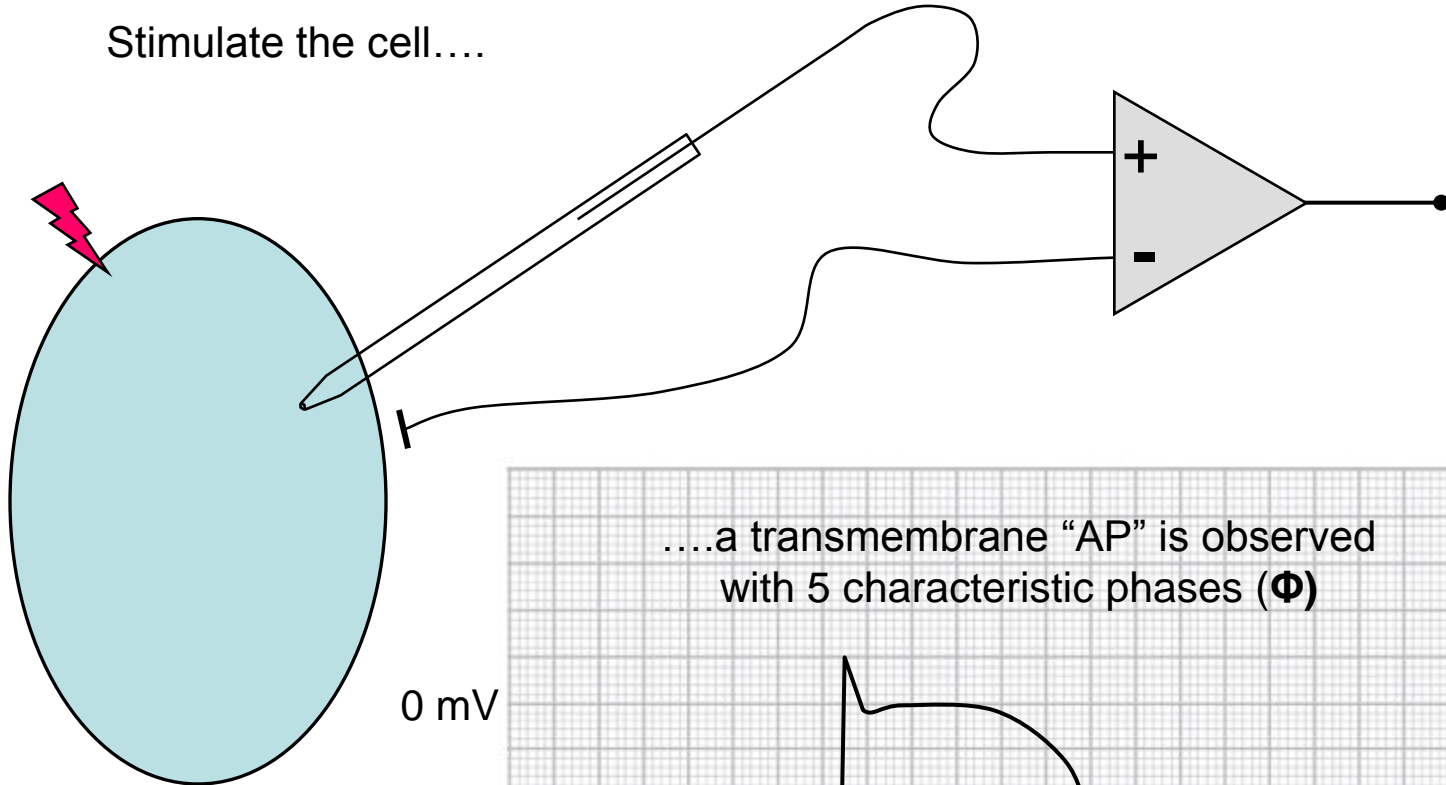


The “resting” potential
maintained by an ATP
sodium-potassium “pump”
Na⁺ ions outward and K⁺ ions inward (3-to-2).

The gradient of ion-concentration
charge across the membrane of -90 mV.

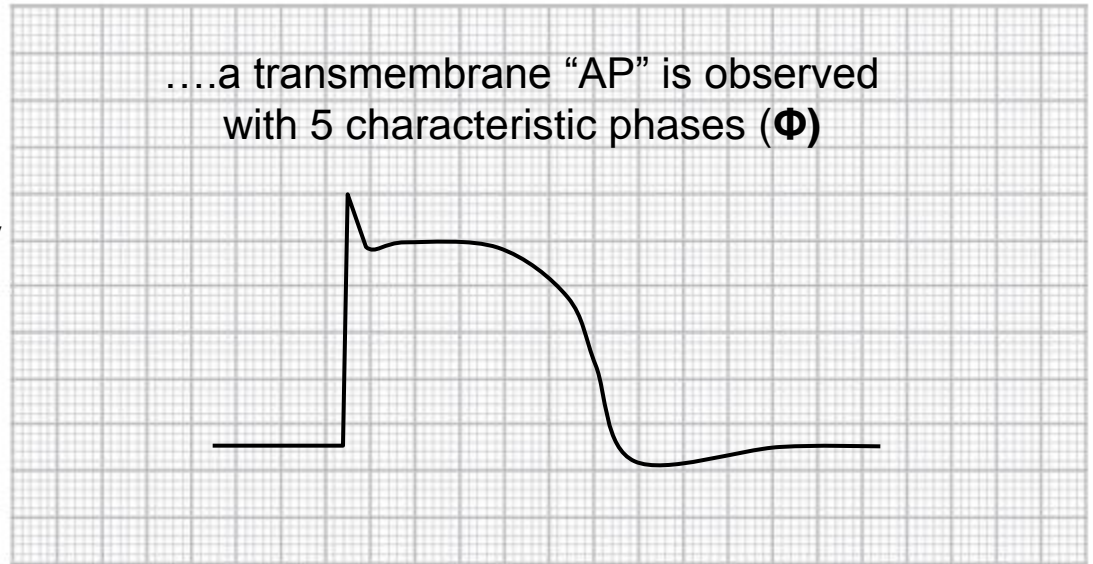
Cell Membrane Action Potential (AP)

Stimulate the cell....



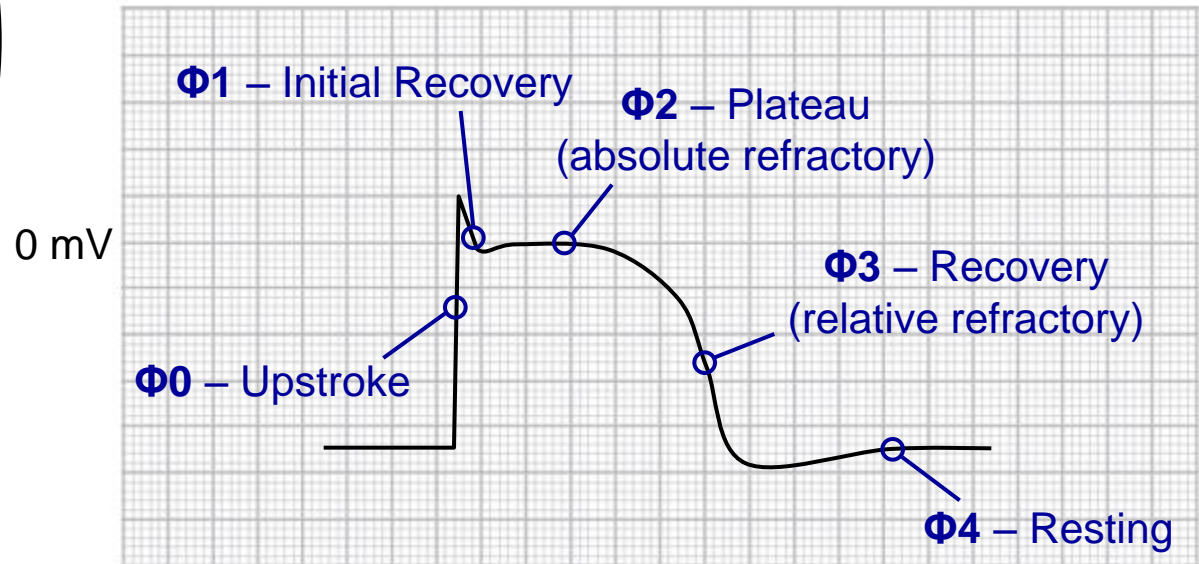
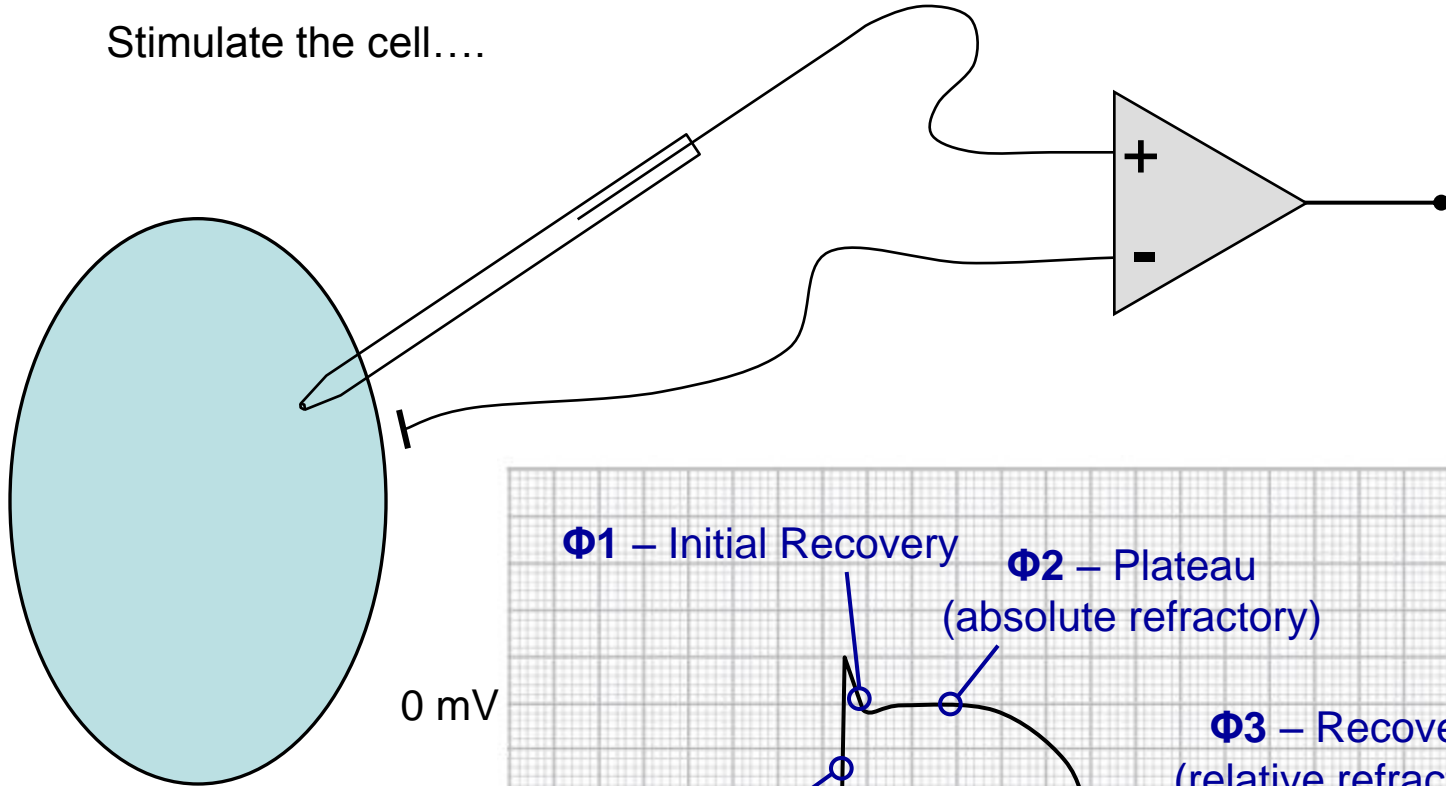
....a transmembrane "AP" is observed
with 5 characteristic phases (Φ)

0 mV



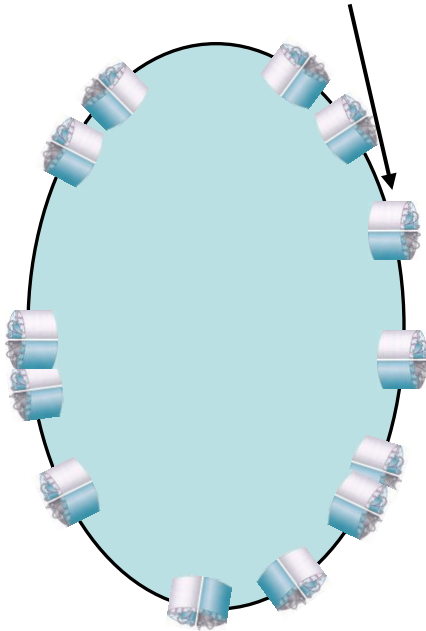
Cell Membrane Action Potential (AP)

Stimulate the cell....



Cell Membrane Ion Channels

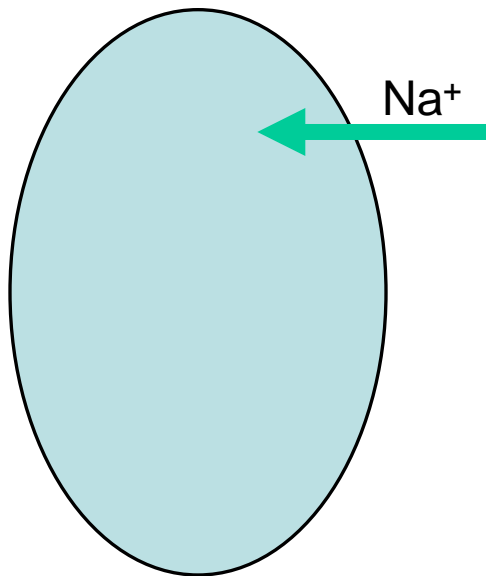
Voltage-gated, ion-selective channels open and close to generate the AP



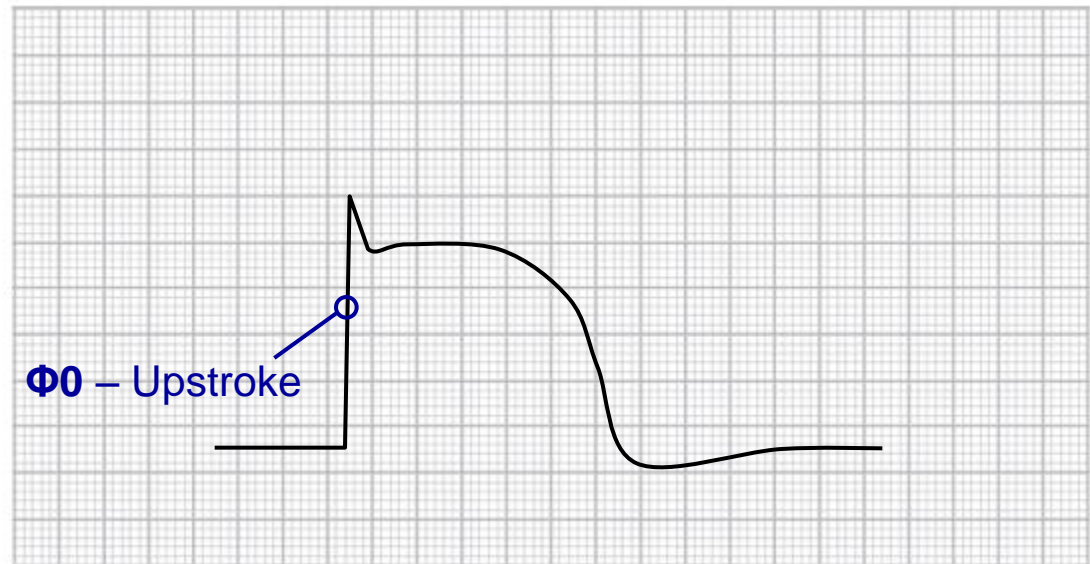
Many types of channels are known, each selective to a specific species of Na^+ , K^+ , and Ca^{++} ions

Cell Membrane Ion Channels

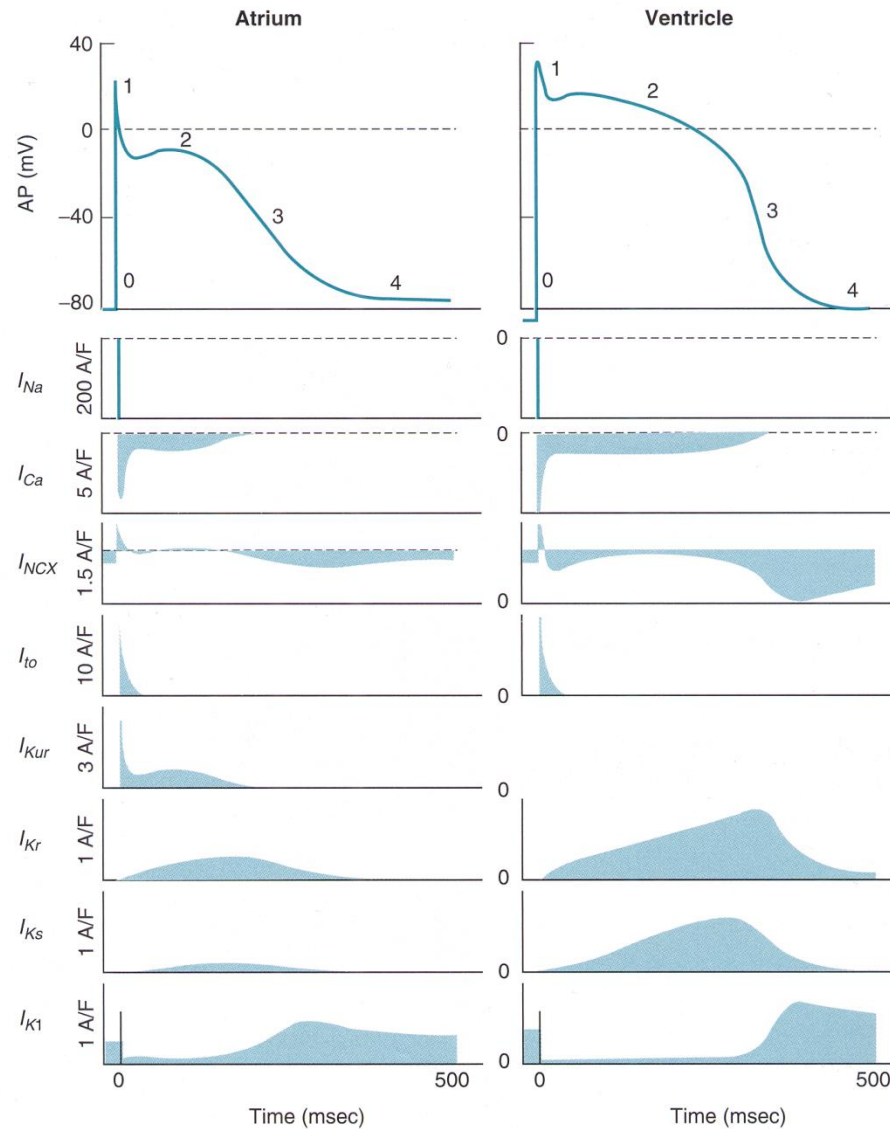
Transmembrane AP formation follows an organized sequence in response to stimulation:



