

Pacing the Heart

Ayo Ositelu

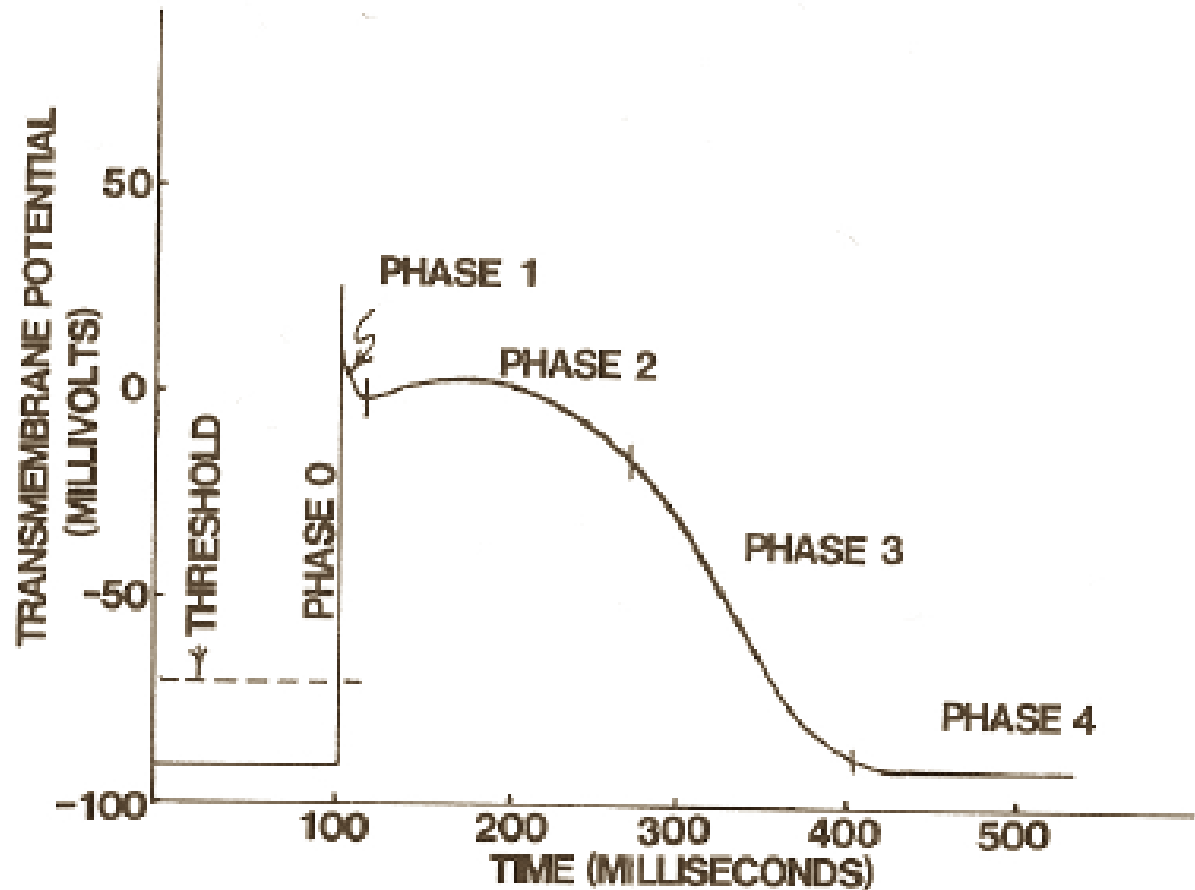
ECE 5030 Final Presentation

Tuesday, 15 December 2009 @ 1:00pm

Outline

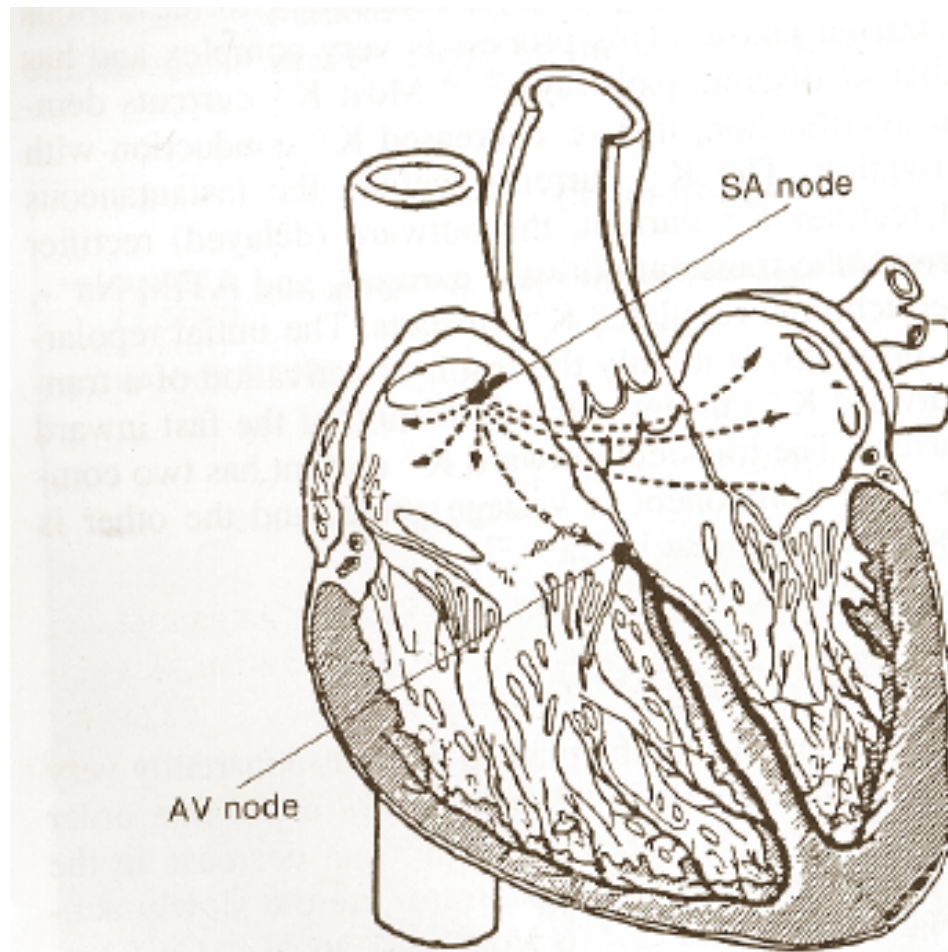
- Background
- Main Features
- New Features

The Cardiac Action Potential



Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 7.

Natural Pacemakers of the Heart



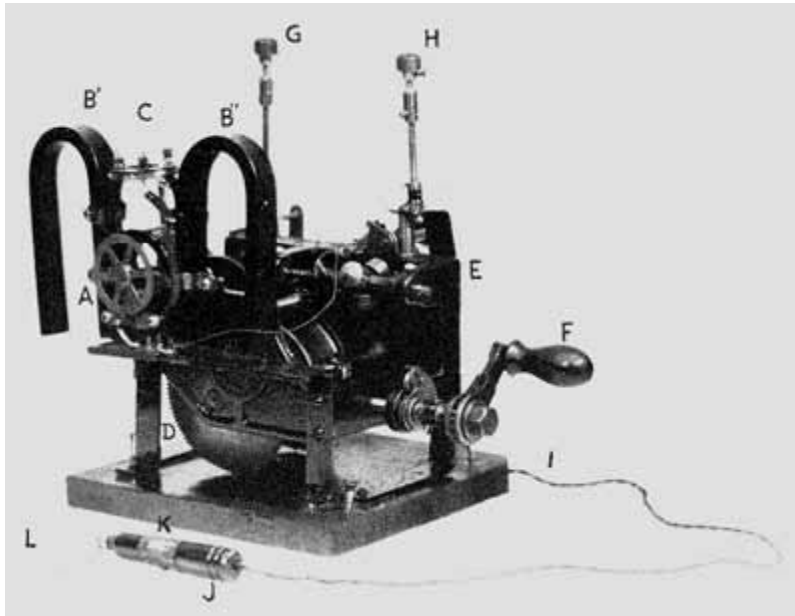
Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 8.

