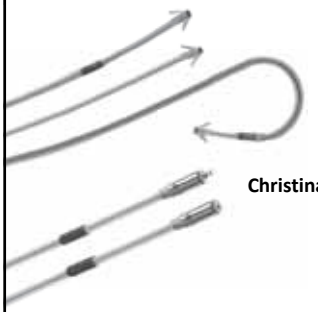
Electrodes for Bioelectric Signals

Sensing and Stimulation



Christina Engelhard / Thomas Meier / Christian Rockstroh / Dr. Alexander Rzany

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BIOTRONIK

MB-JASS 2009

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Electrotherapy of the Heart - Implantable High Tech

- Multisite pacing
- Rate adaptive pacing
- Implemented defibrillation capability

Physiologically adequate replacement of the natural pacemaker

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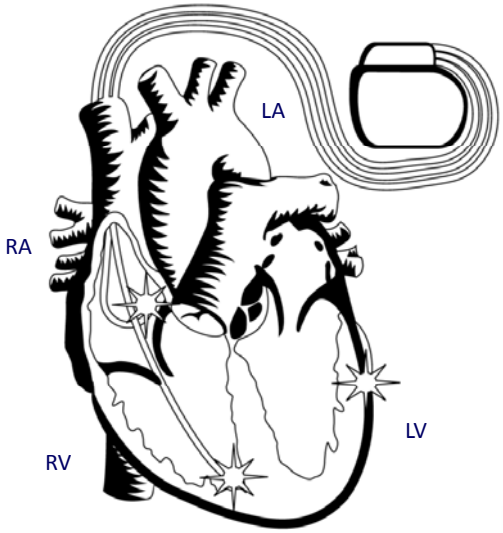
Cardiac Pacemaker – Pacing Sites



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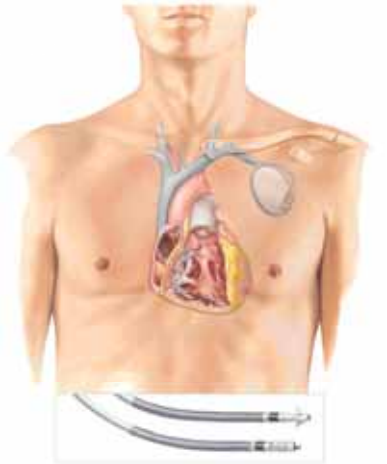
IPGs and ICDs

Implantable Cardiac Pacemaker
Implantable Pulse Generator (IPG)



Implantable Cardiac Defibrillator (ICD)

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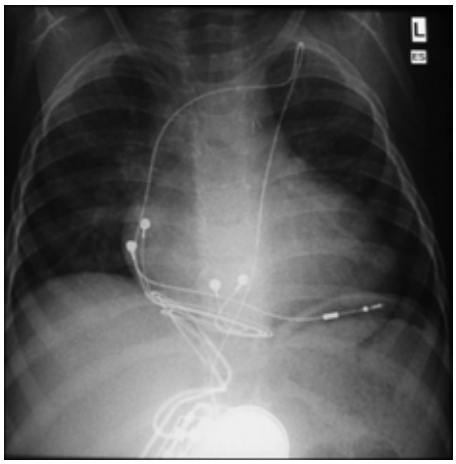
Electrotherapy of the Heart

- BIOTRONIK Philos DR-T
- Woman 56 years old



- BIOTRONIK Philos II
- Child 4 years old

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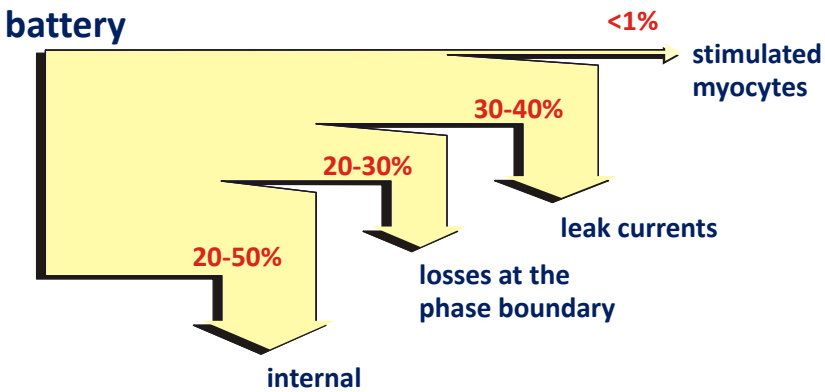
Cardiac Pacemakers – Energy Consumption