1) Fast, inward Na^+ channels open, rapidly depolarizing the membrane and triggering closure of the channels (Φ_0 – upstroke and overshoot)



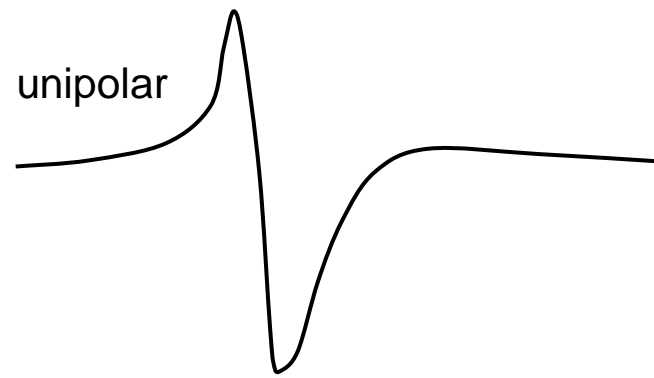
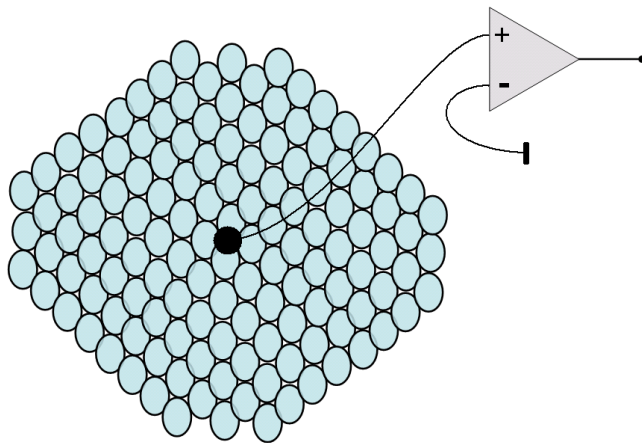
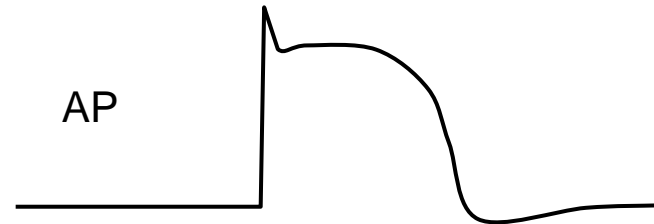
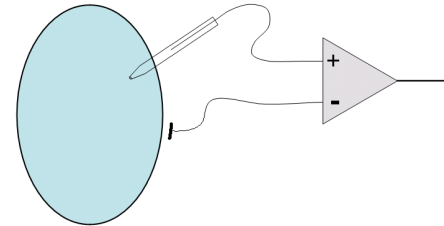
Cell Membrane Ion Channels



AP and Unipolar Electrogram

While an AP is recorded across the membrane of a single active cell....

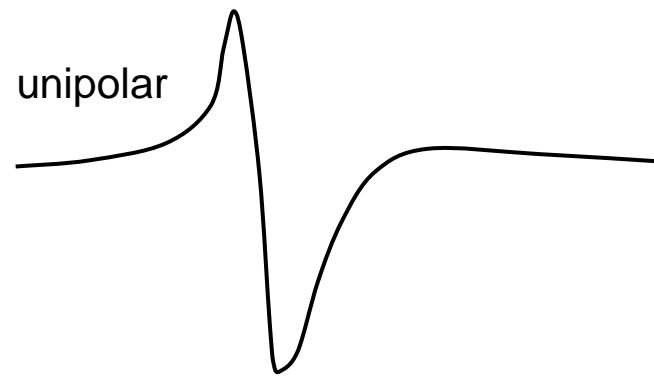
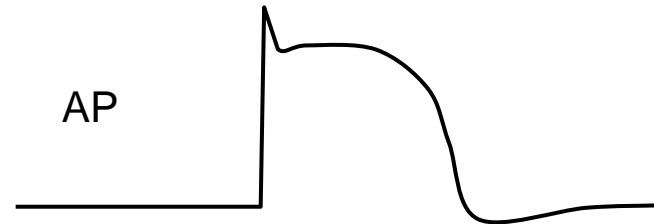
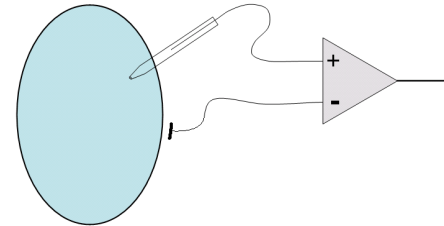
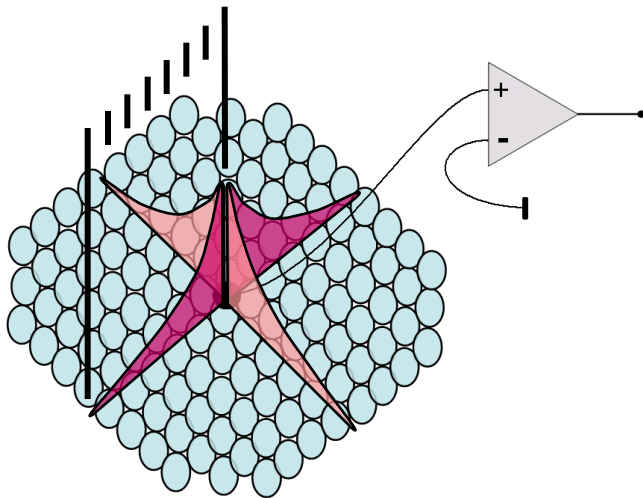
....an extracellular unipolar electrogram is recorded from the whole population of active cells surrounding the electrode, relative to a distant reference



AP and Unipolar Electrogram

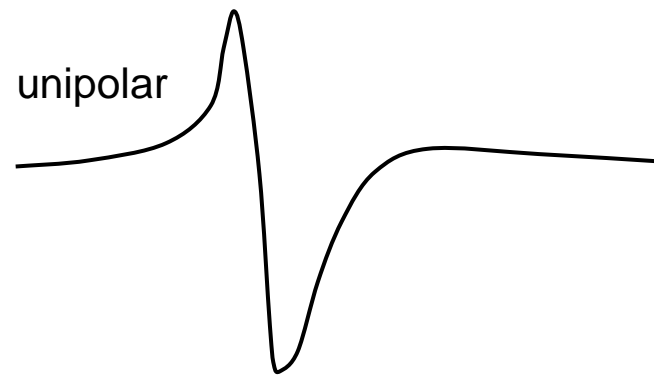
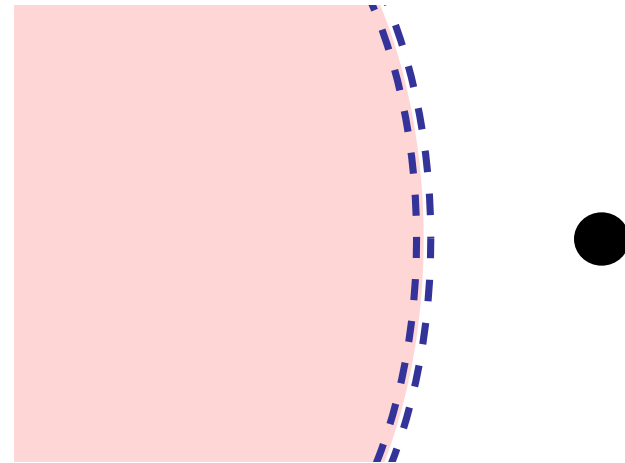
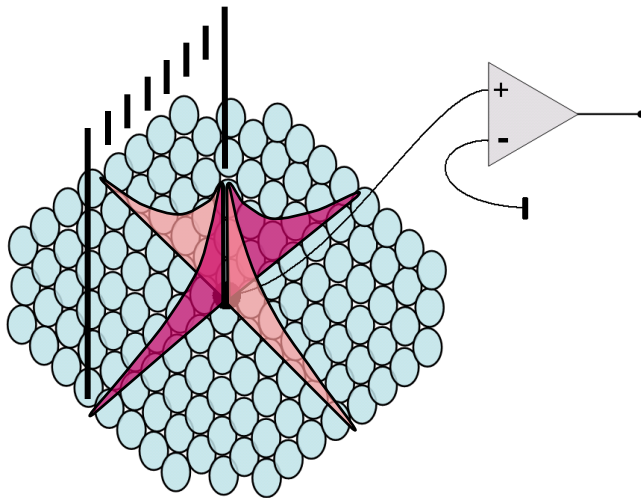
The influence of any active cell upon the unipolar recording:

- related to the projected angle between the ion channel and the line-of-sight to the electrode
- inversely related to the distance between the ion channel and the electrode



AP and Unipolar Electrogram

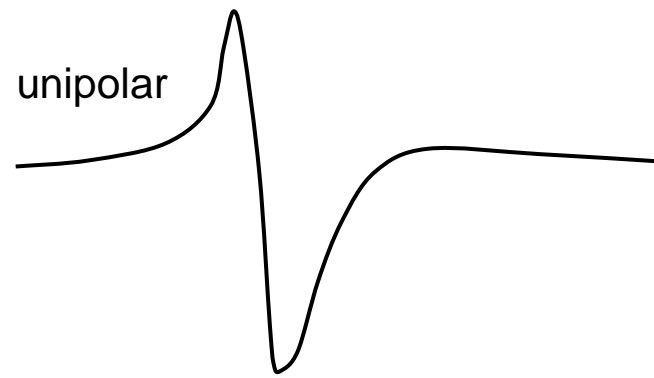
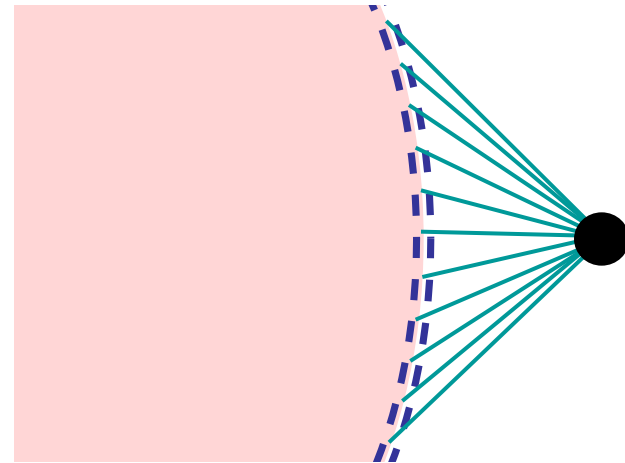
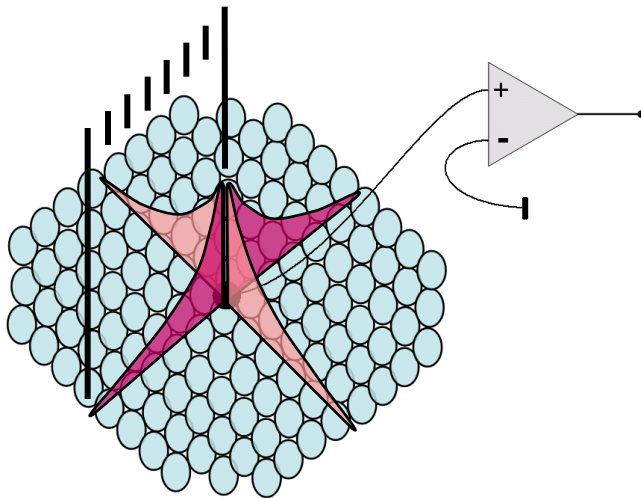
Because activation propagates from cell-to-cell, active cells are organized along a wave "front"



AP and Unipolar Electrogram

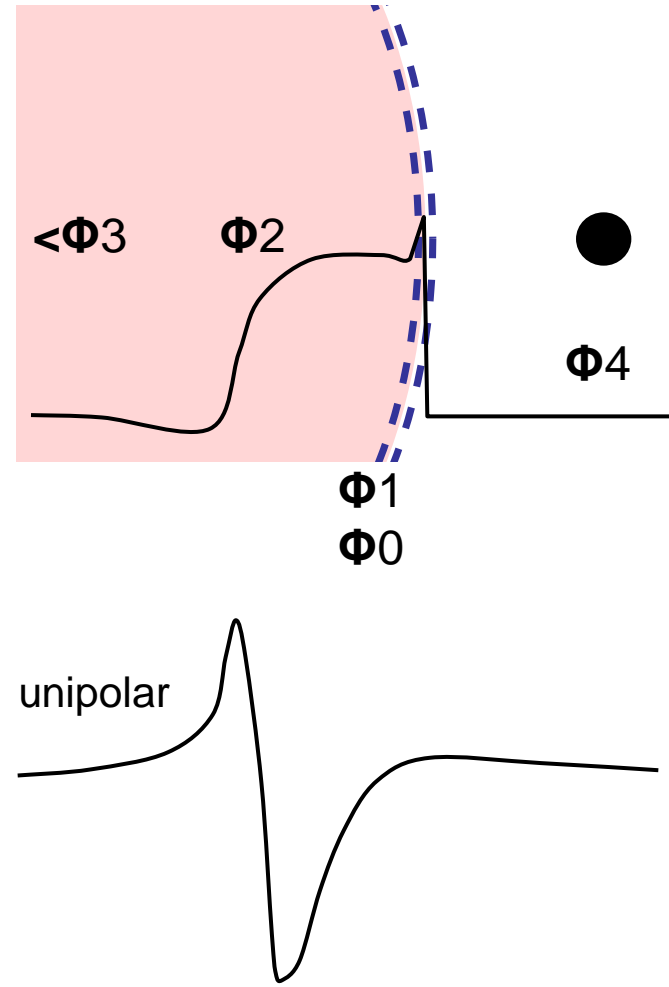
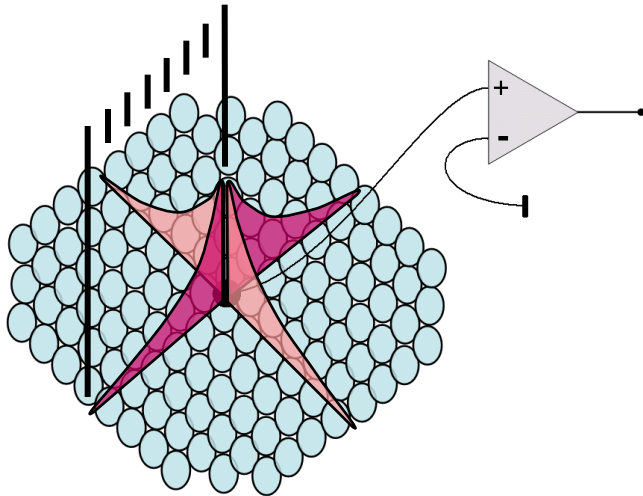
Because activation propagates from cell-to-cell, active cells are organized along a wave “front”

.... and the unipolar electrogram is a summation-effect from all of the membrane currents along the wavefront “line”



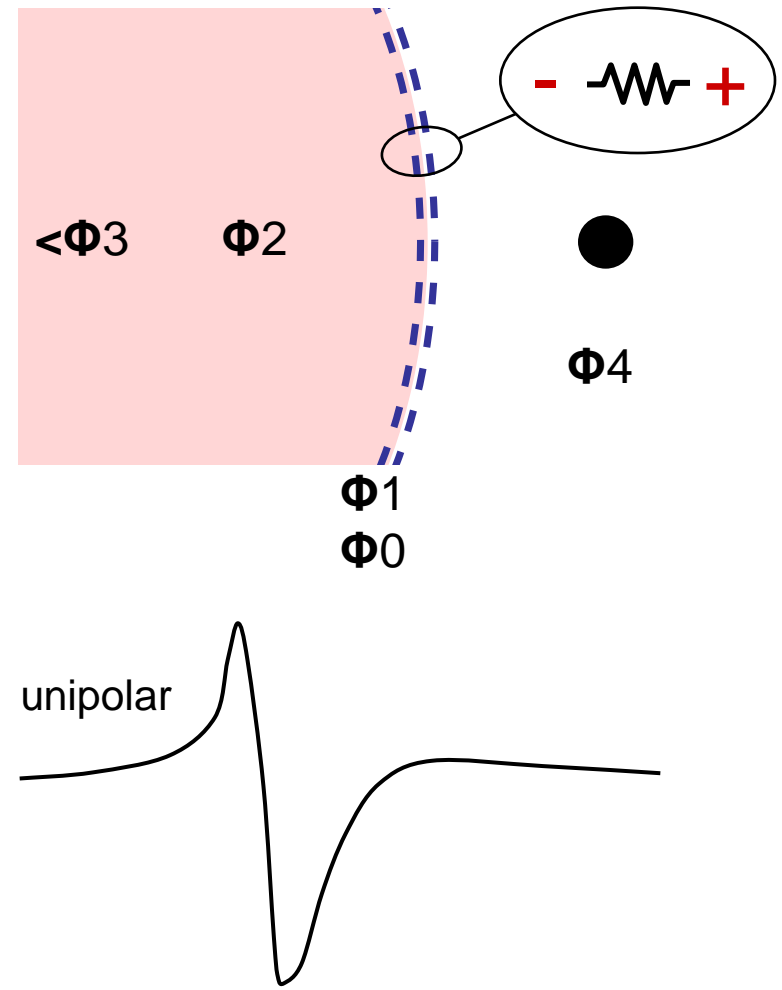
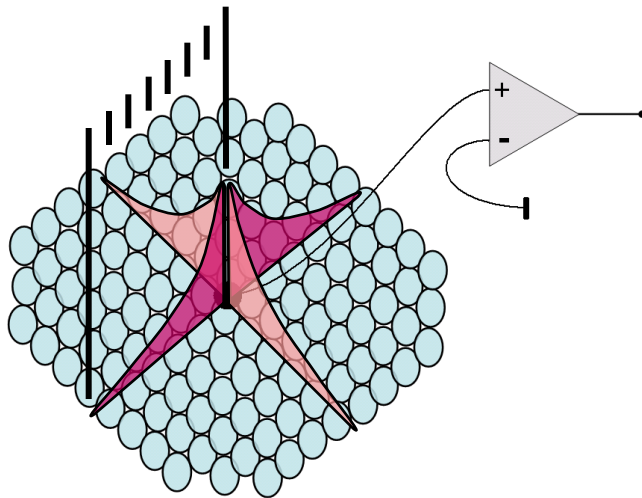
AP and Unipolar Electrogram