Two Schools of Thought

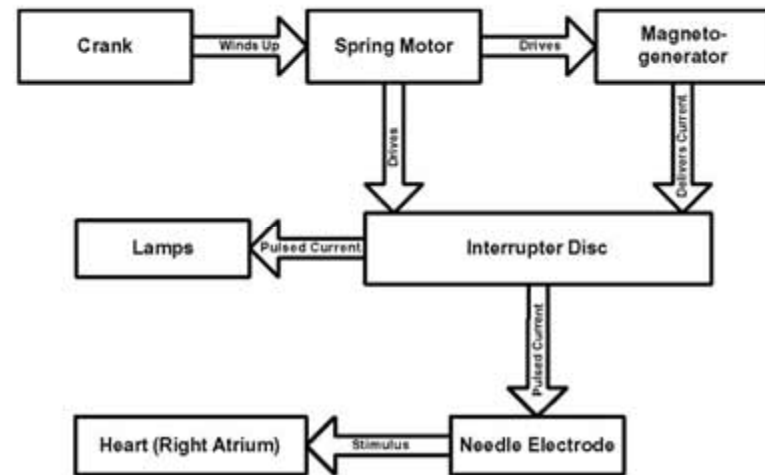
- *Current density theory*
- “The critical factor required to induce a regenerative wave front of depolarization is the **magnitude of current** flowing through a given mass of myocardium...”
- *Electric Field Theory*
- “The critical factor affecting myocardial depolarization is the **magnitude of the electric field** that is induced in the myocardium...”

History

Hyman's Pacemaker of 1932



Accompanying Flow Diagram



Flow Diagram of Hyman Pacemaker

Diagram detailing how the spring-wound Hyman pacemaker produced stimuli.

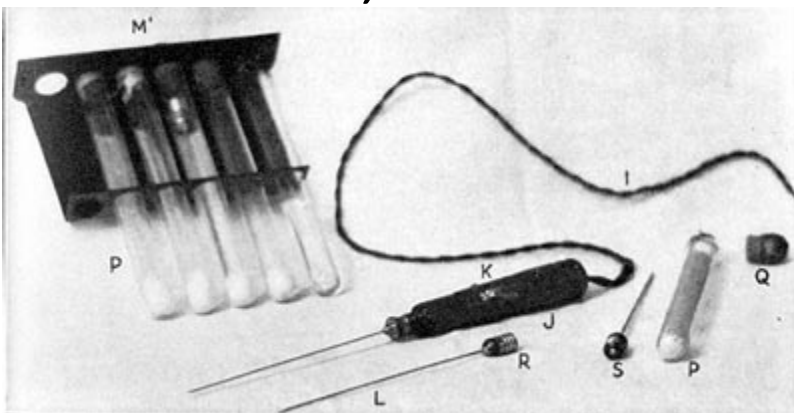
<http://www.hrsonline.org/News/ep-history/topics-in-depth/hymanspacemaker2.cfm>

Components

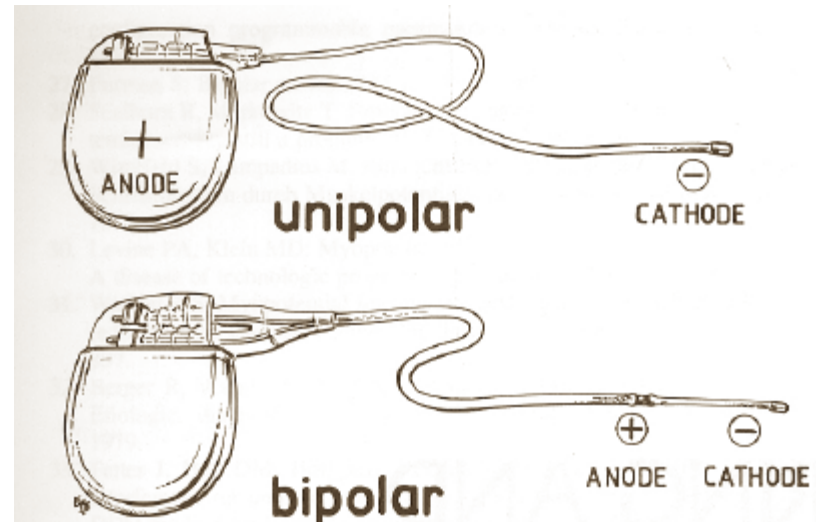
- Pacemaker Leads
- Pulse Generator
- Power Source (not discussed)

Pacemaker Leads

- “The leads are the only link between the sophisticated electronics in the pulse generator and the heart.”
- Relevant Issues: Polarization, electrode porosity, electrode composition, the electrode-tissue interface, etc.

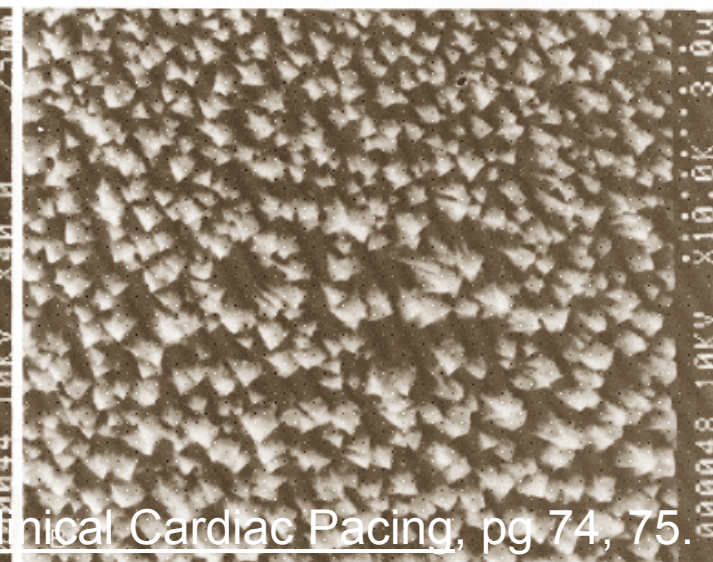
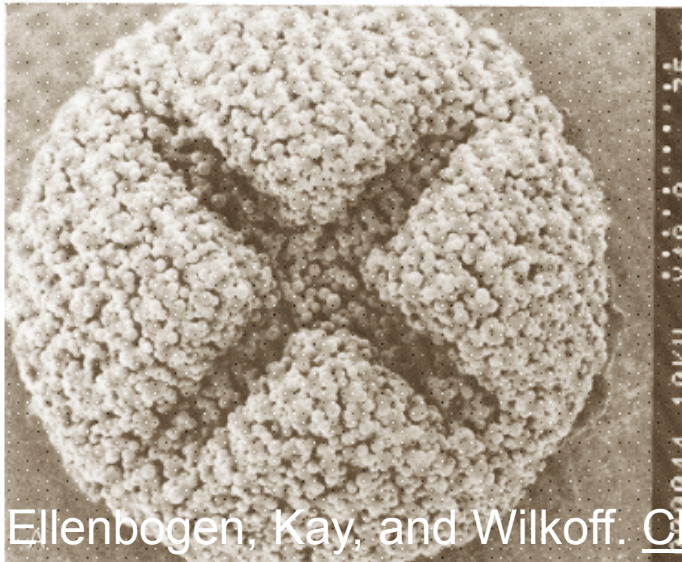
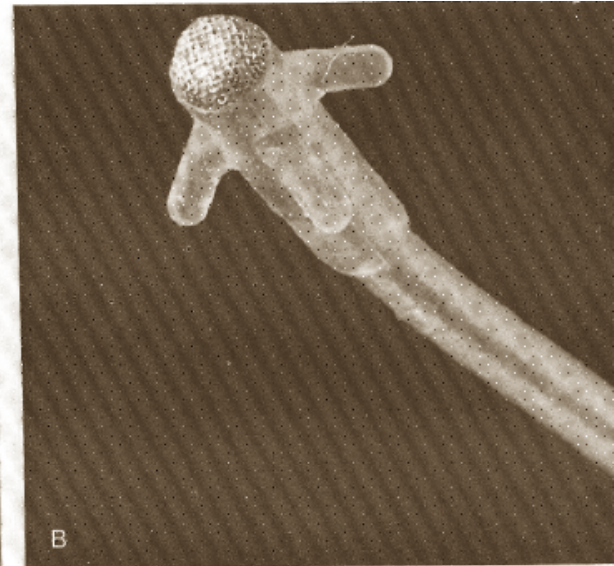
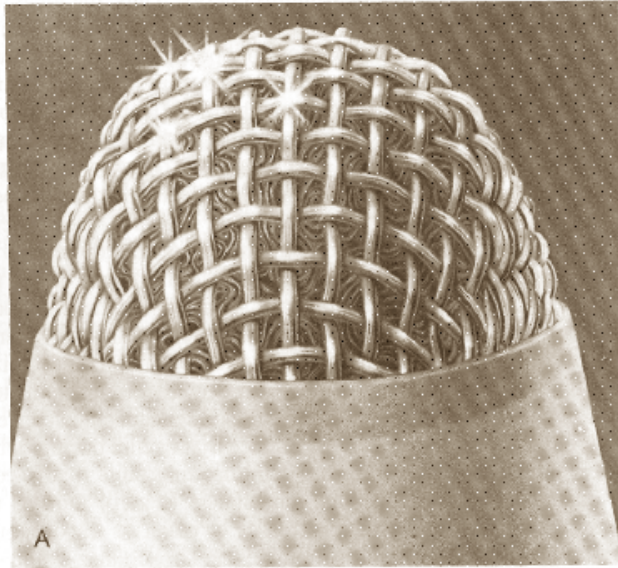