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Dual Function of the Pacemaker Electrode

- **The Pacing Electrode**
  Task: deliver a charge pulse from the pace-maker to the cardiac tissue
  (approx. 10^{-6} As per stimulus)
- **The Sensing Electrode**
  Task: measure very small voltages with minimal distortion of the waveform
- Research recently focused on sensing:
  Improved sensing properties provide access to valuable physiologic parameters of the natural cardiovascular control loop
  → improved **rate adaption**

The Electrode-Tissue Interface

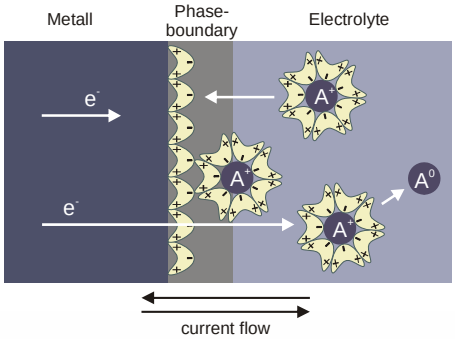
- Interface:

electrode = solid metal = electrons

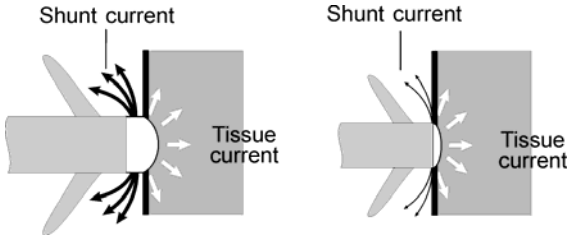
tissue/blood = electrolyte = ions

→ no direct charge transfer!

- Electrochemical phase boundary:



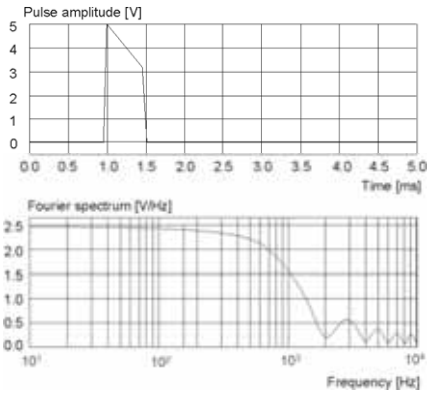
Electrode shunt current



- A larger electrode surface area leads to bigger shunt currents and thus to higher losses
- From the clinical standpoint small electrodes are desirable for undisturbed blood flow
- Problem: A small electrode surface area decreases the interface capacity and thus increases the impedance

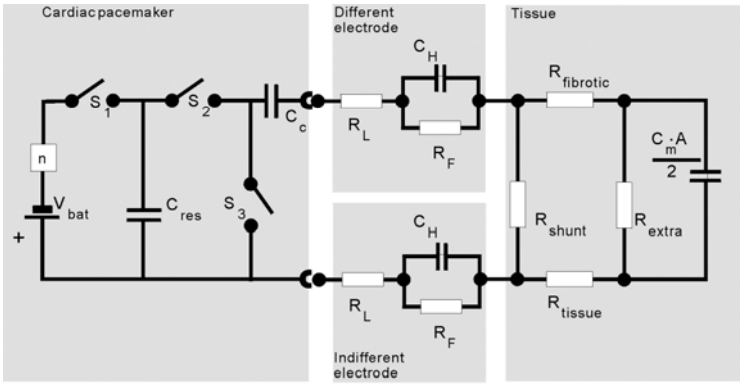
Electrodes with a small geometric surface but a large effective surface are the best solution for saving energy during stimulation

The Stimulation Pulse



- The main frequency components of a typical pulse are located below 1 kHz
- To save energy a lower impedance at lower frequencies is necessary
- The only way is to increase the capacity, i.e. the electrode surface area and thus lower the cut-off frequency of the high-pass

Pacemaker – Electrode – Tissue



C_{res}: reservoir capacitor, C_C: coupling capacitor, S_3: auto short

Pacemaker – Electrode – Tissue: values

Parameter		Range
Reservoir capacity (C_{res})		5 to 20 µF
Coupling capacity (C_c)		5 to 20 µF
Specific Helmholtz capacity (C_H)		0.1 to 500 µF/mm²
Lead resistance (R_L)		10 to 100 Ω
Geometric electrode surface (A)		1 to 20 mm²
Surface of indifferent electrode (A_{in})	unipolar: bipolar:	500 to 1500 mm² 20 to 100 mm²
Membrane capacity (C_m)		0.01 µF/mm²
Tissue resistance (R)		30 to 70 kΩ
Shunt resistance (R_{Shunt})		0.1 to 2 kΩ