Consequently, each phase of the action potential, as defined in time, also occupies specific regions of substrate "space", relative to the wavefront line



AP and Unipolar Electrogram

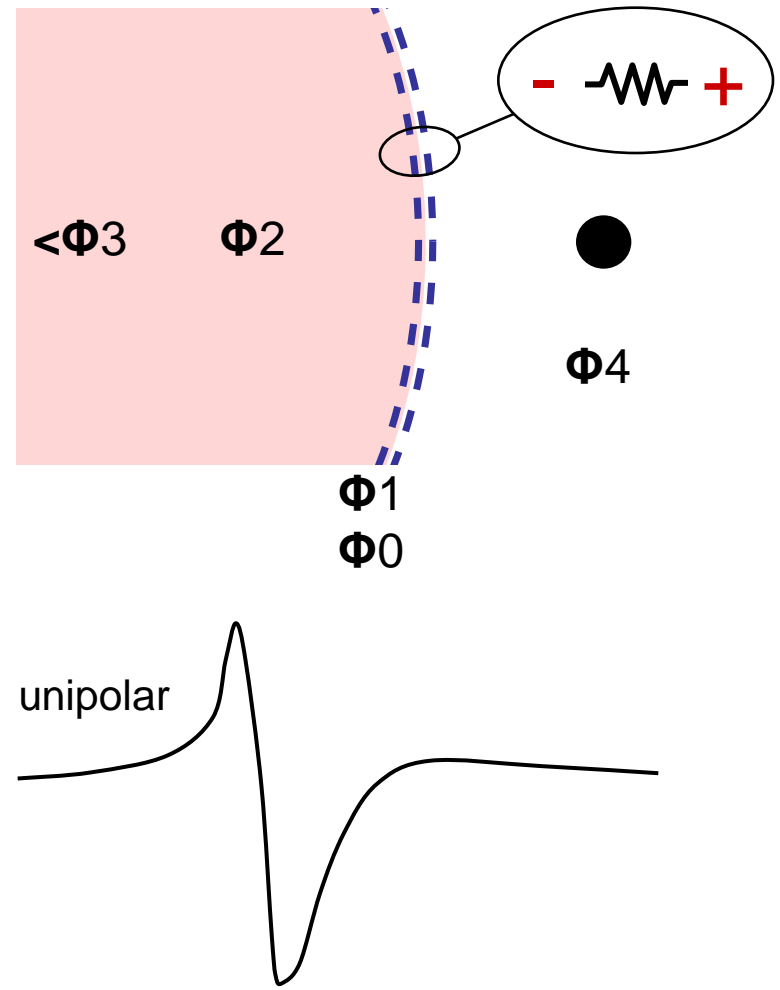
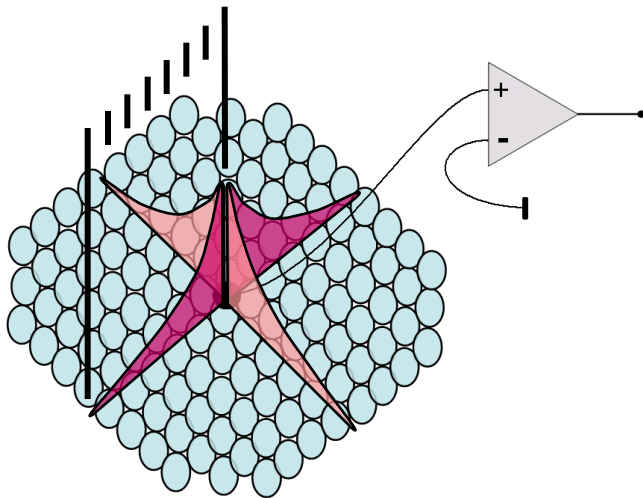
A simplified model can be applied on a single channel to characterize unipolar morphology, based on the dynamics of membrane currents



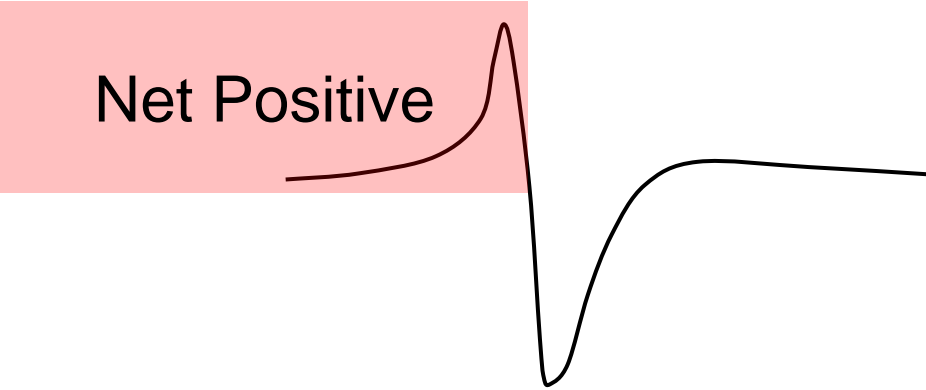
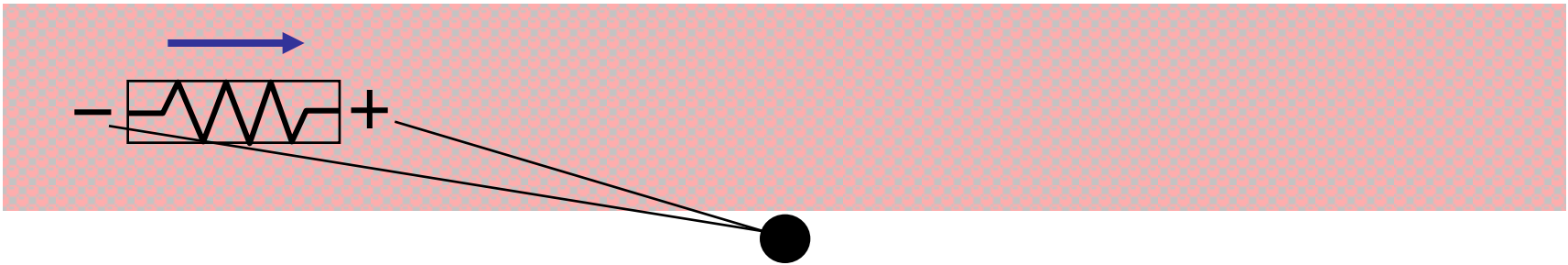
AP and Unipolar Electrogram

A simplified model can be applied on a single channel to characterize unipolar morphology, based on the dynamics of membrane currents

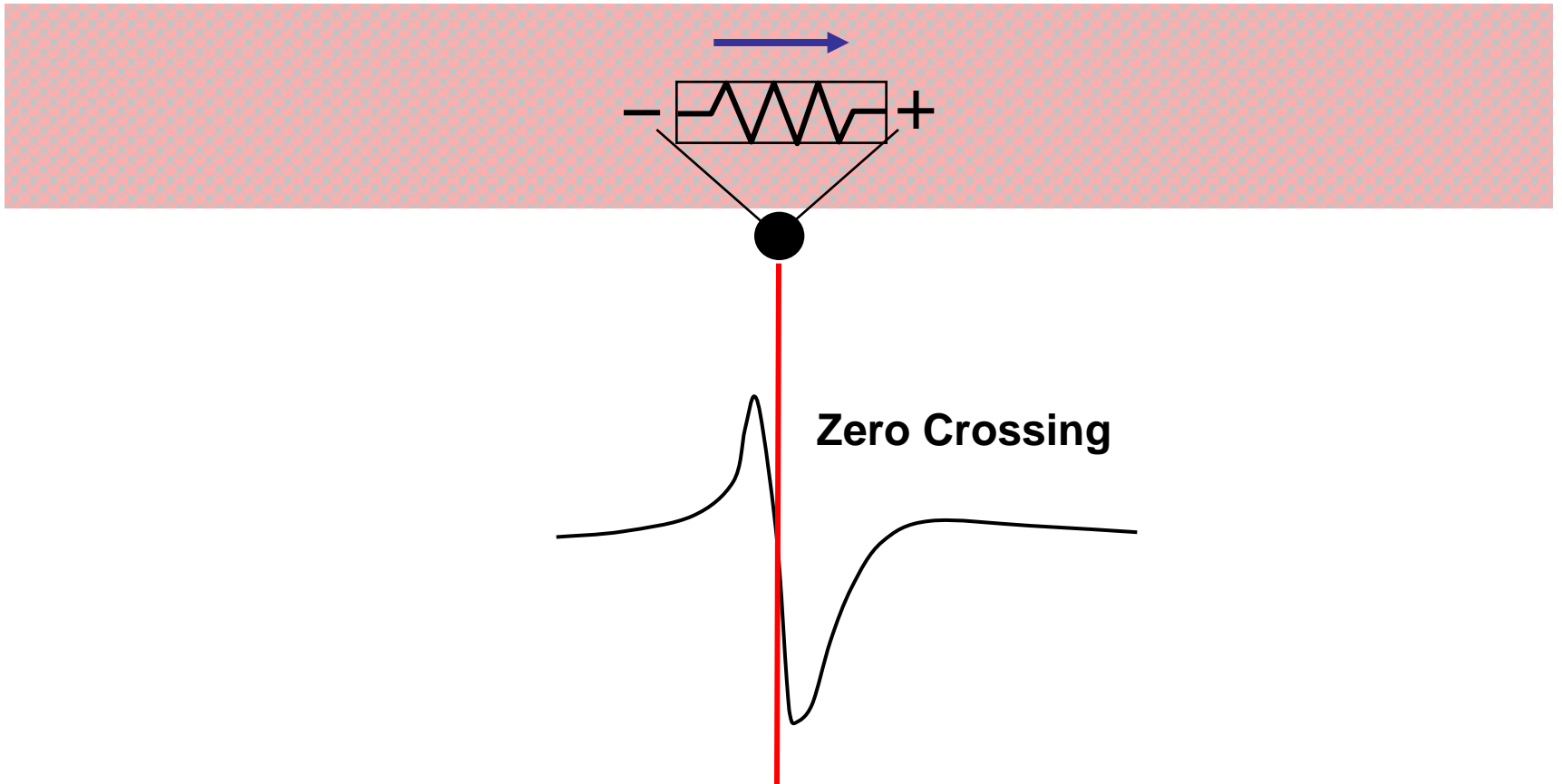
“Actual” unipolar electrograms have a composite morphology resulting from the sum of all active channels



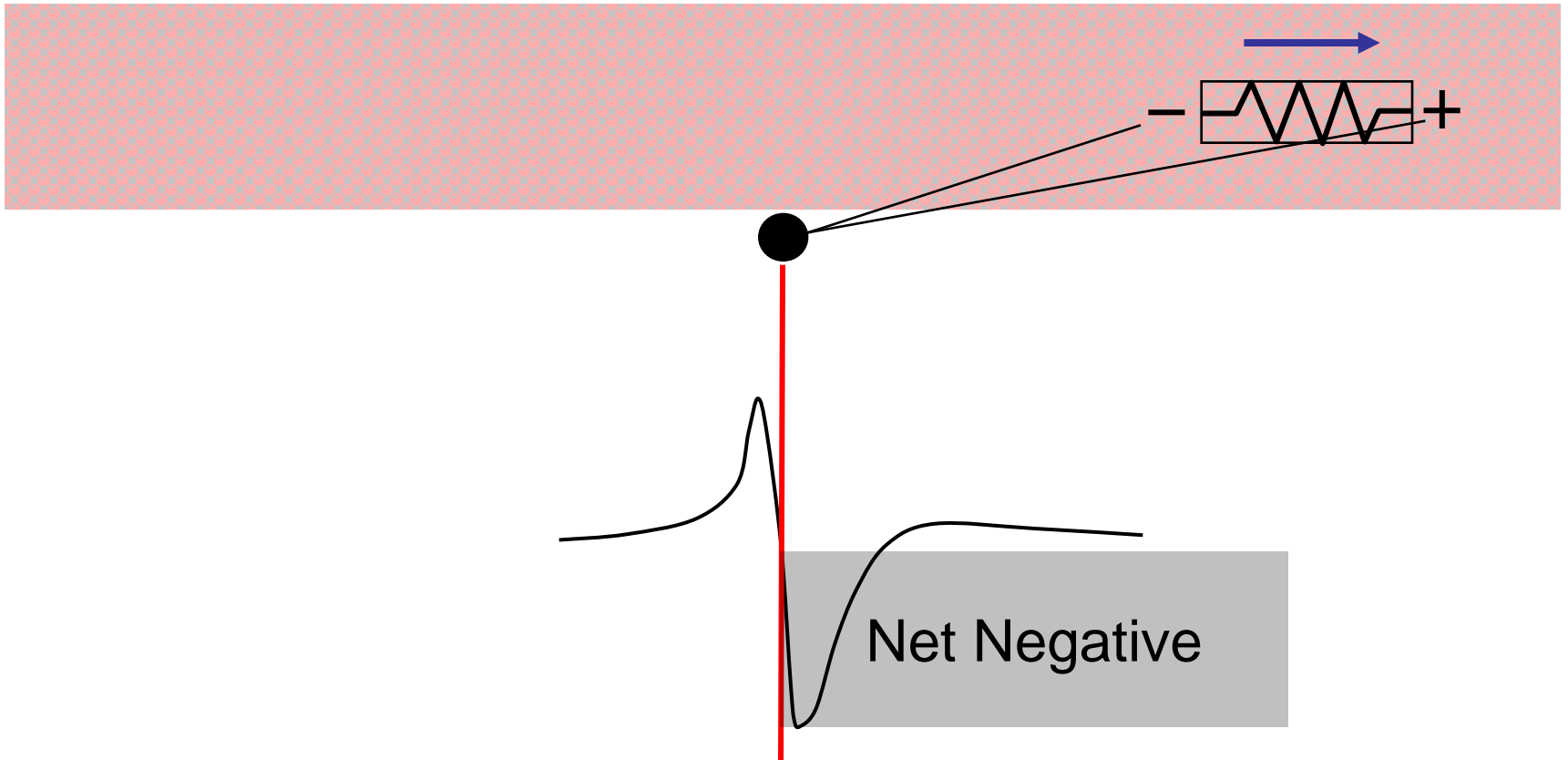
Influence of Single, Dipolar Channel



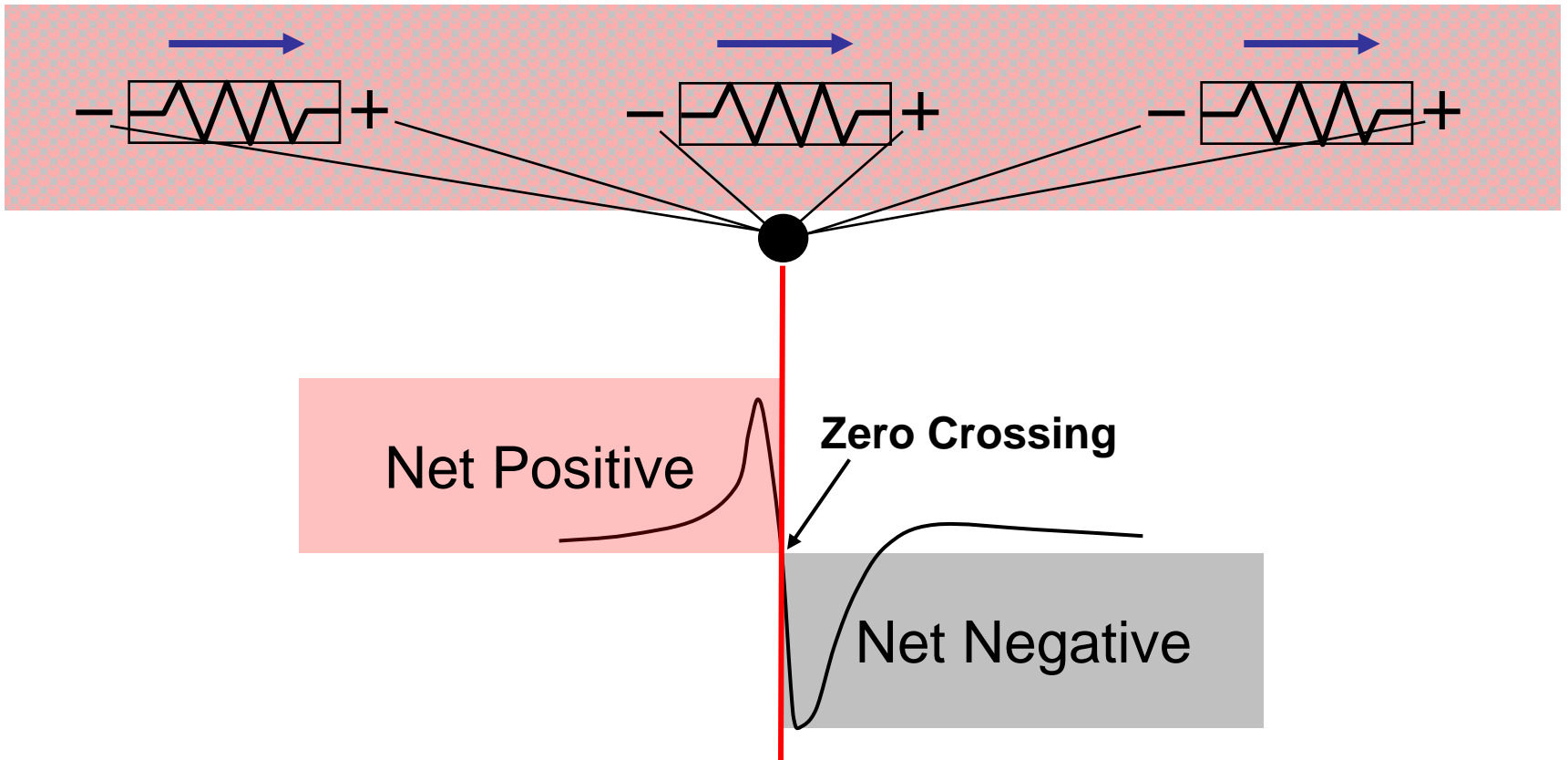
Influence of Single, Dipolar Channel



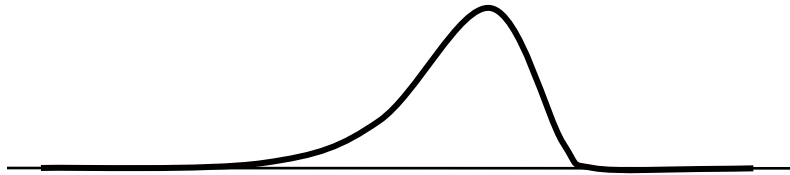
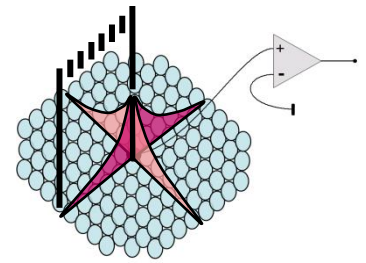
Influence of Single, Dipolar Channel