<http://www.hrsonline.org/News/ep...>



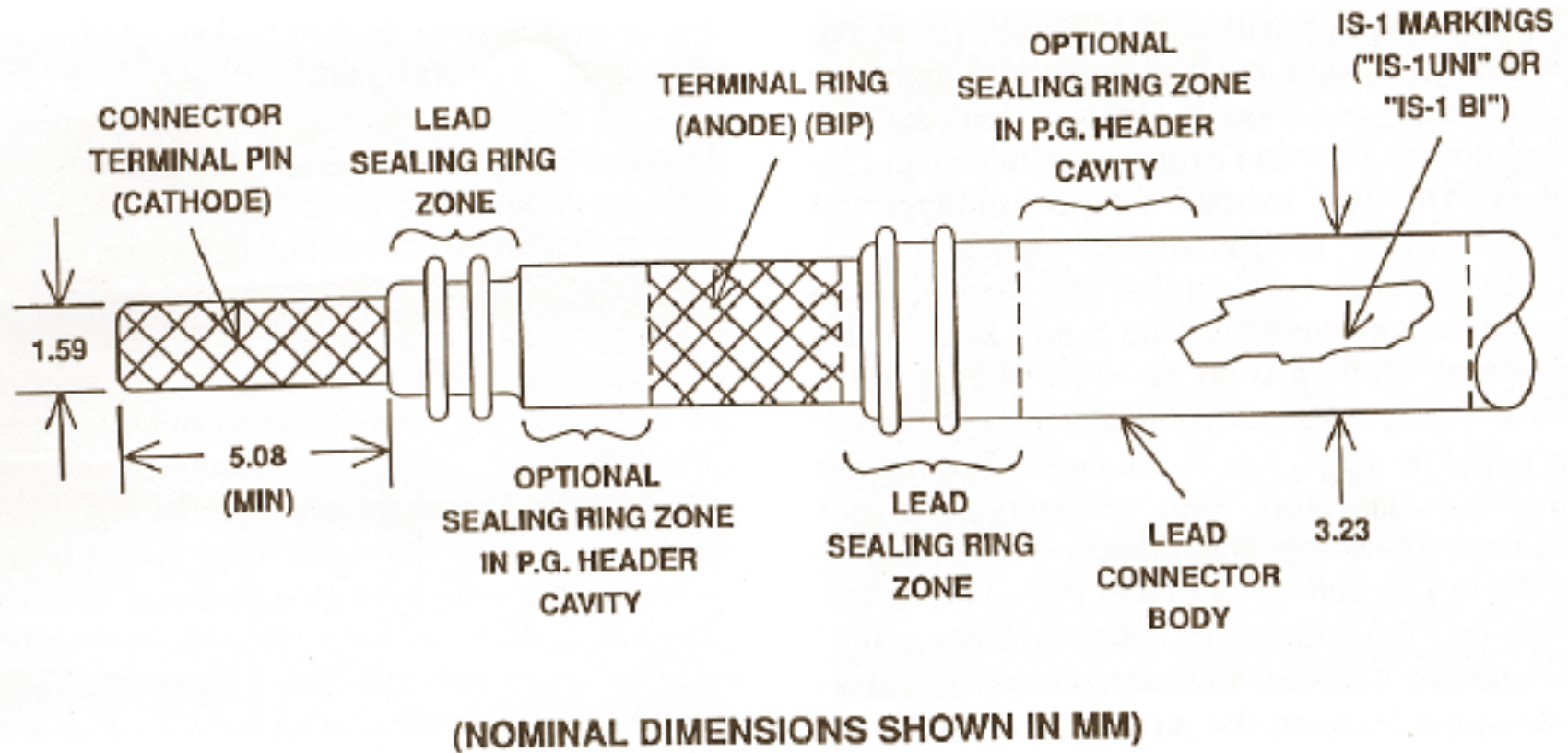
Clinical Cardiac Pacing, pg 70.

Pacemaker Leads



Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 74, 75.

Pacemaker Leads

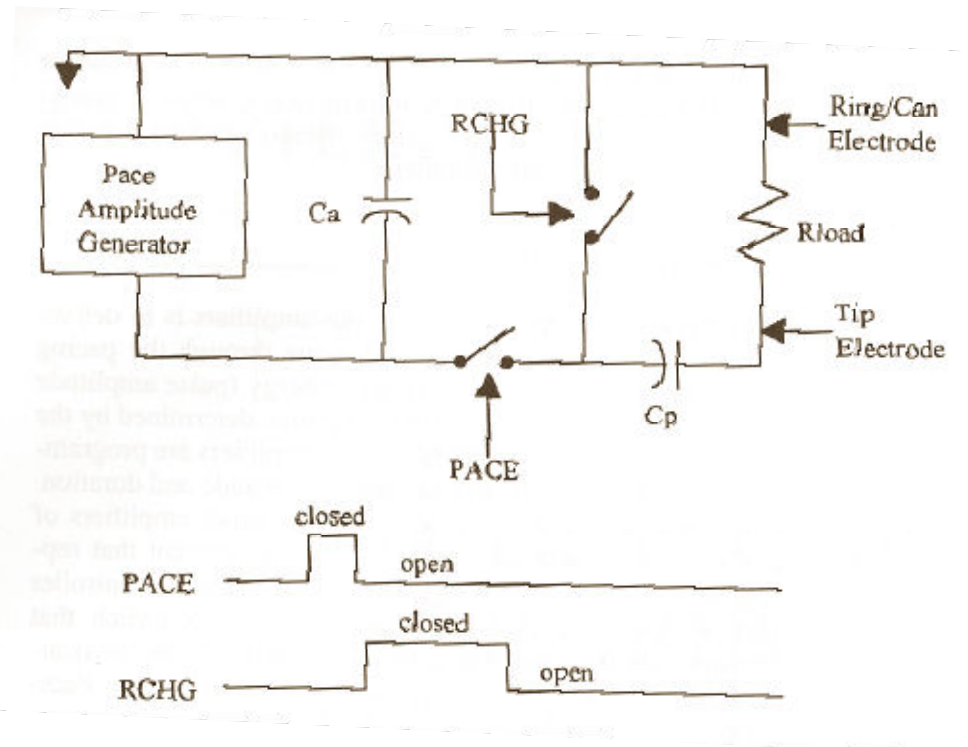
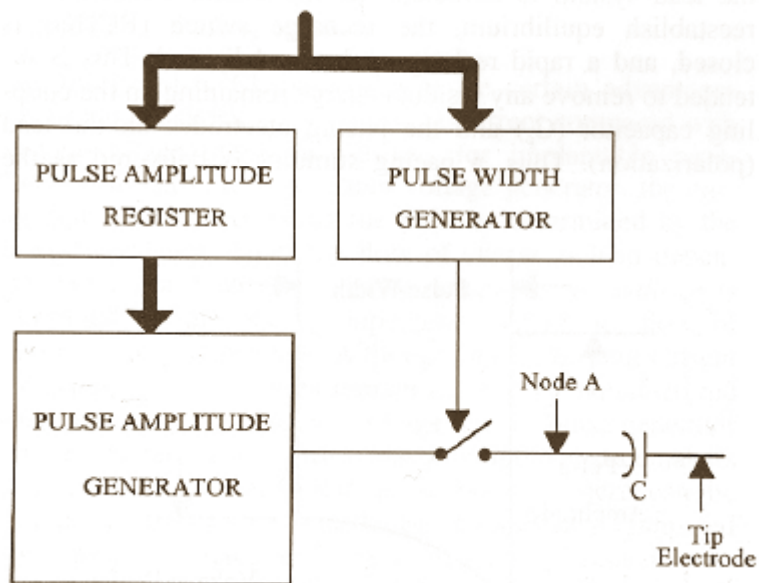


Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 86.

Pulse Generator

- Pacing therapy controller
- Output amplifiers
- Sense amplifiers
- Diagnostic subsystem

Pulse Generator



Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 113, 114.