Workshop Electrodes

Christina Engelhard / Thomas Meier / Christian Rockstroh

- The phase boundary electrode/electrolyte
- Impedance spectroscopy
- Fractal coating of electrodes

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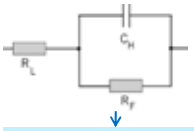
Electrodes for Bioelectric Signals - Summary



important:
- low impedance
- low shunt current
- low afterpotential

↓

small tip with high Helmholtz capacity needed

↓

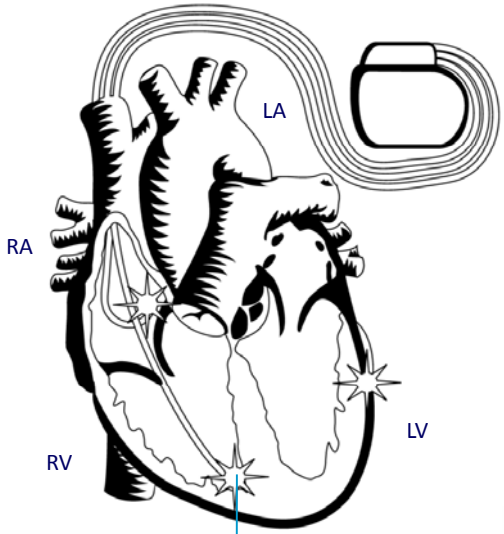
realized by fractal coating of the electrode

↓

electrode:
- pacing
- sensing
- impedance measuring

↓

Contraction Dynamics - CLS



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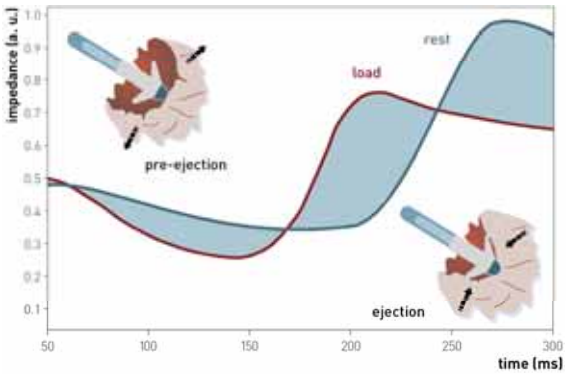
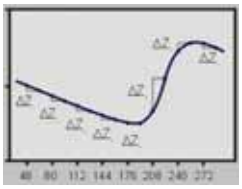
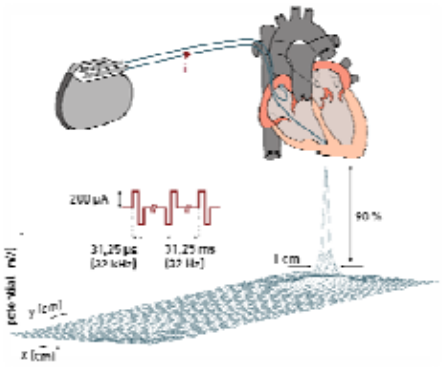
Closed Loop Stimulation by Contractiliy Monitoring

Changed morphology of the impedance curve reflects changes in myocardial contraction dynamics



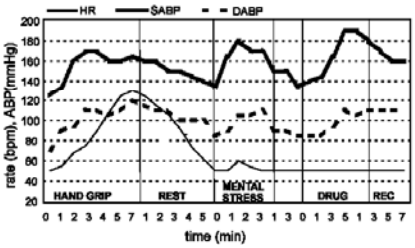
Rate adaption by Impedance Measurement



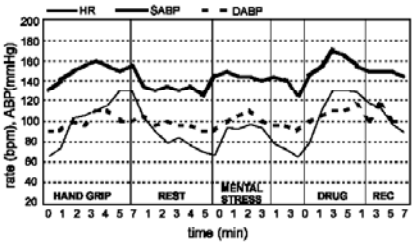


- Reference impedance waveform: Corresponds to period of rest
- Change in impedance waveform: Measure for increased contractility
- Patient specific auto-response factor: Factor that translates a change in contractility to a change in heart rate

Closed Loop Stimulation– Results



- Heart rate (HR), systolic (SABP) and diastolic (DABP) arterial blood pressure in a male patient with dual, minute ventilation and activity, sensor pacemaker.



- Heart rate (HR), systolic (SABP) and diastolic (DABP) arterial blood pressure in a male patient with Closed Loop Stimulation.