Influence of Single, Dipolar Channel



Abnormal Morphology



normal, *late*-chamber morphology

-plus-

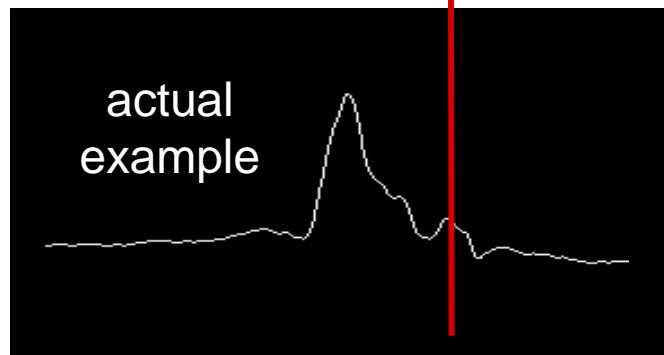


abnormal, localized, *late*-chamber morphology

equals:

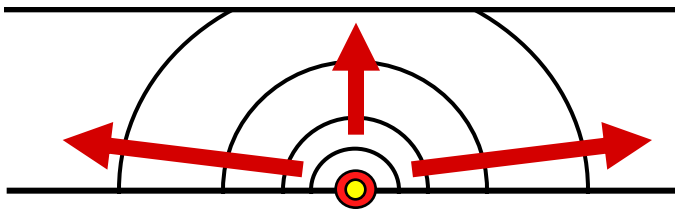
multi-component, abnormal morphology

(summation effect)



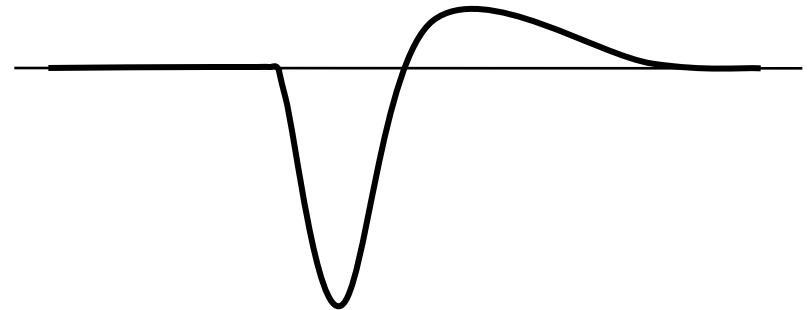
Depth of Origin

Epi

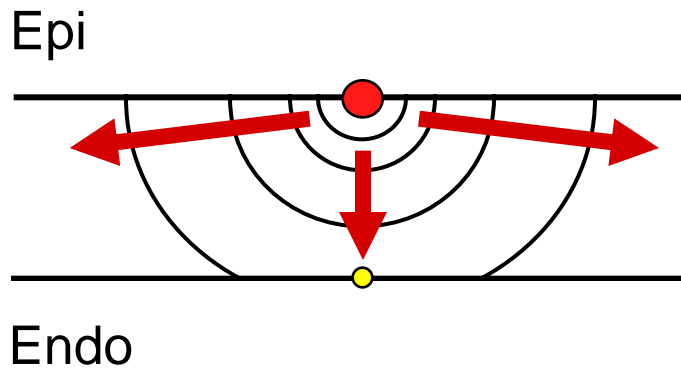


Endo

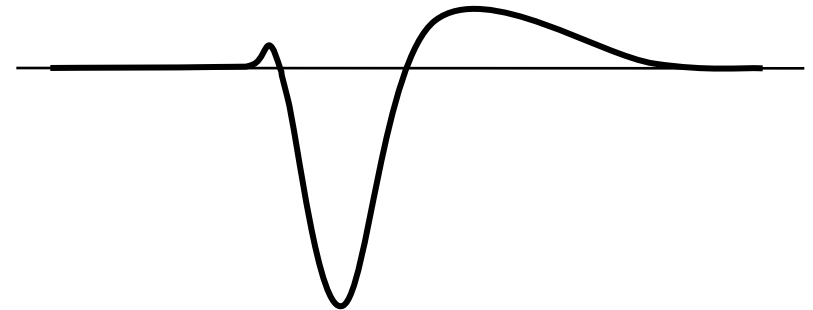
“sharp” QS, *only* with
endocardial origin at location
of electrode



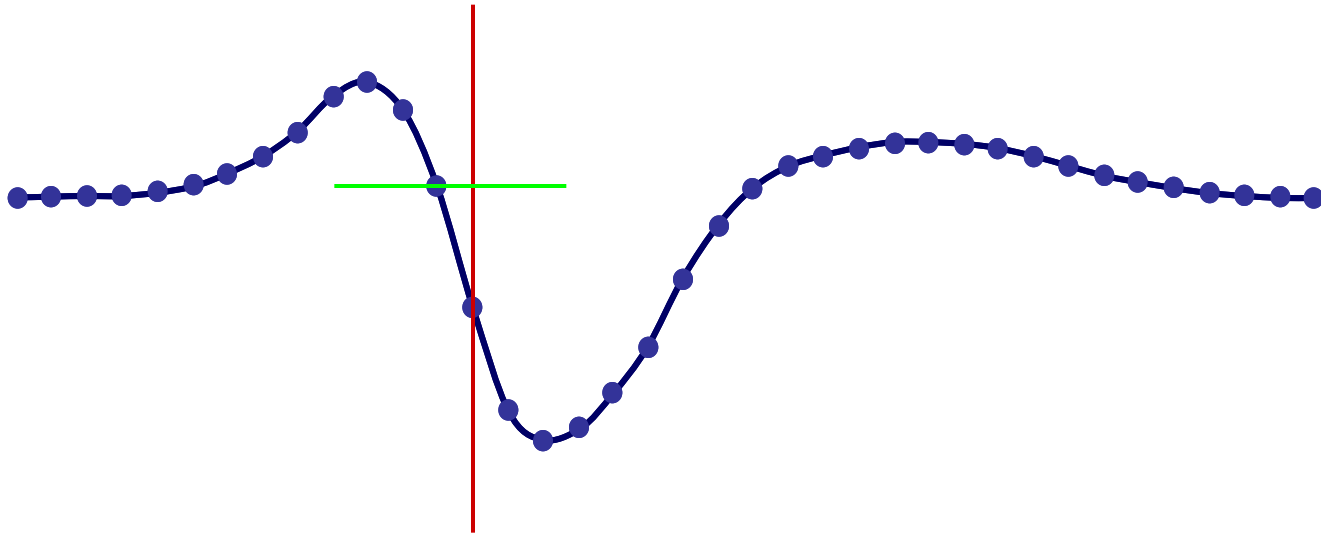
Depth of Origin



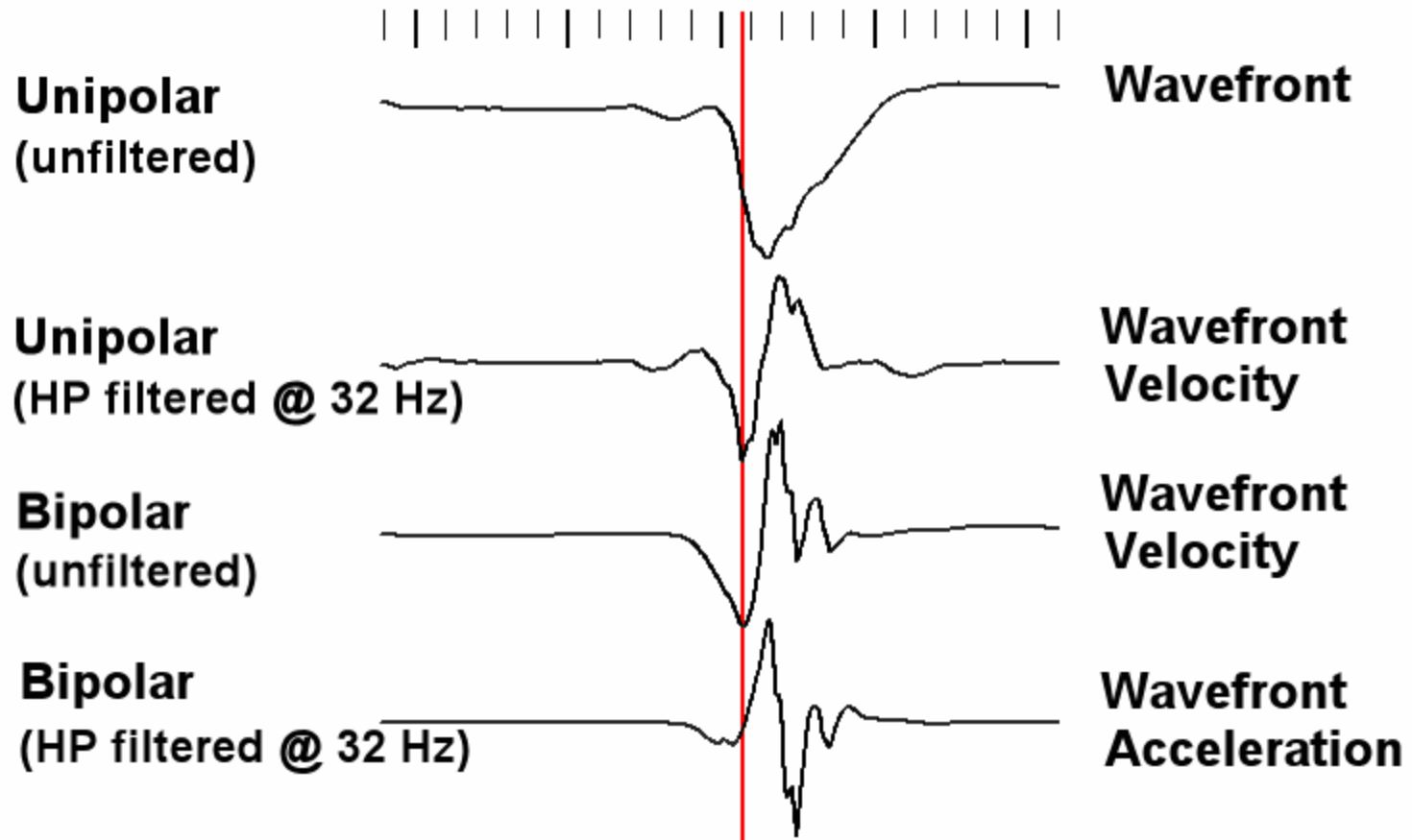
small, leading R-wave with
intramural origin – deep from
location of electrode



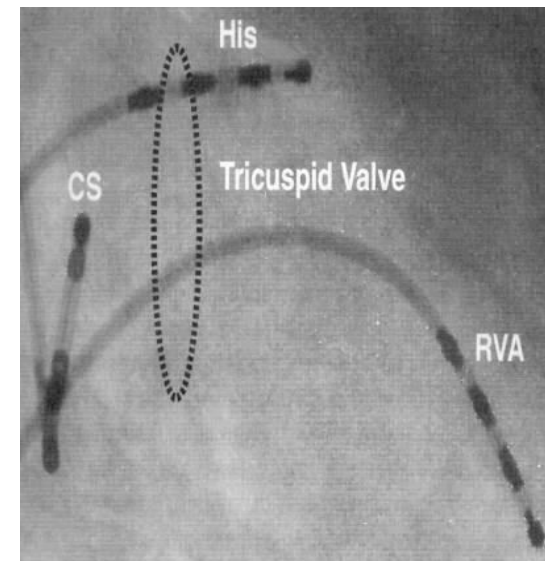
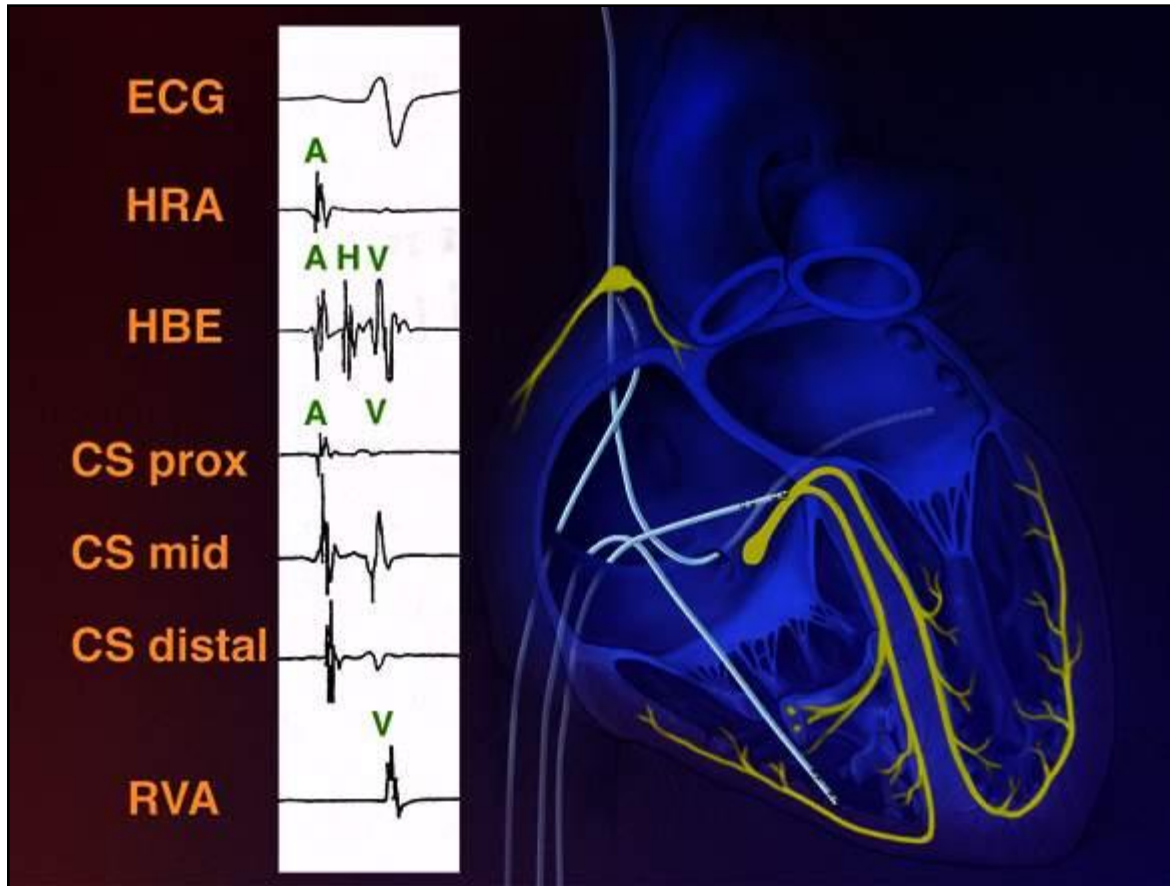
Bipole-Unipole relationship