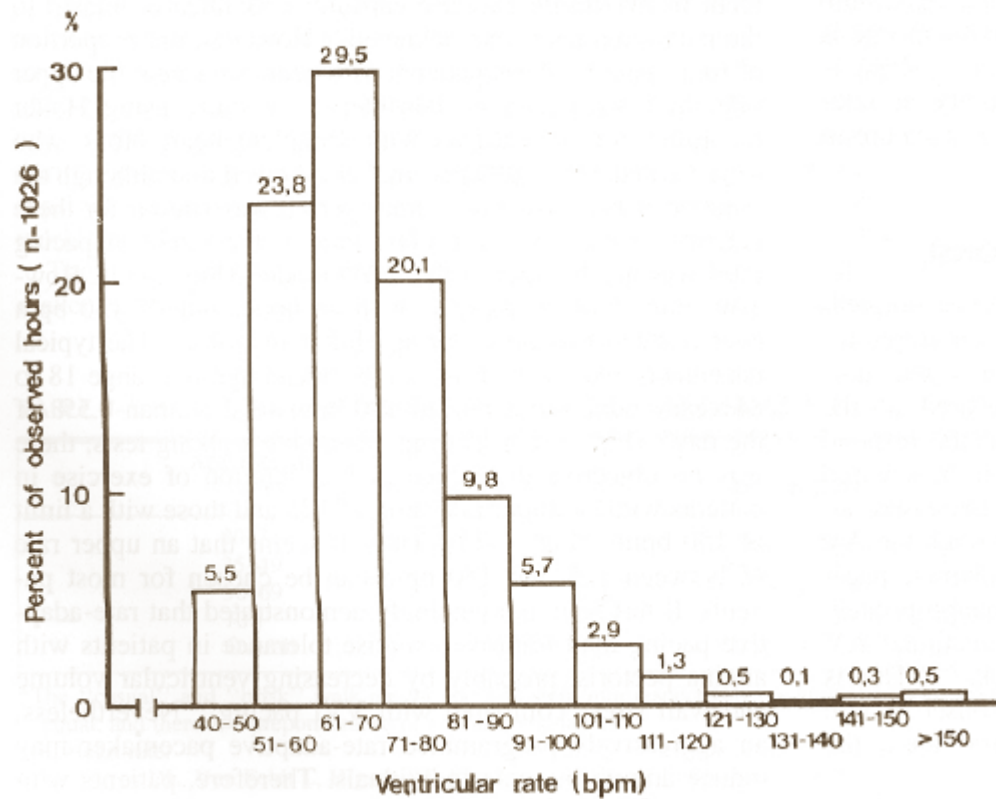
New Features

- Sensing
- Telemetry
- Improved SNR

Rate-Adaptive Sensors

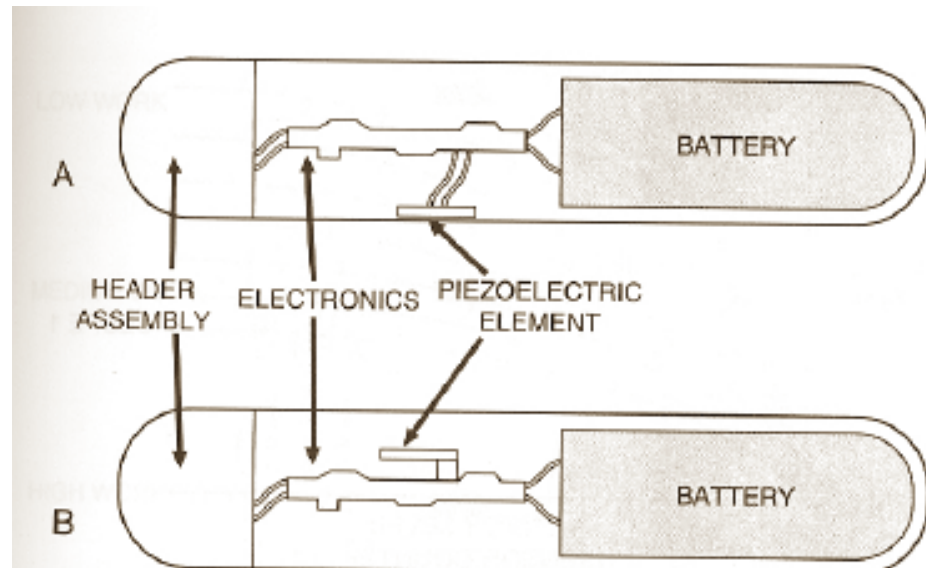
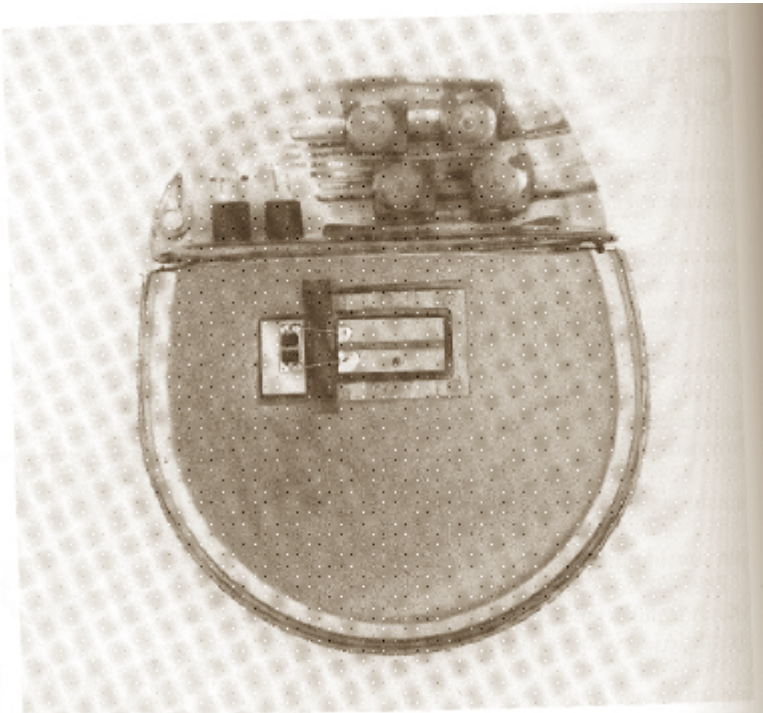
- Activity-Sensing Rate-Adaptive Sensors
- Rate-Modulated Pacing Controlled by Mixed Venous Oxygen Saturation
- Temperature-Controlled Rate-Adaptive Pacing
- Rate-Adaptive Pacing Controlled by Dynamic Right Ventricular Pressure (dP/dt_{max})
- Rate-Adaptive Pacing Based on Impedance-Derived Minute Ventilation, etc.

Rate-Adaptive Sensors



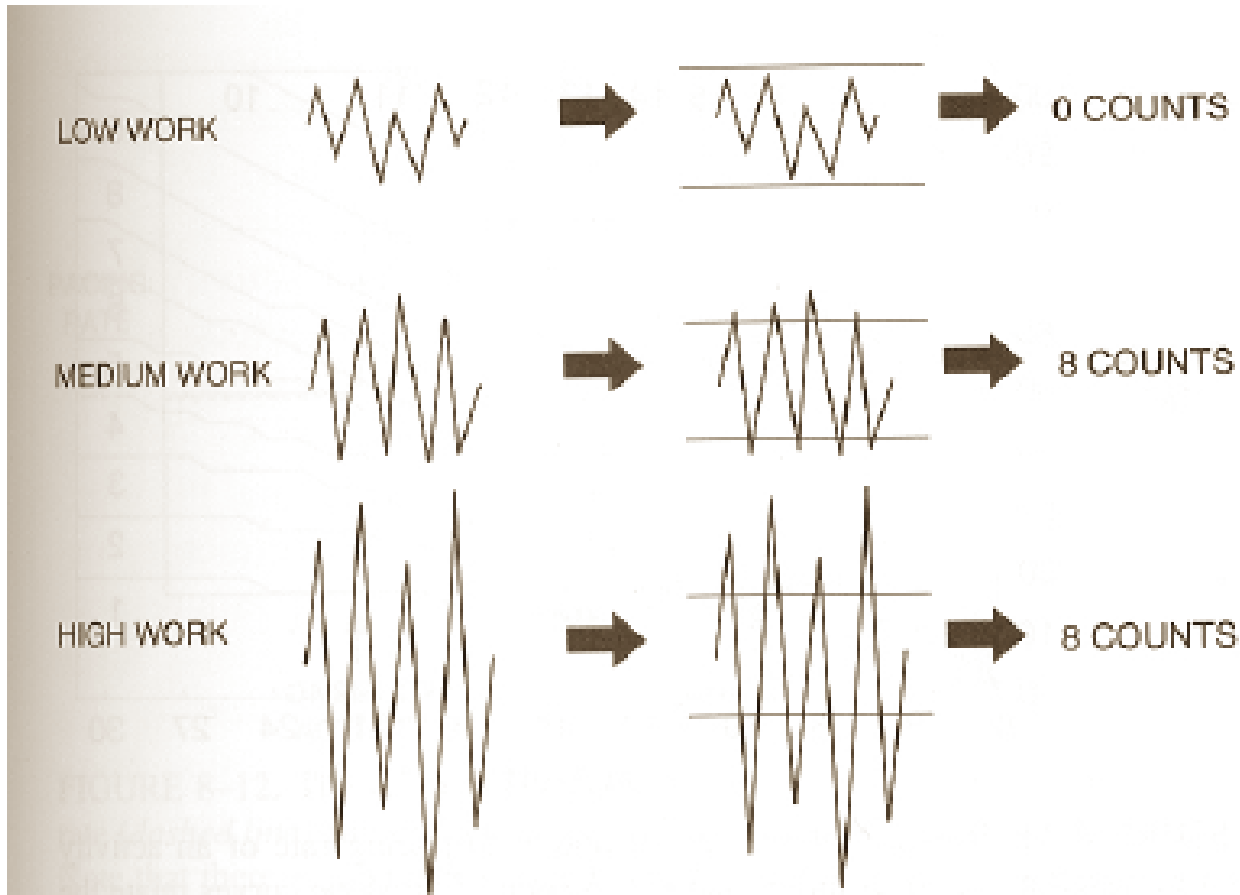
Kristensson, et al.

Activity-Sensing Sensors



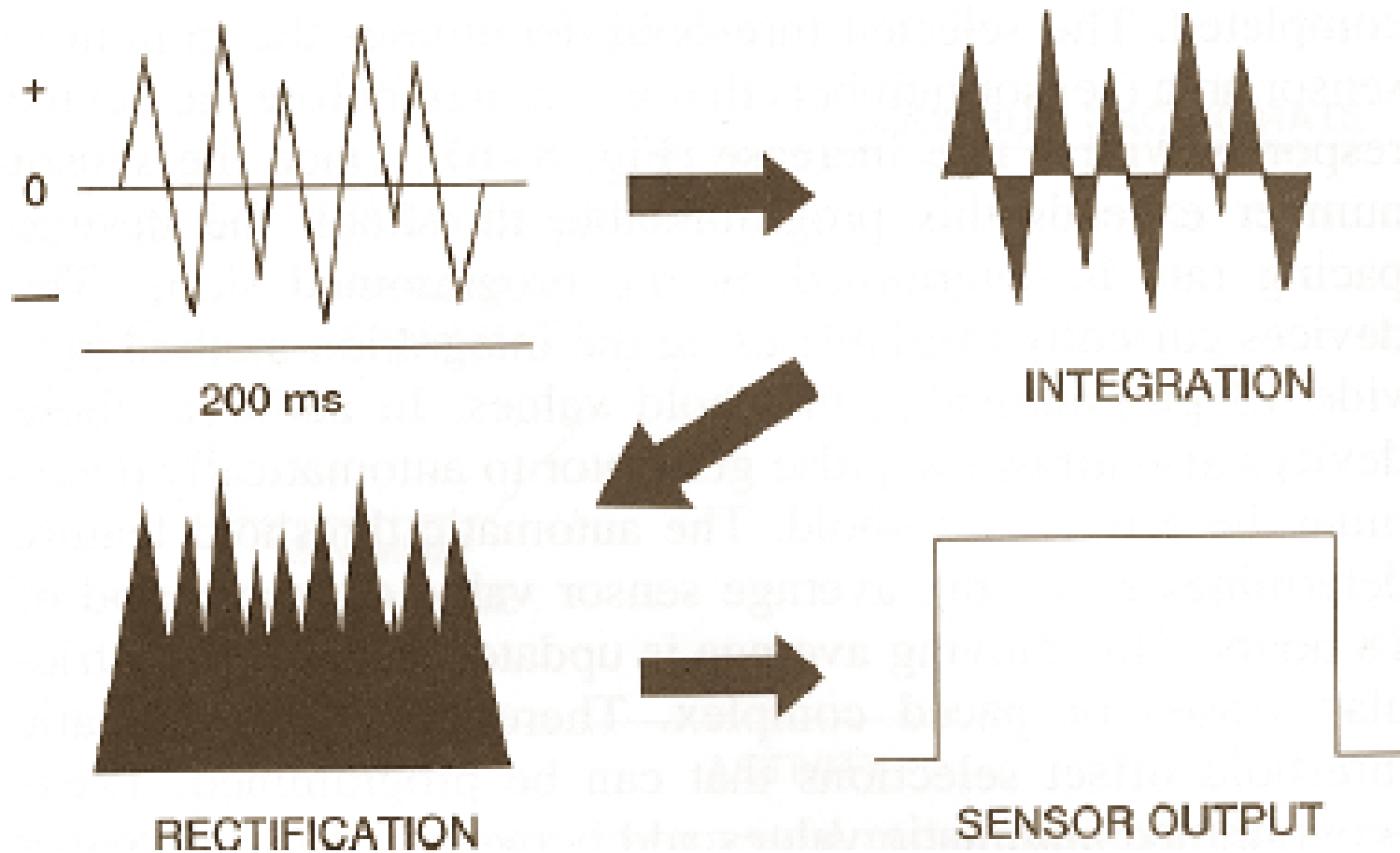
Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 168, 169.

Activity-Sensing Sensors



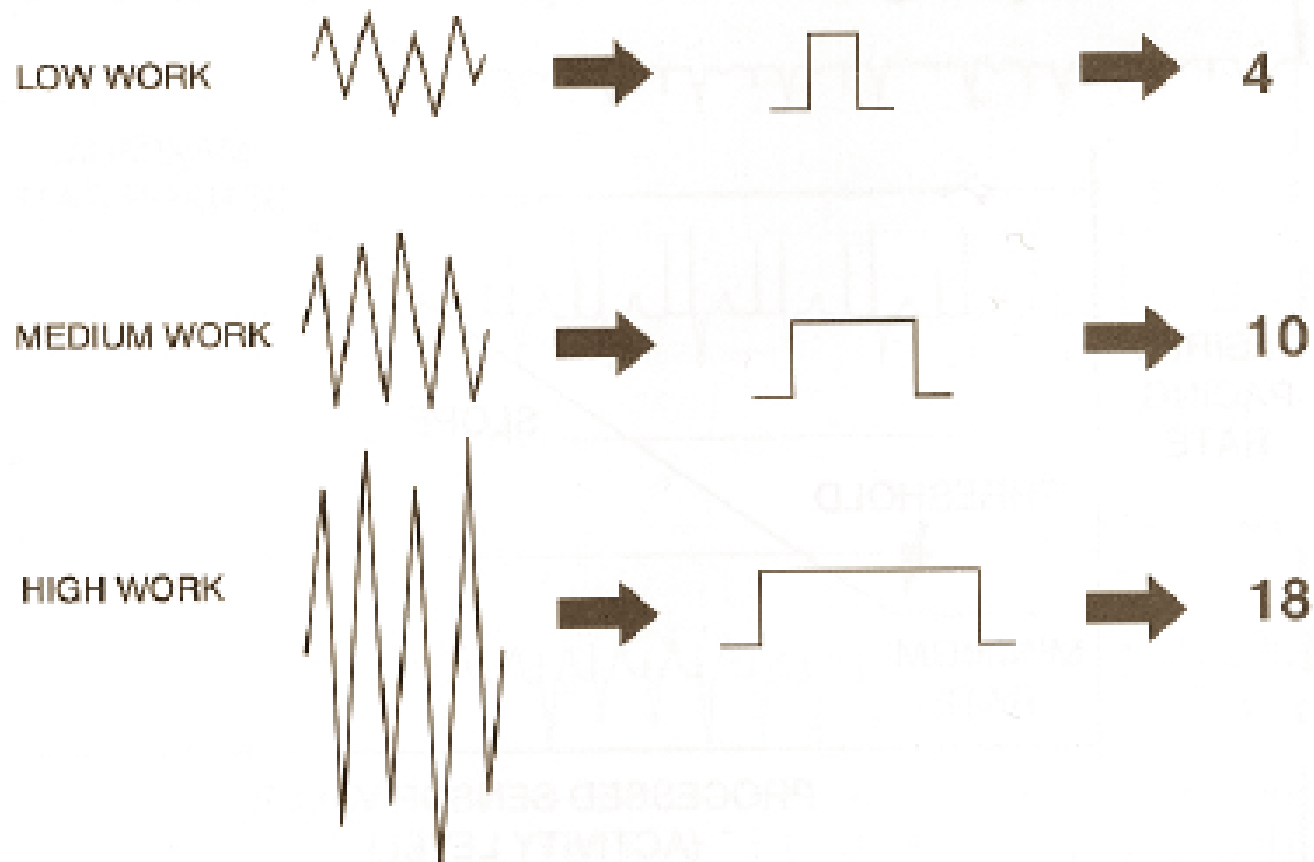
Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 171.