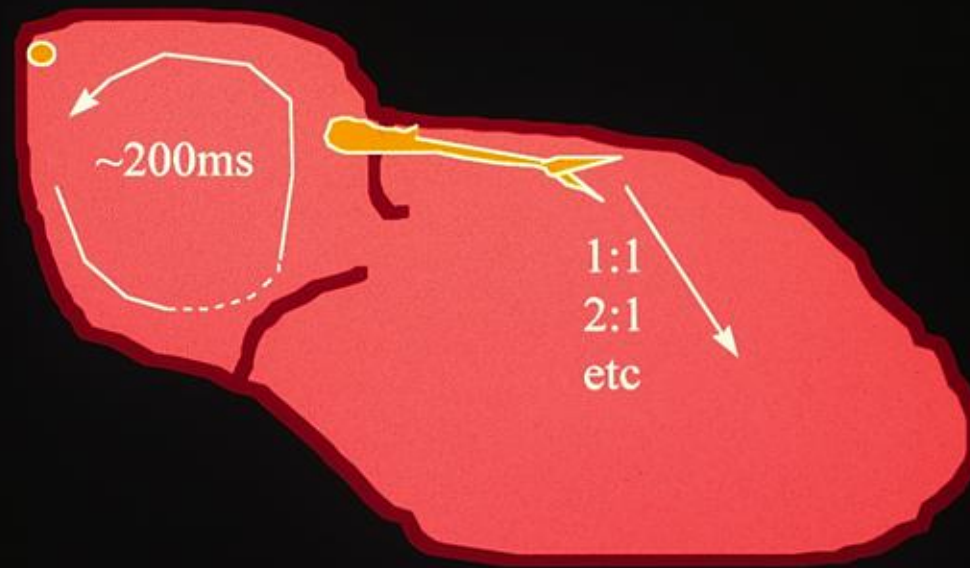
Biophysical Meaning of Filtering



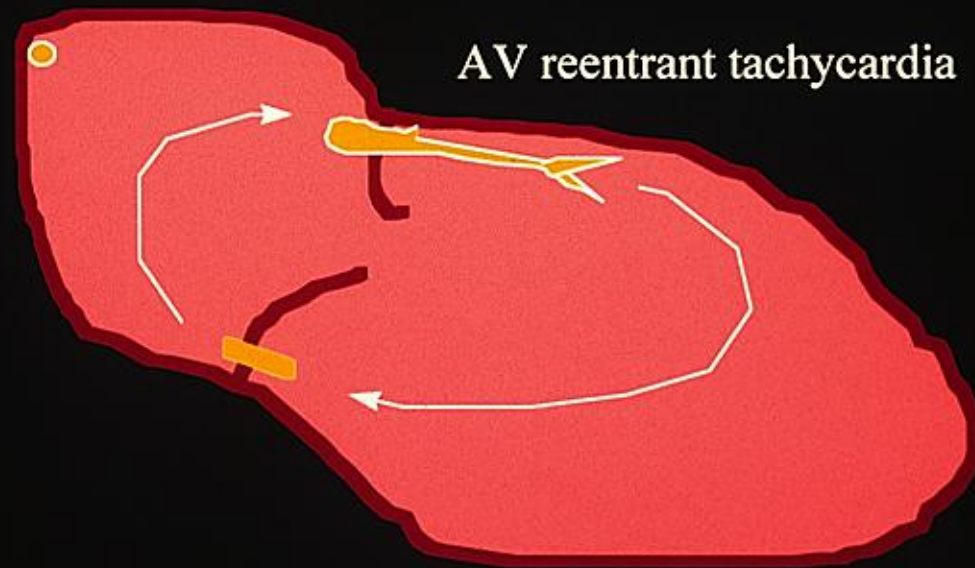
Catheter Placement



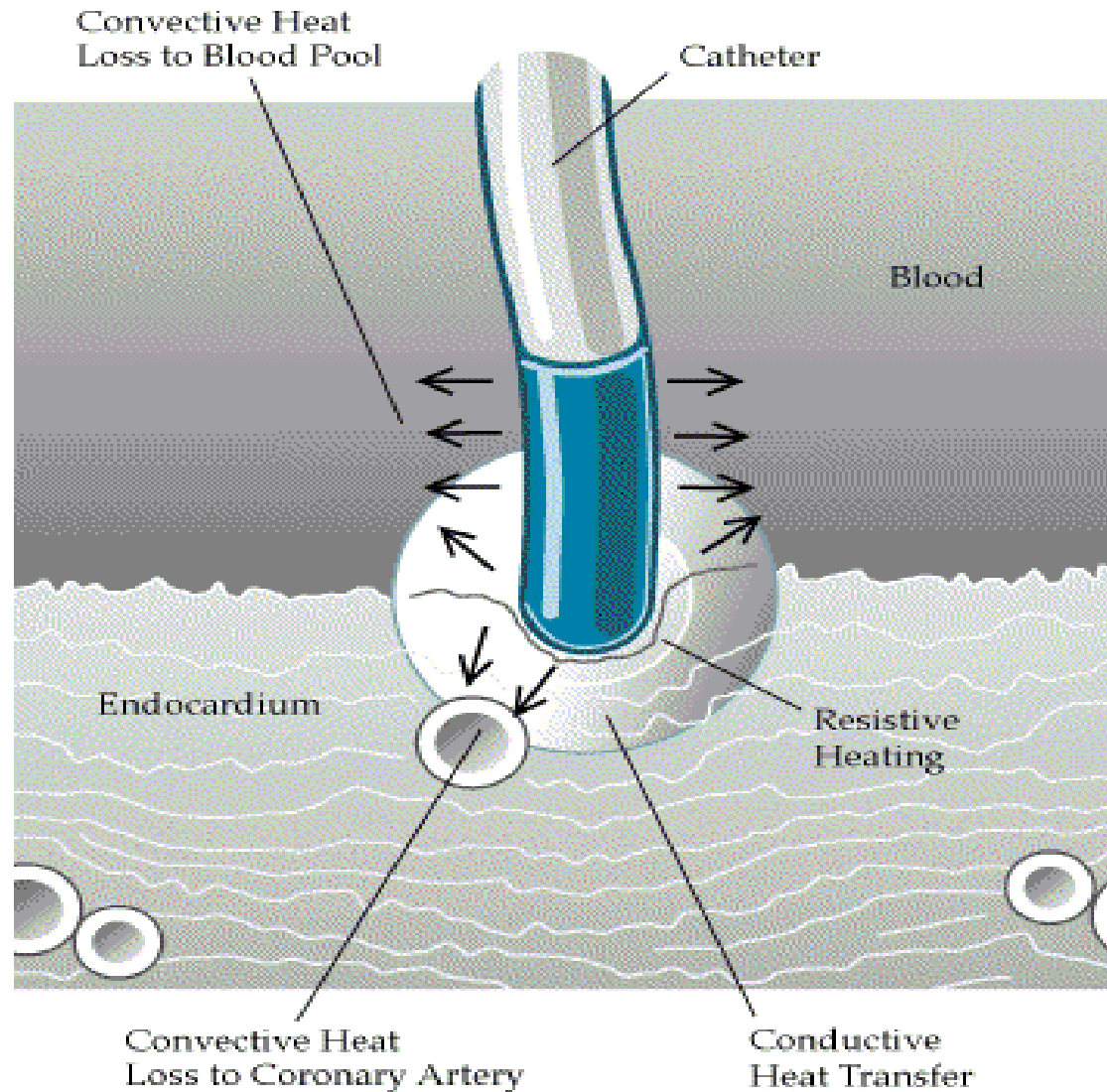
ATRIAL FLUTTER

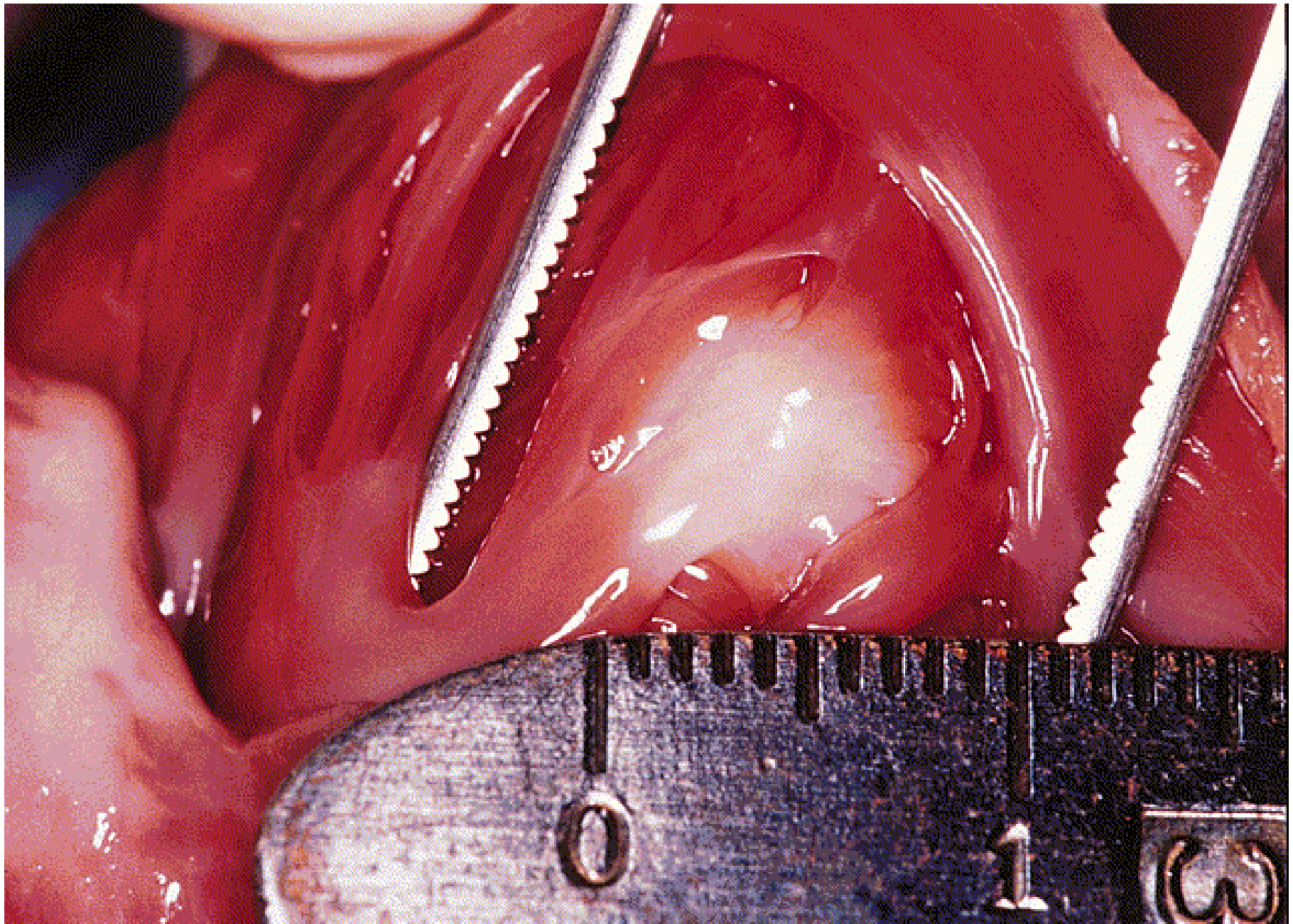


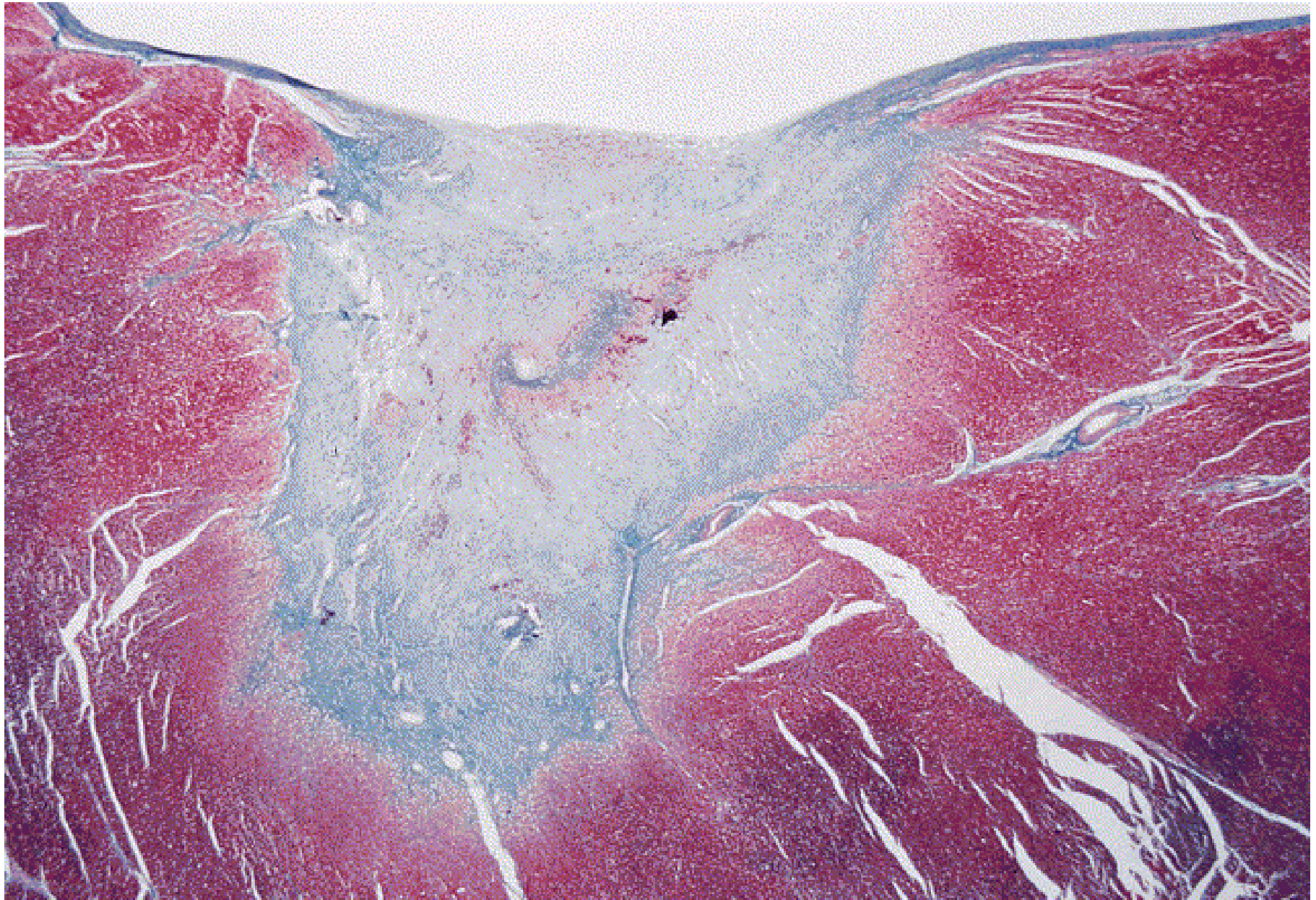
ACCESSORY AV PATHWAY Wolff-Parkinson-White Syndrome



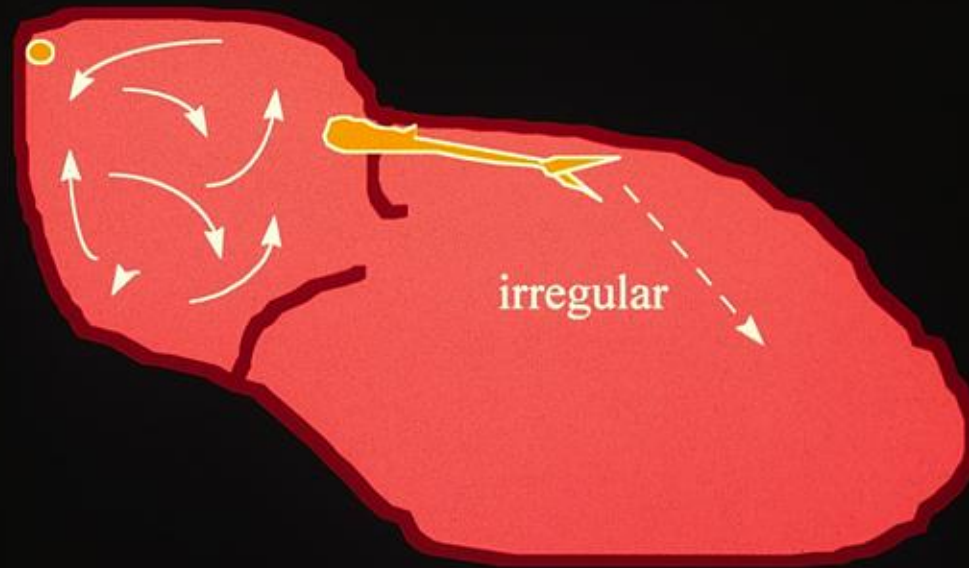
RADIOFREQUENCY ABLATION

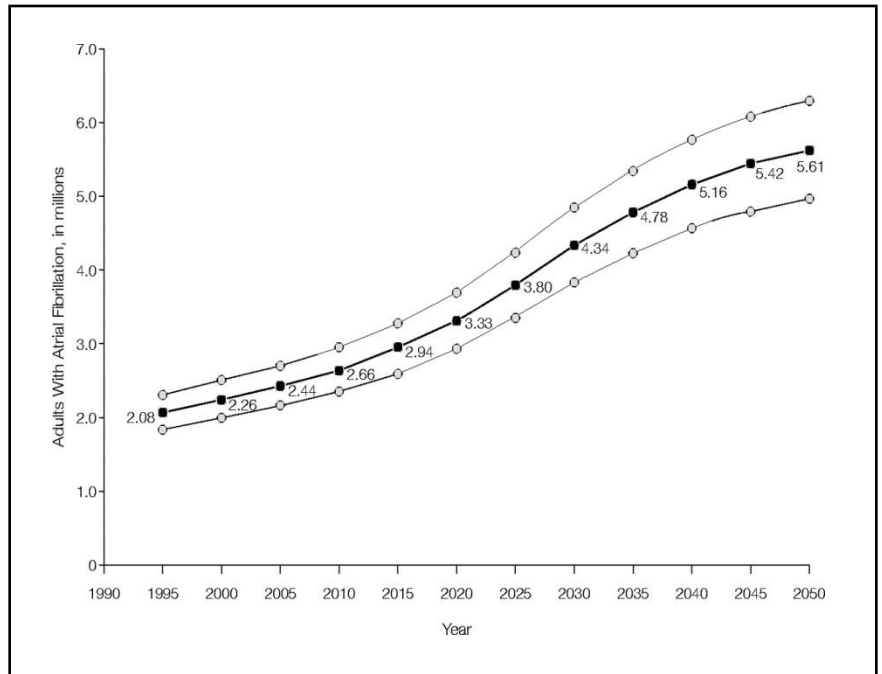
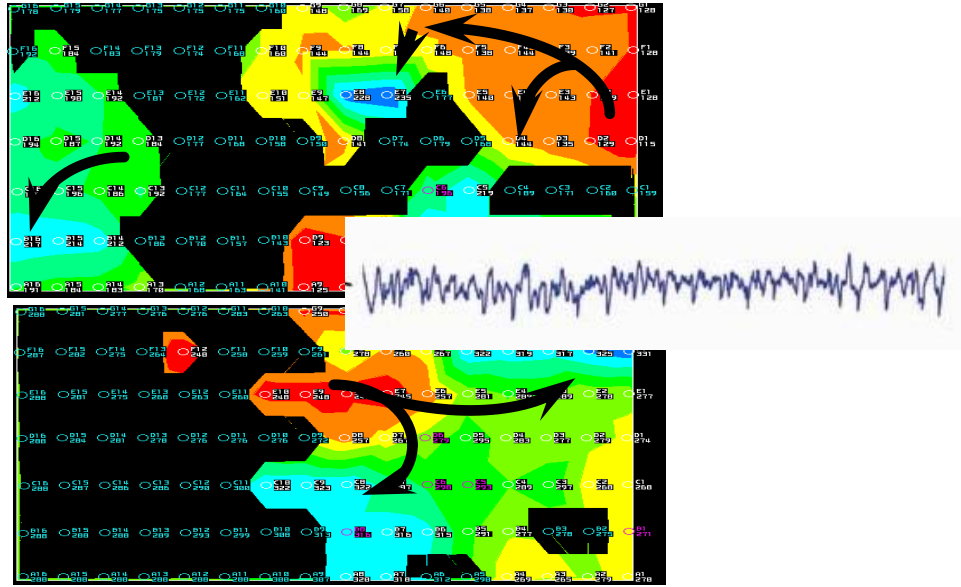
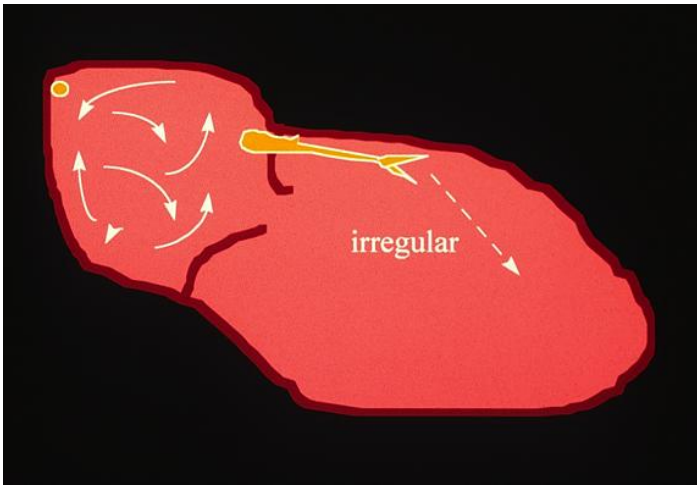