Activity-Sensing Sensors



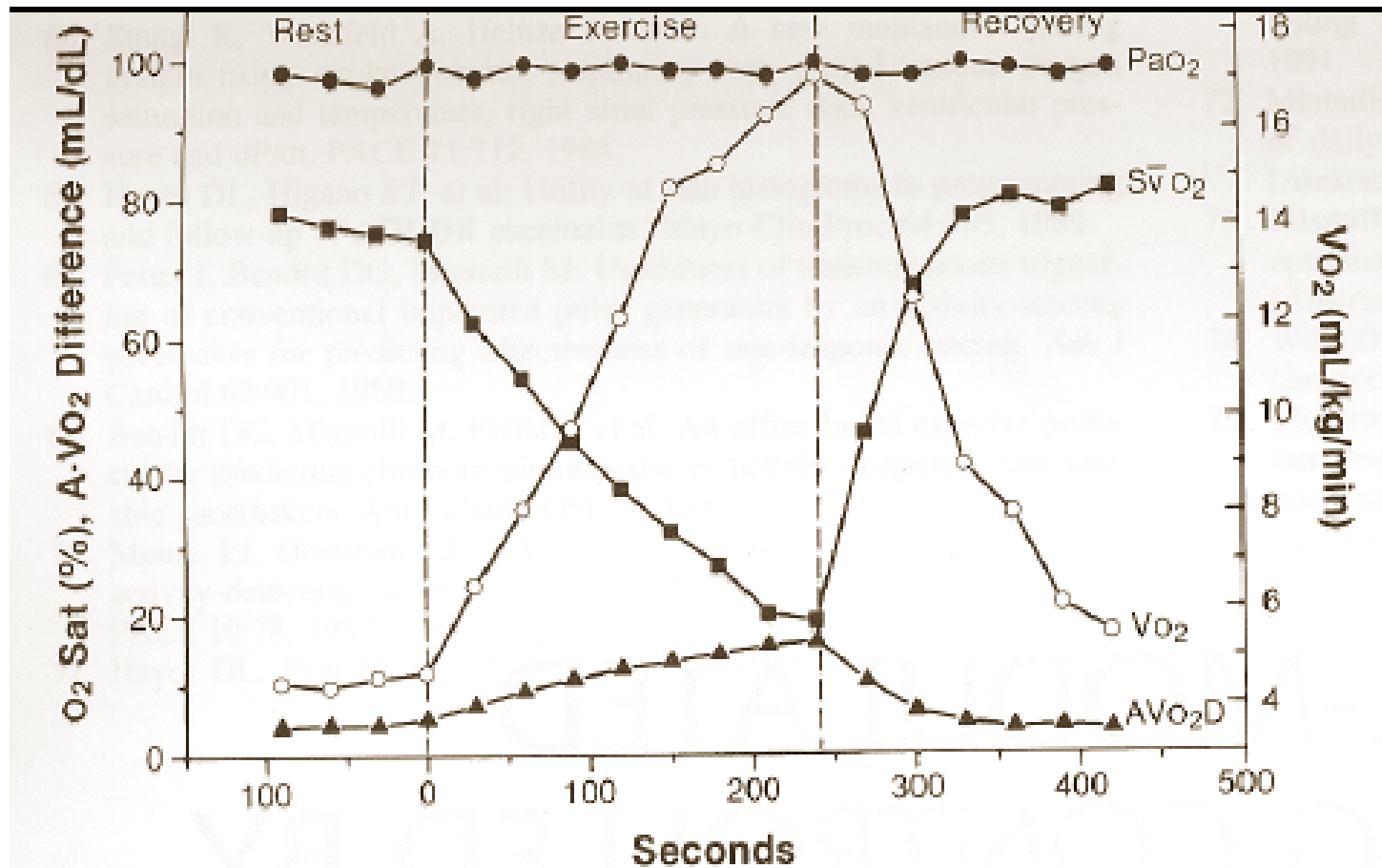
Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 171.

Activity-Sensing Sensors



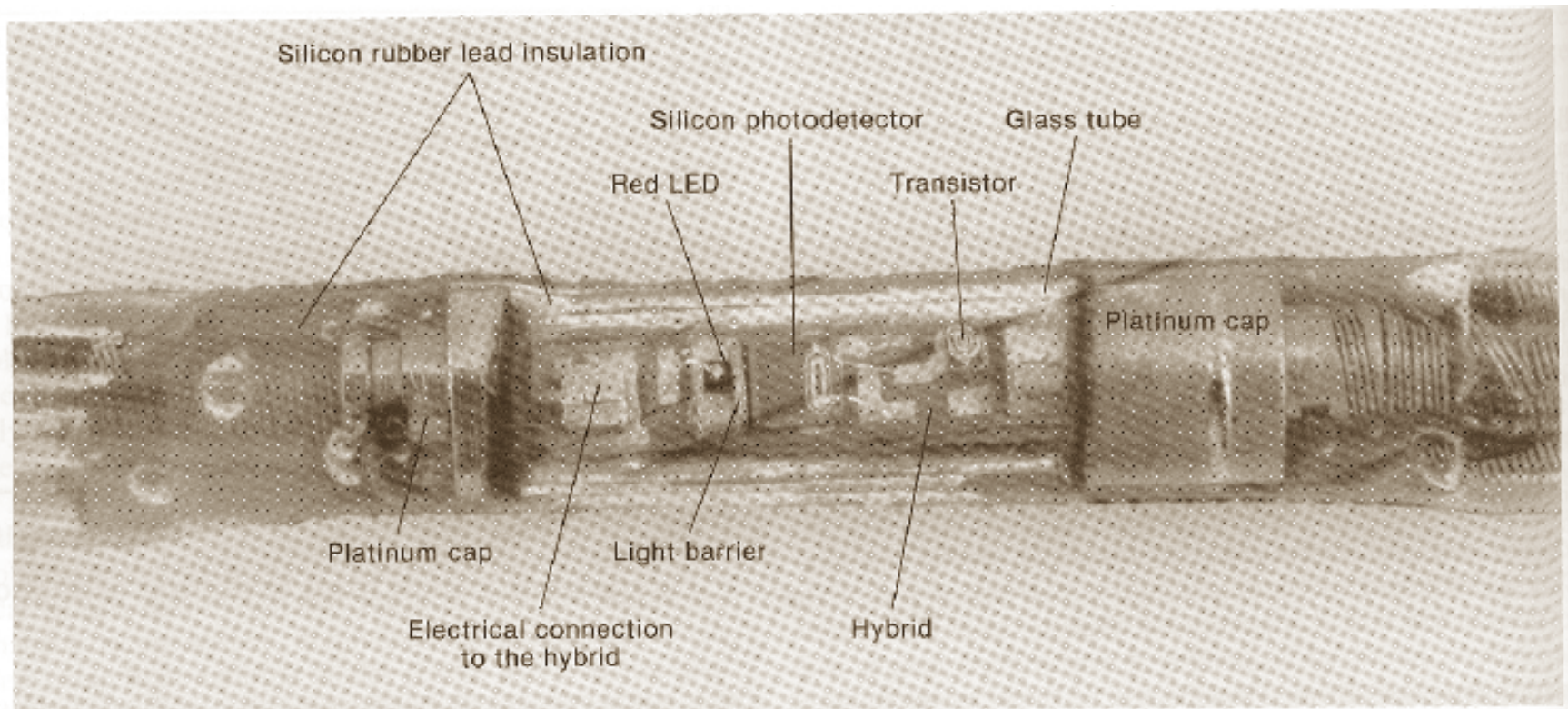
Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 171.