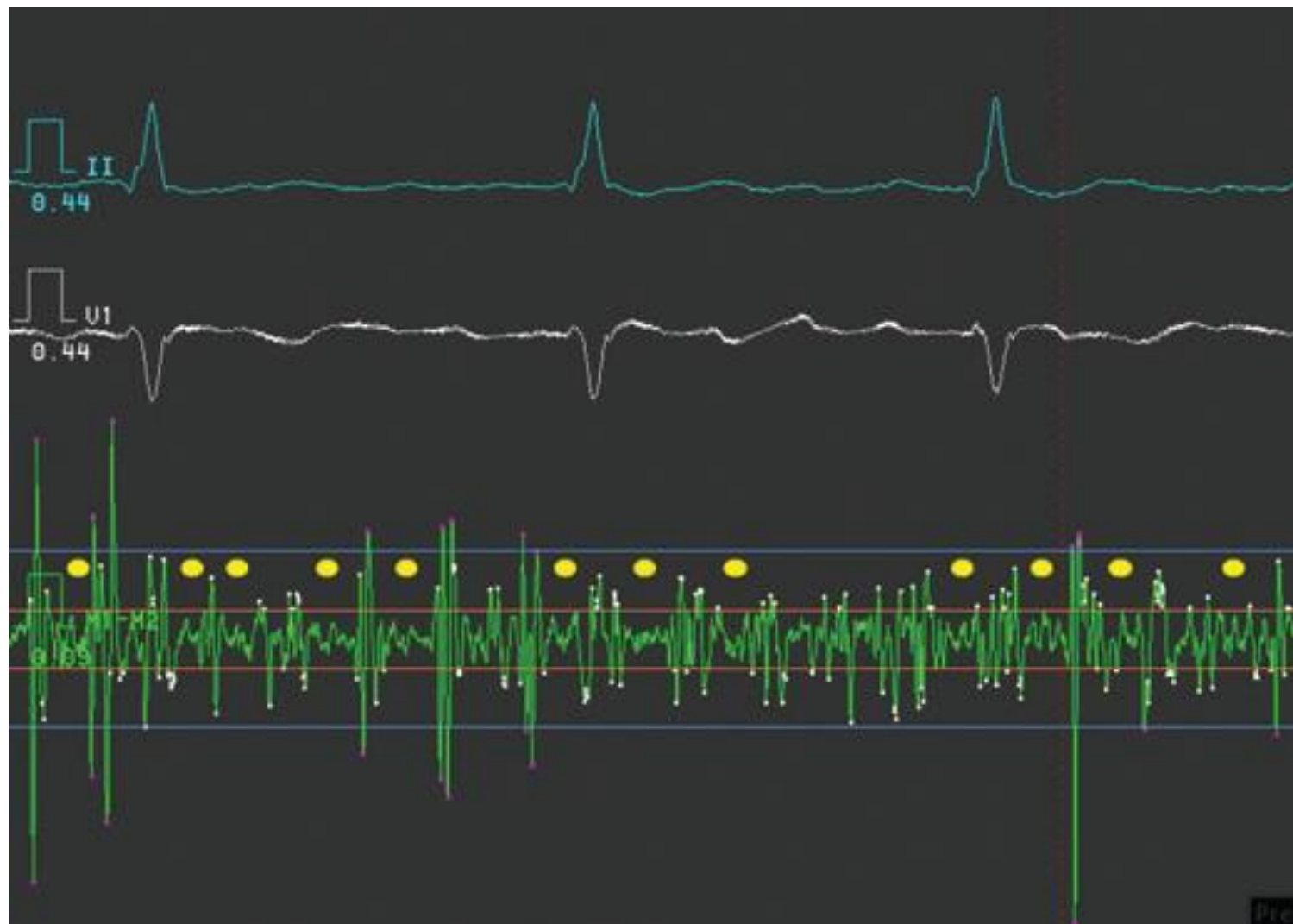




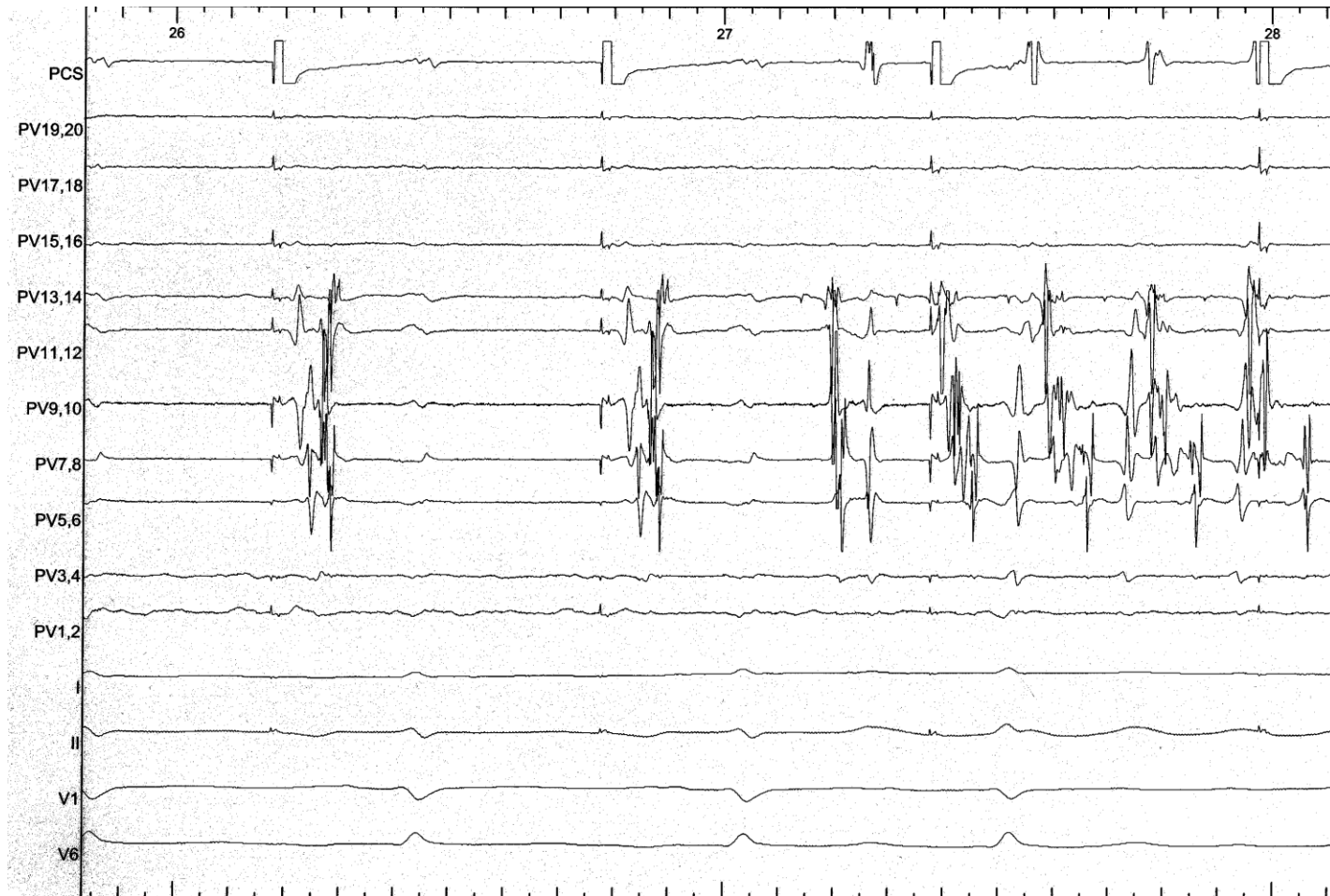
ATRIAL FIBRILLATION

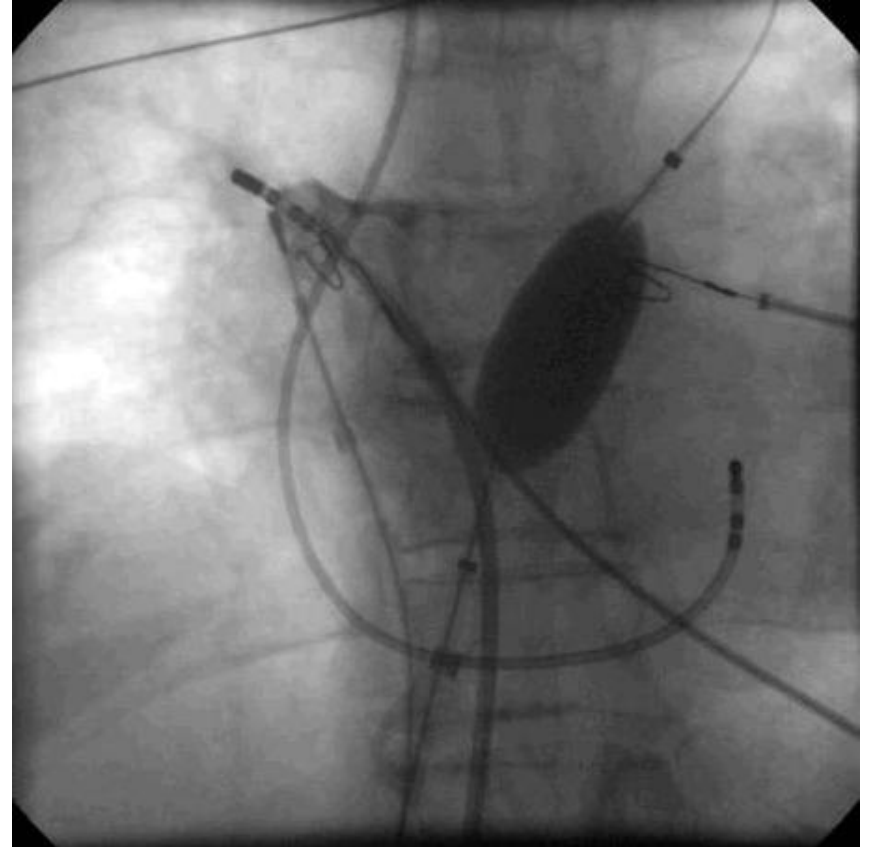
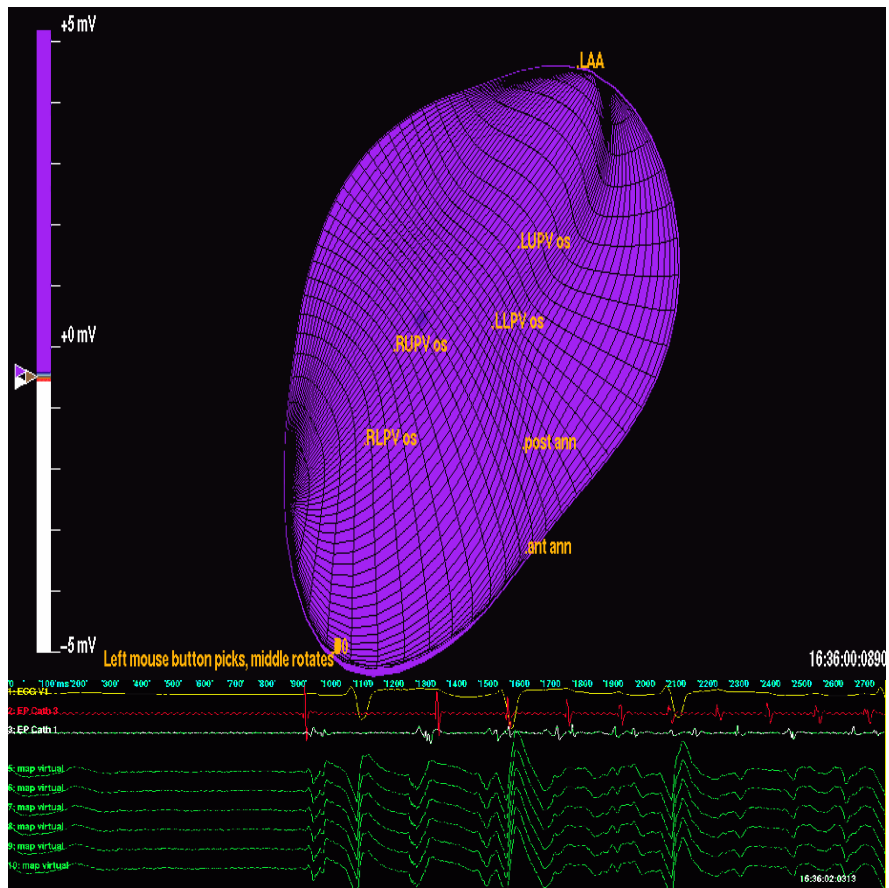






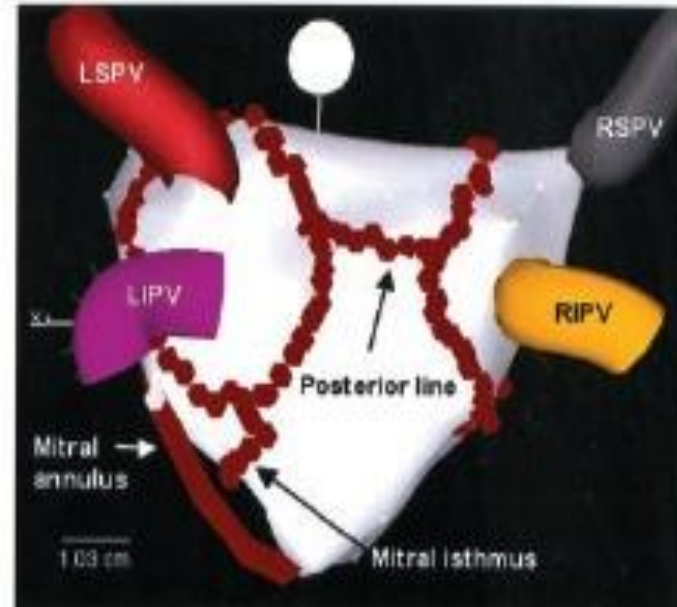
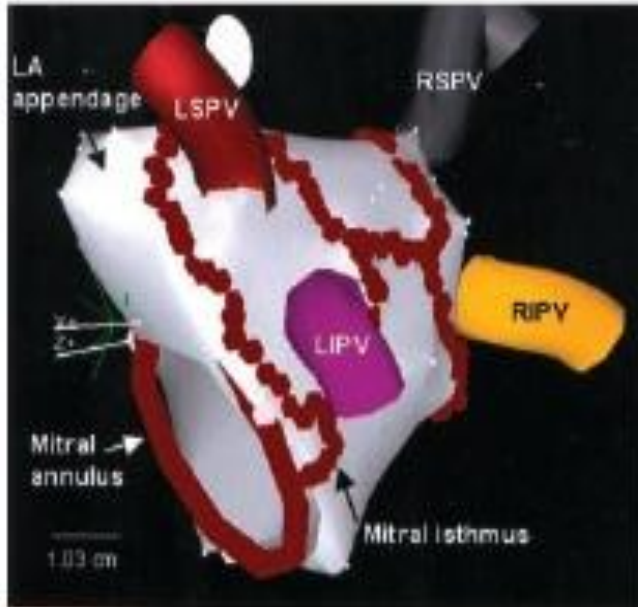
Atrial Fibrillation: initiation by LPV ectopic

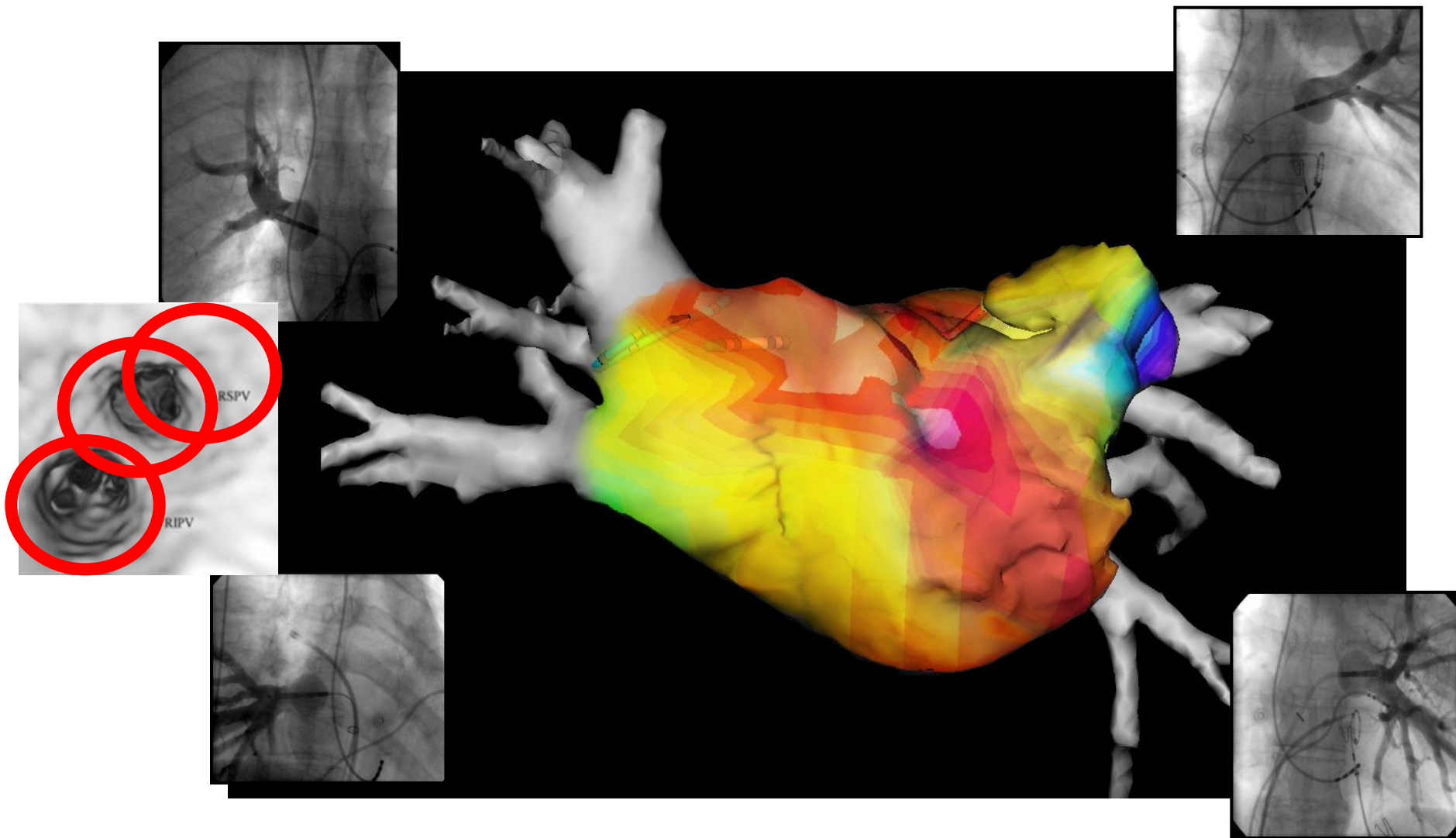


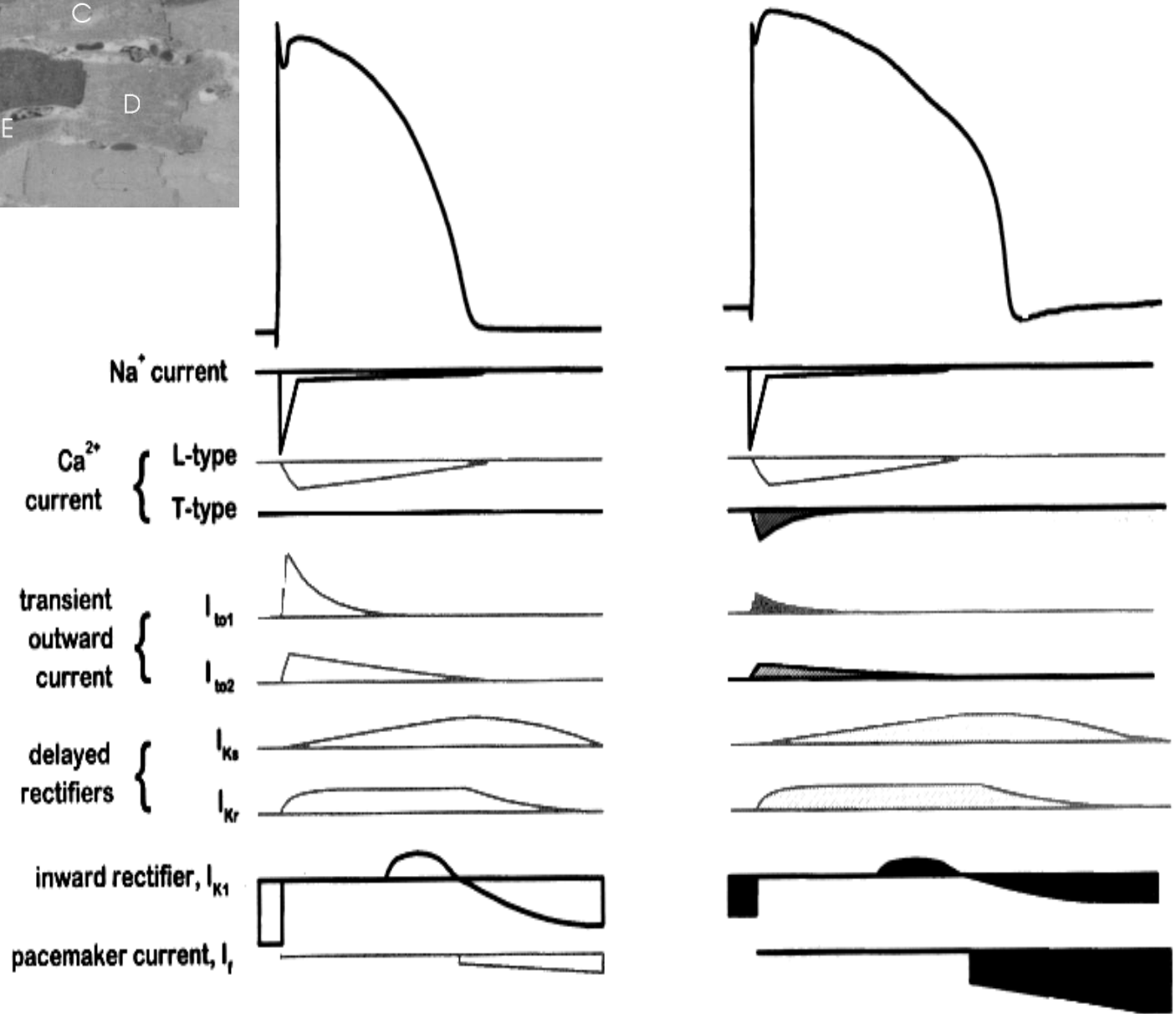
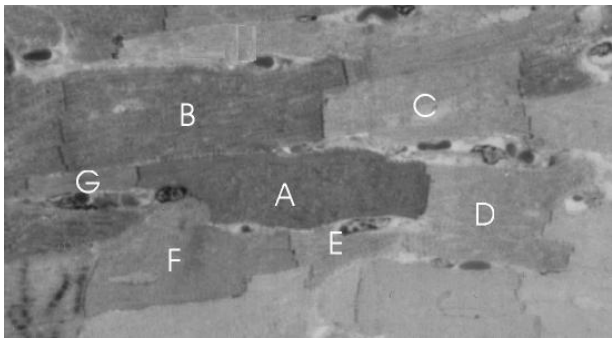


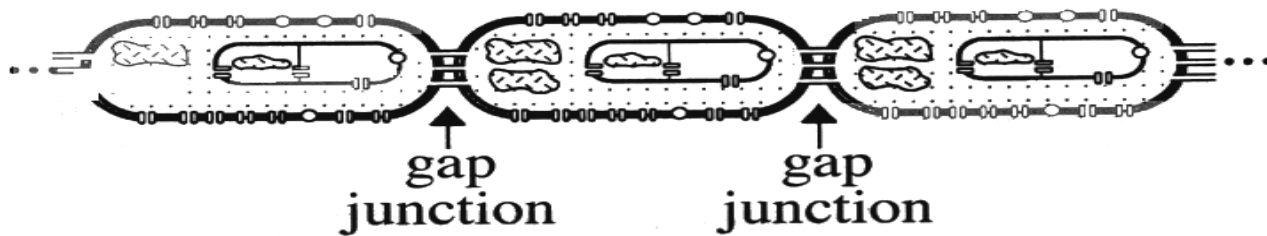
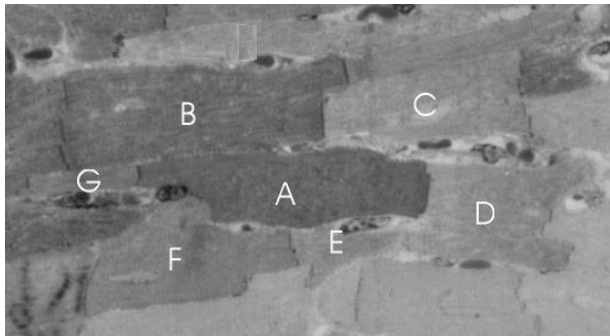
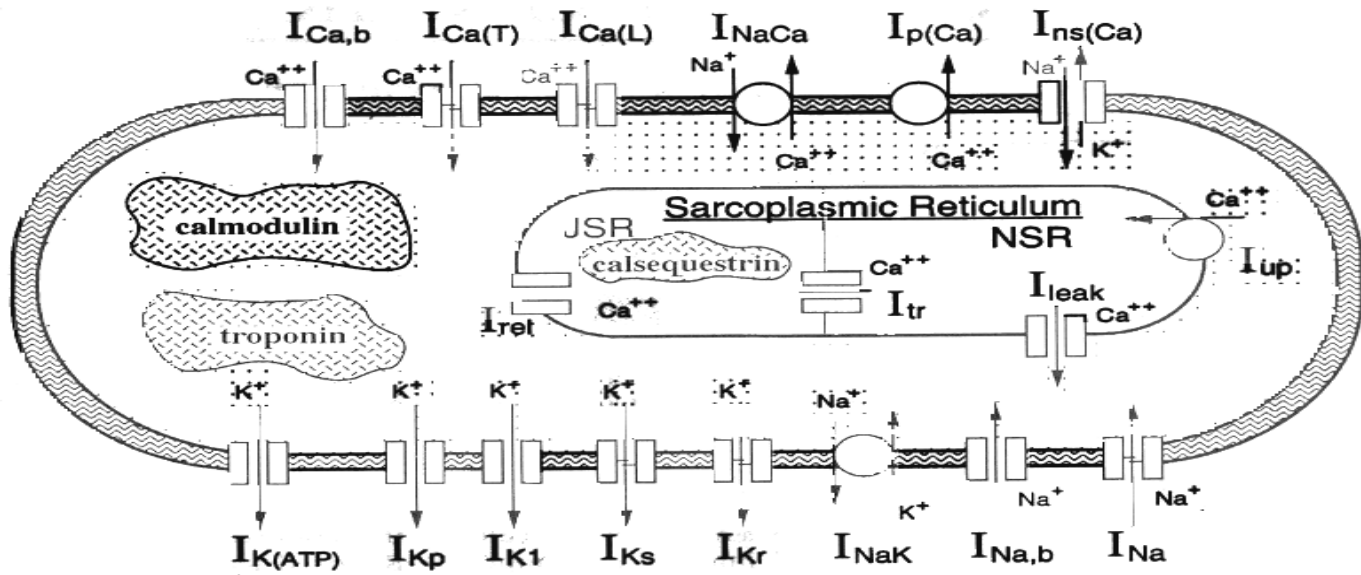
RHYTHM CONTROL

Percutaneous linear LA ablation



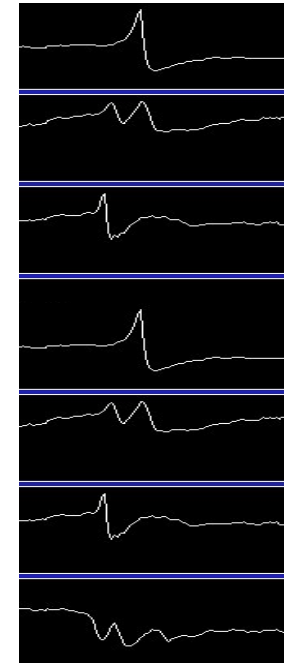
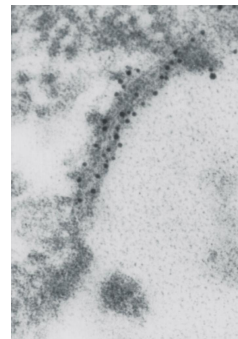
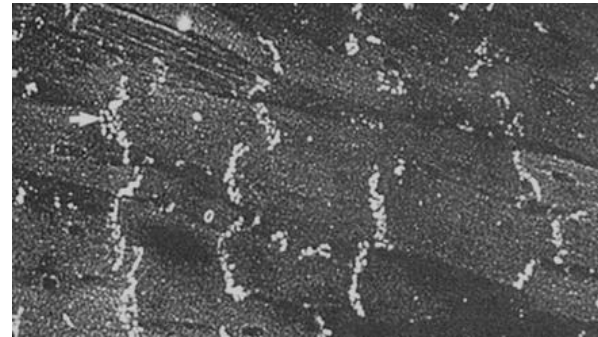
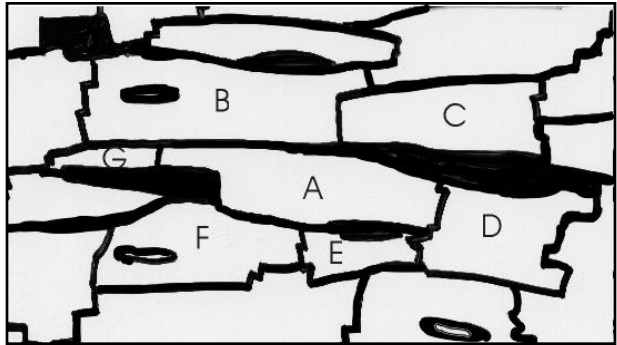
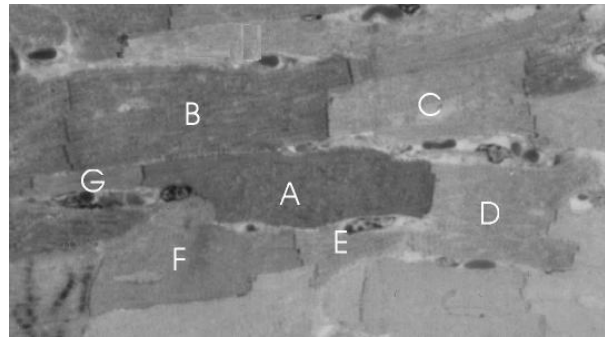
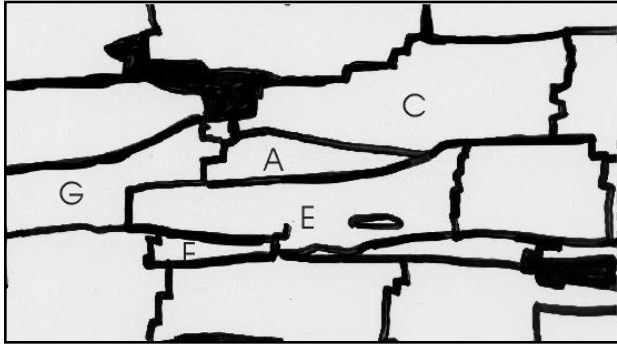