Rate-Adaptive Venous Oxygen Sensor



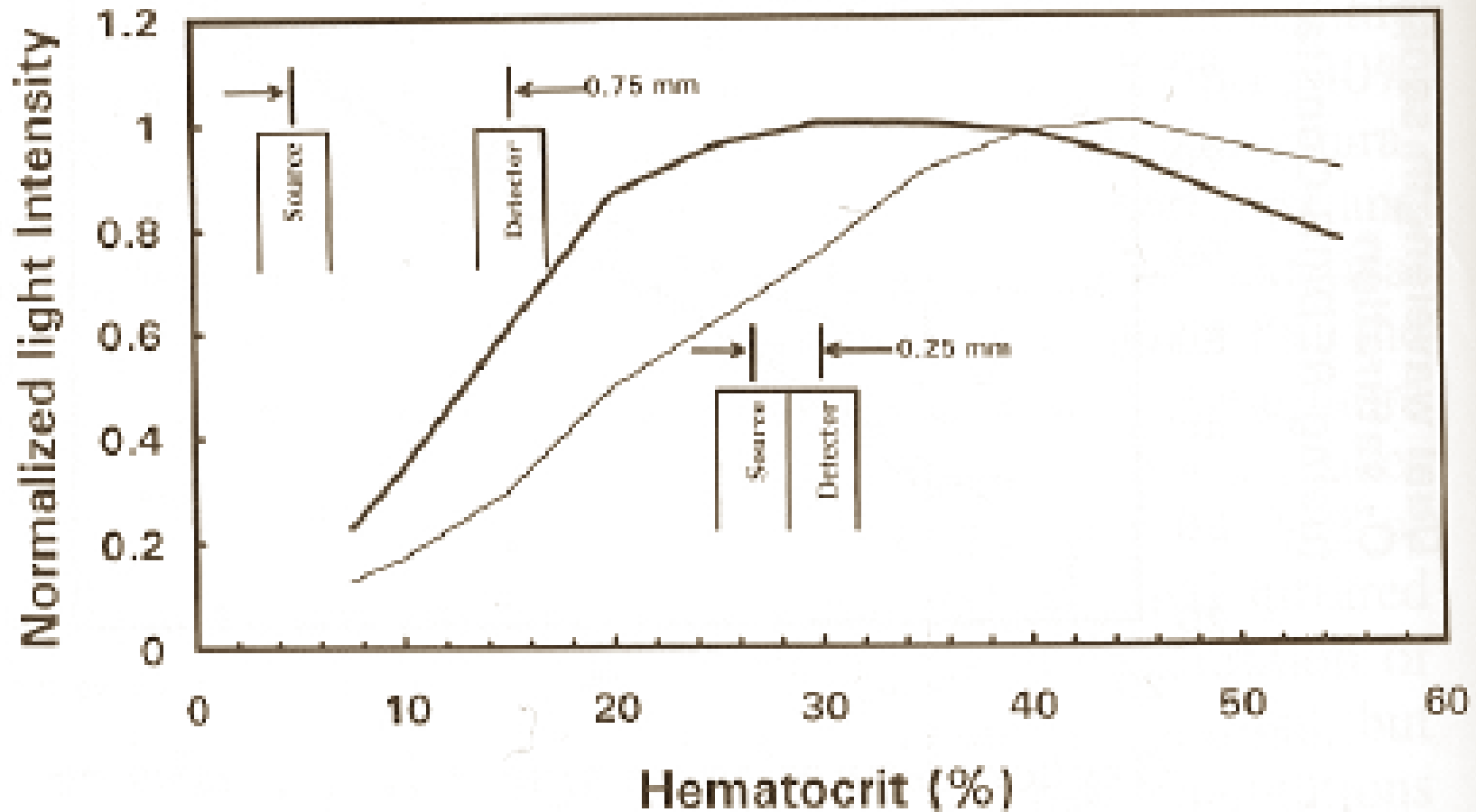
Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 188.

Rate-Adaptive Venous Oxygen Sensor



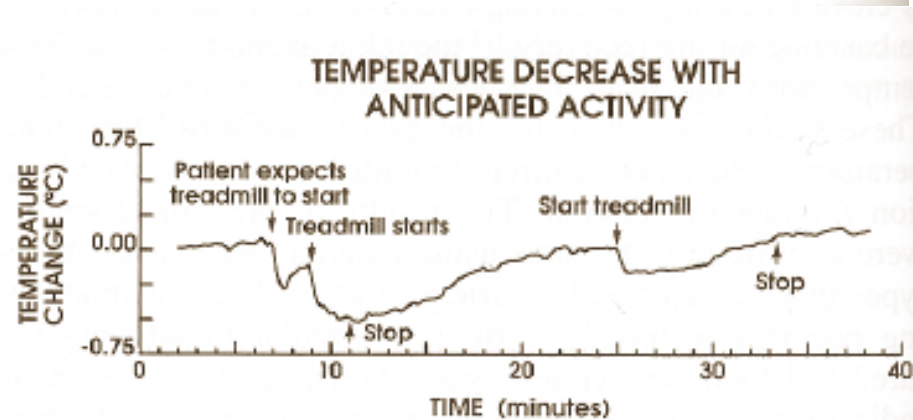
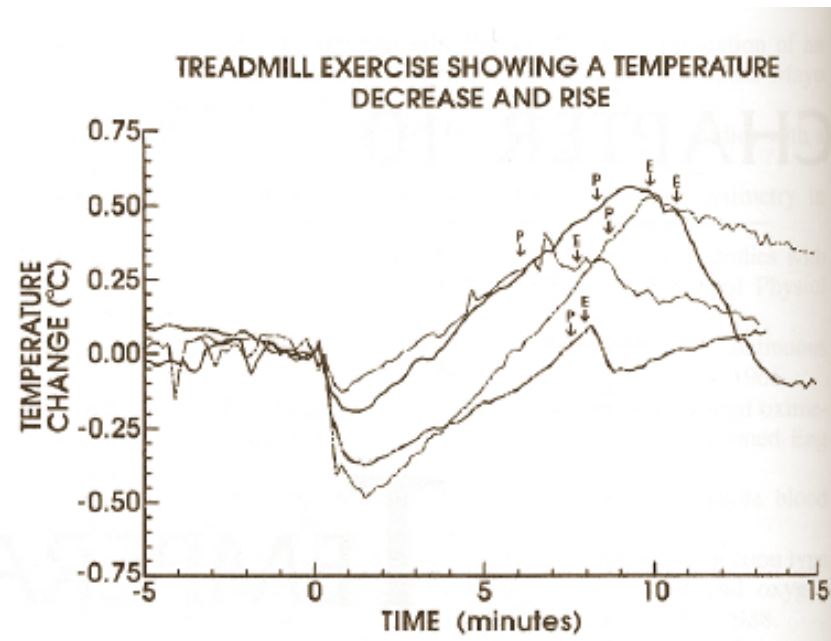
Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 192.

Rate-Adaptive Venous Oxygen Sensor



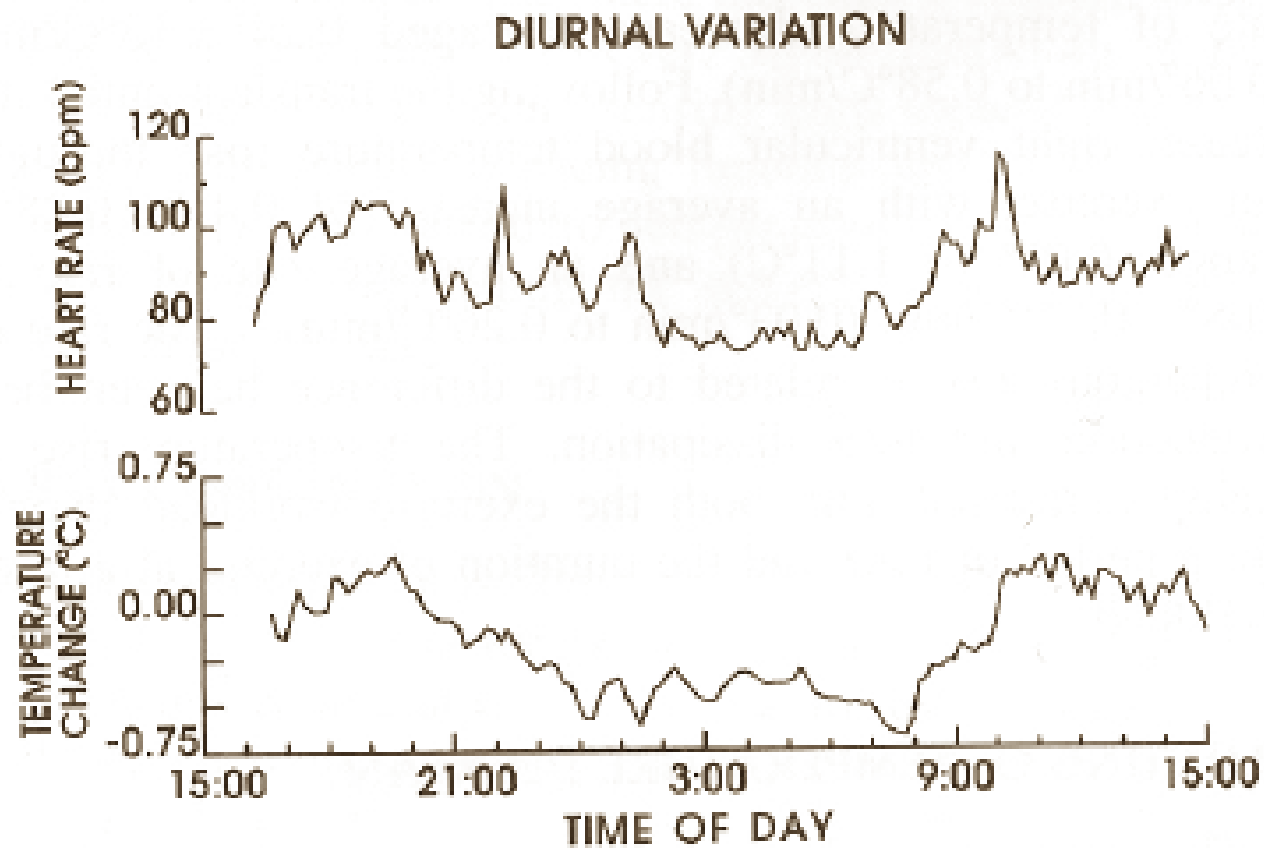
Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 192.