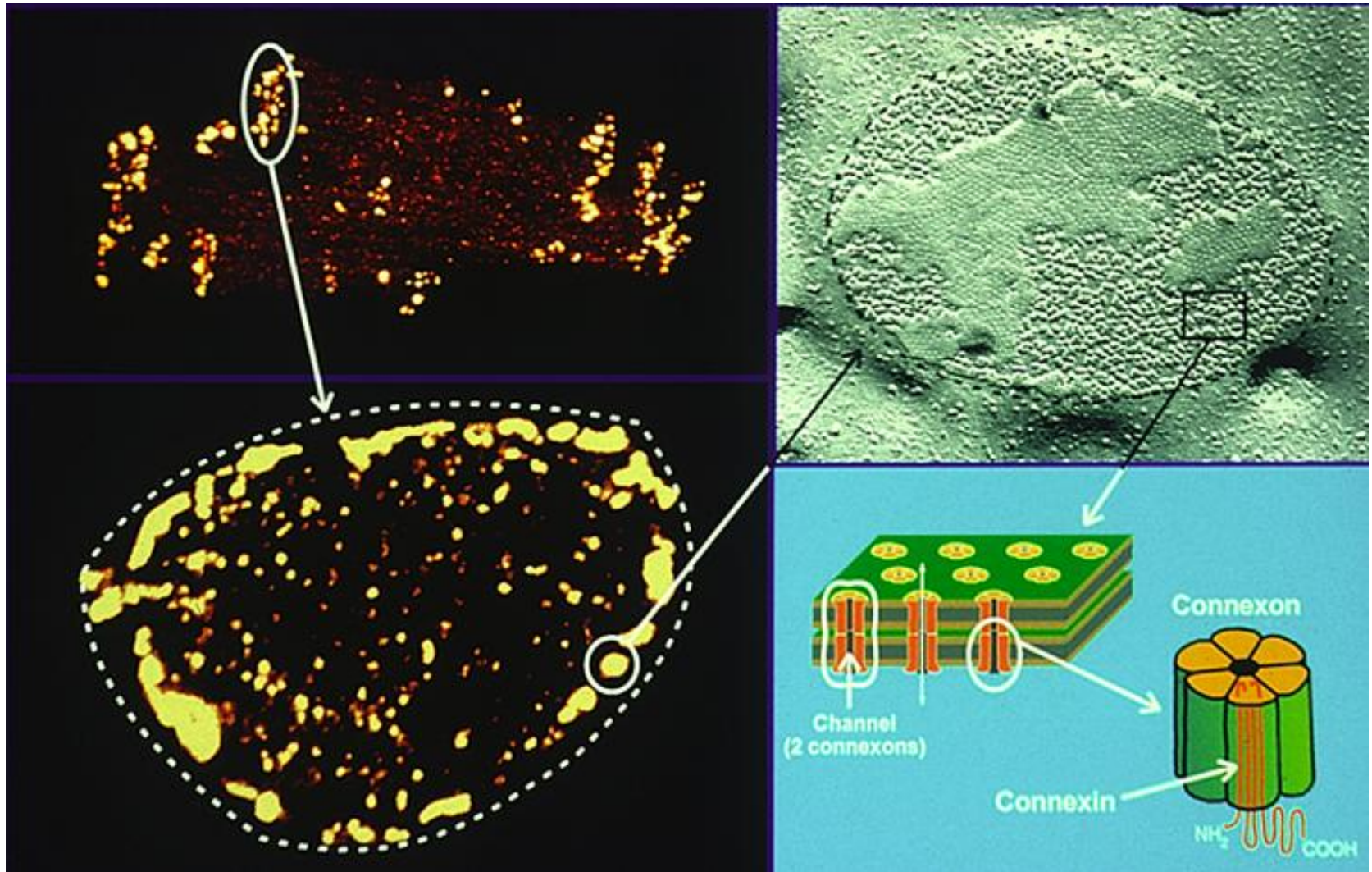


MICROSCOPICAL COMPLEXITY

Structure and Function



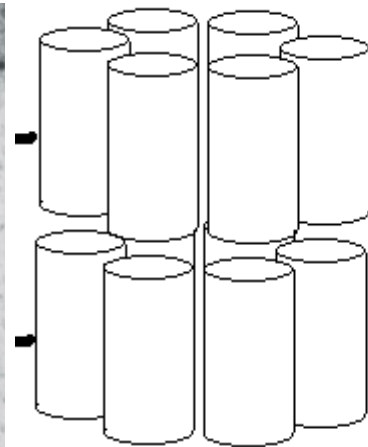
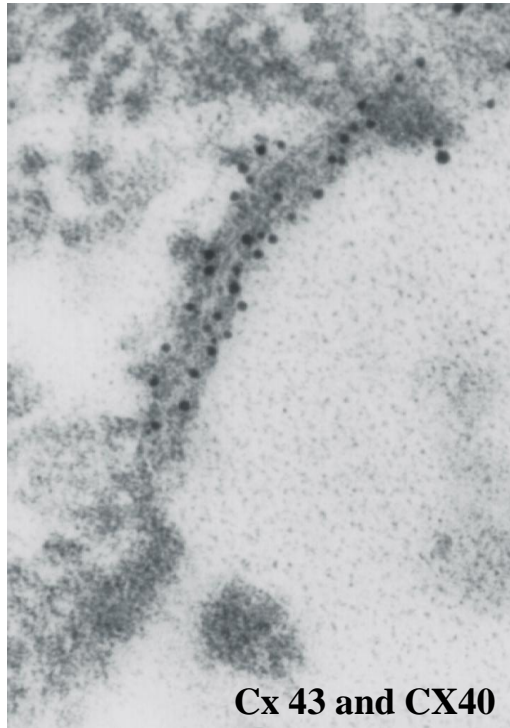
Structure of the Gap Junction



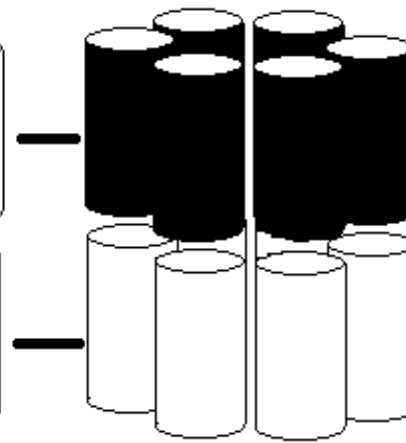
Ventricle: Cx43, (Cx45)

Atrium: Cx43, Cx40, (Cx45)

Types of Gap Junction Channels

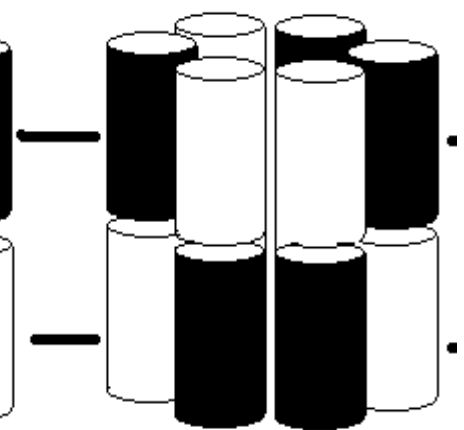


Homotypic



Heterotypic

Cx43/Cx40
Non-functional

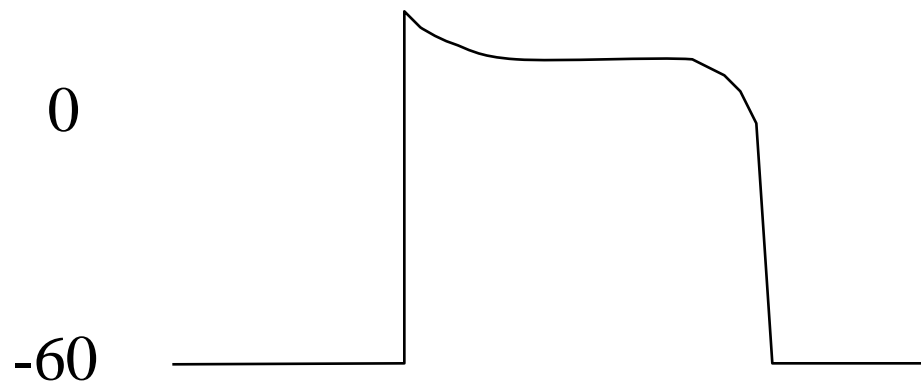


Heteromeric

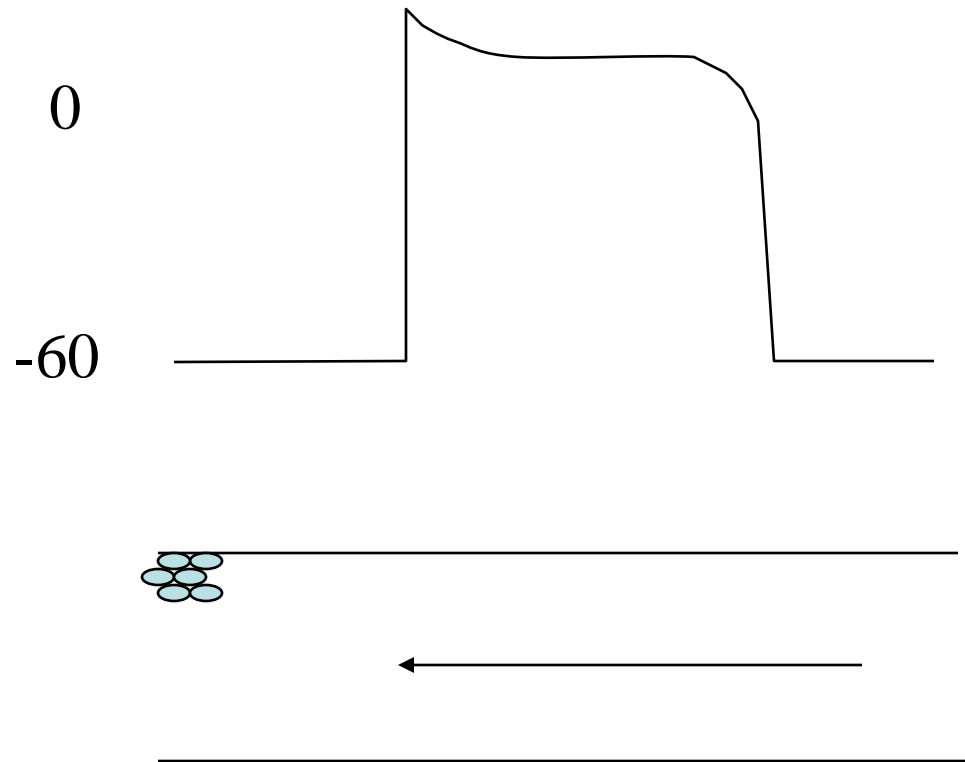
Cx43/Cx40
?

?Conduction

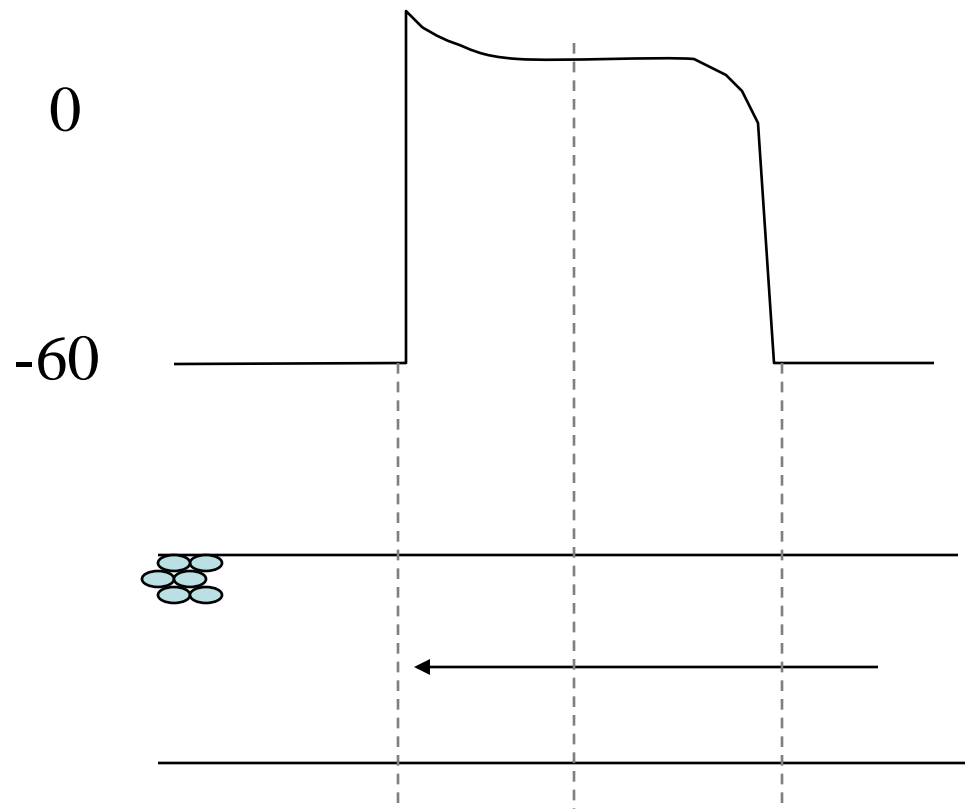
Action potential



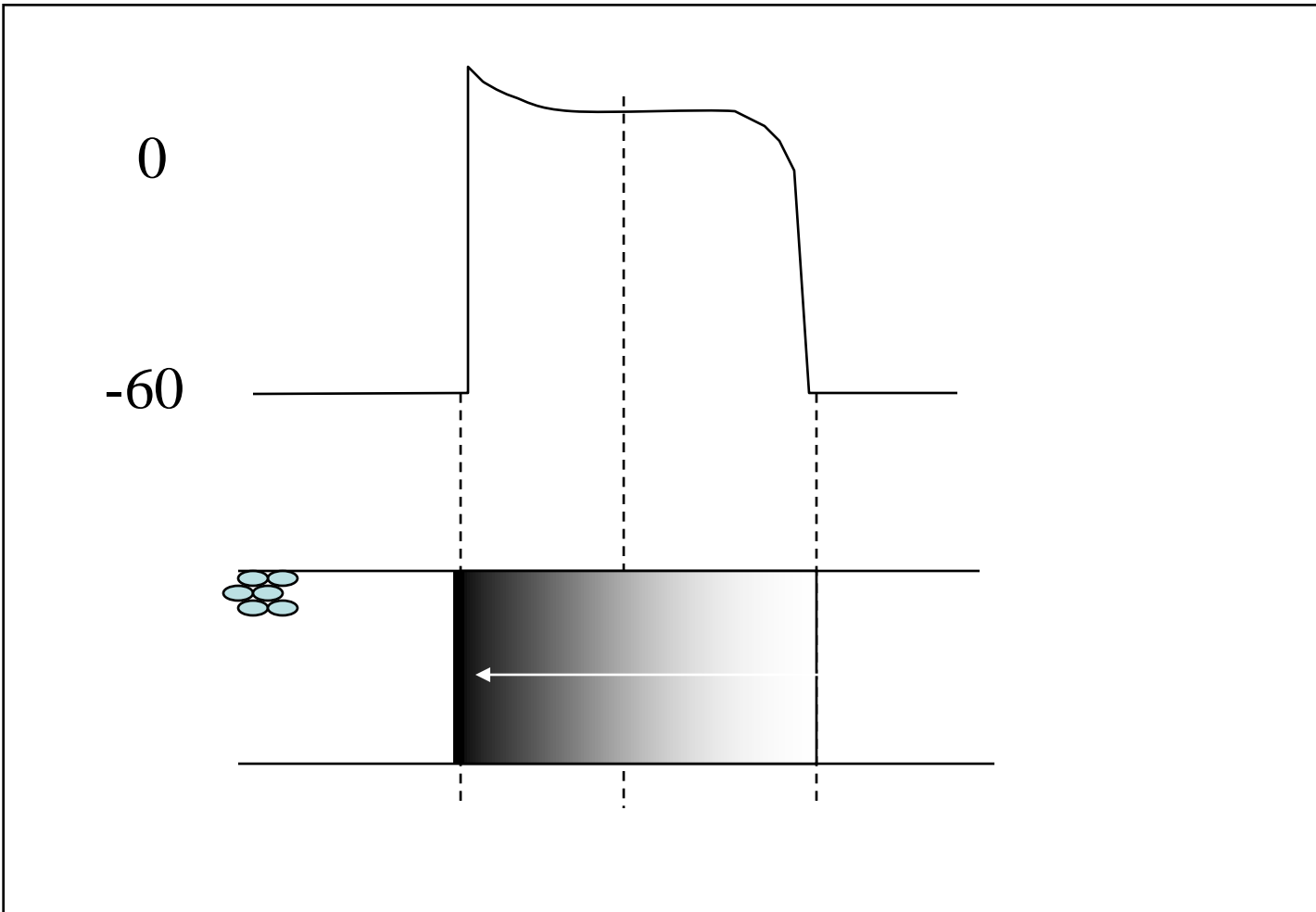
Propagating action potential



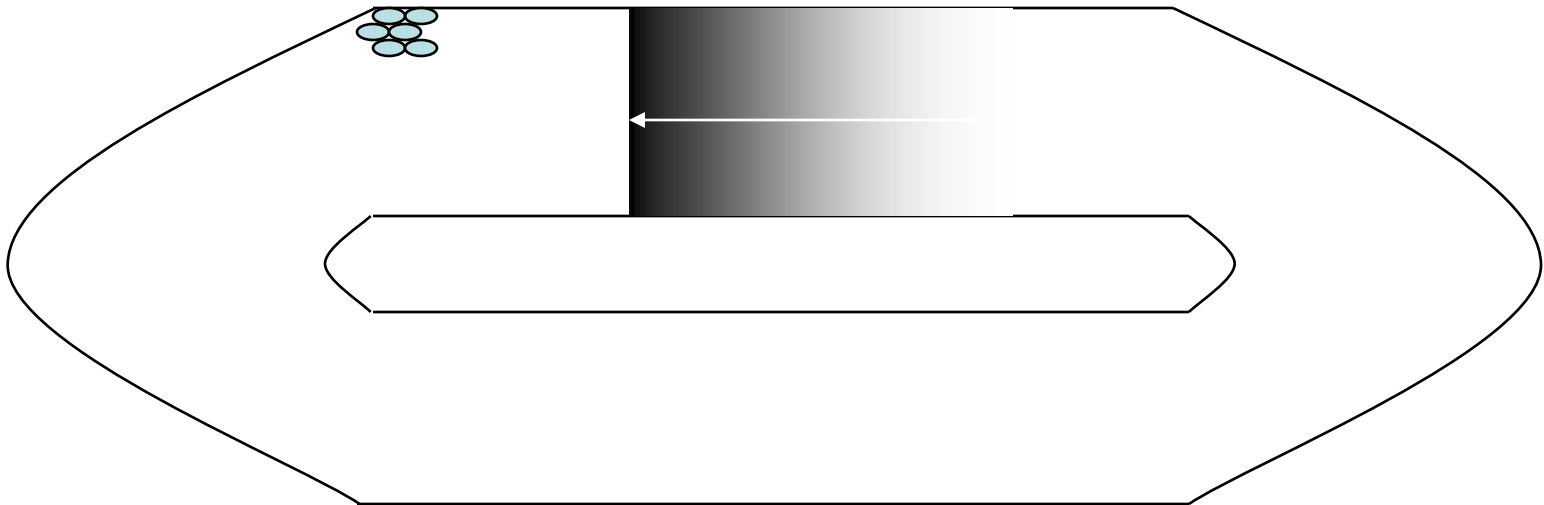
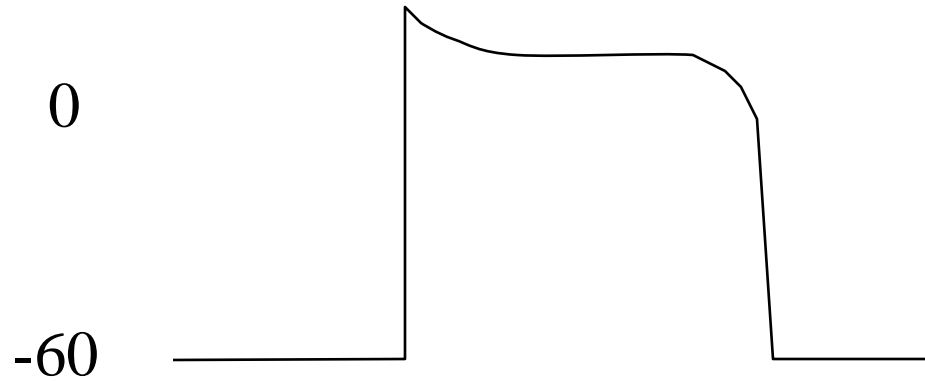
Propagating action potential



Propagating action potential



Propagating action potential



Focal Arrhythmia