Temperature-Controlled Sensor



Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 202.

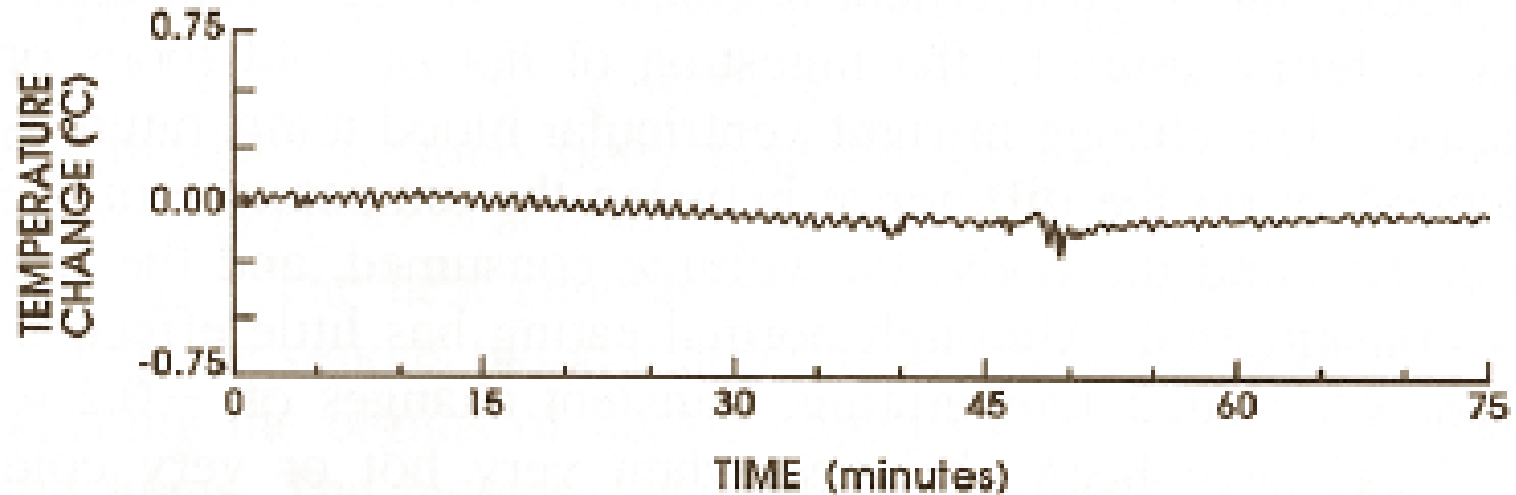
Temperature-Controlled Sensor



Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 203.

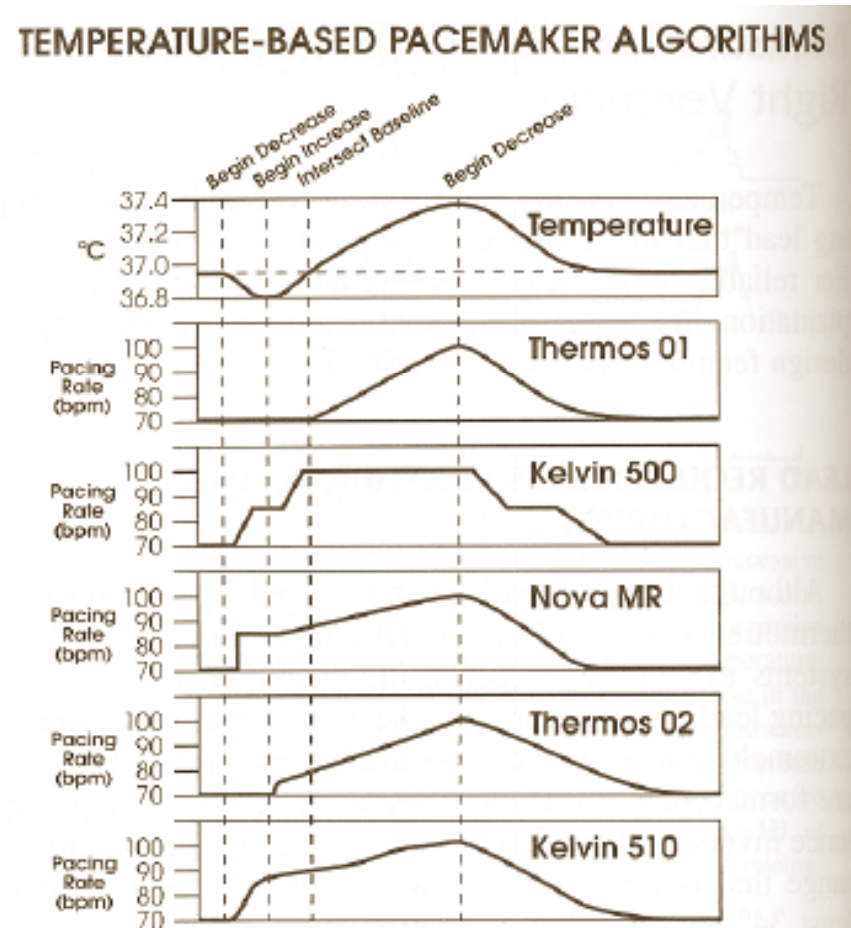
Temperature-Controlled Sensor

CYCLIC VARIATION DURING DEEP SLEEP



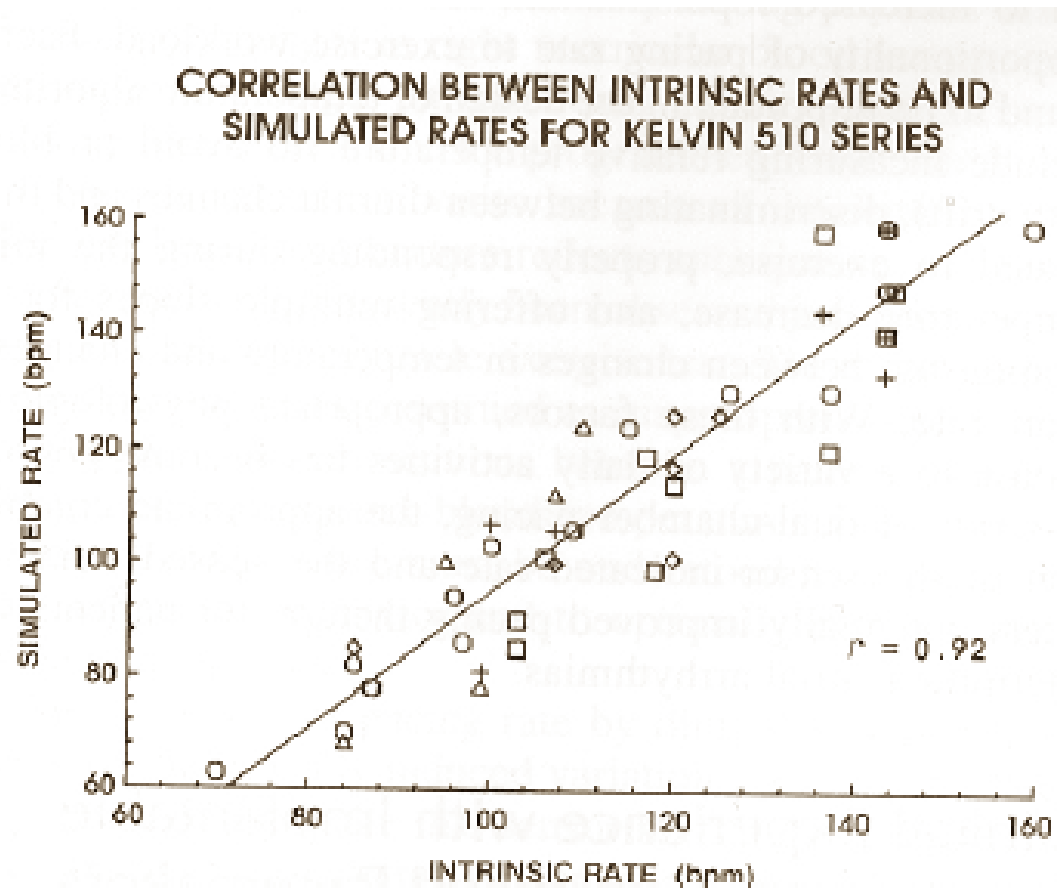
Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 203.

Temperature-Controlled Sensor



Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 206.

Temperature-Controlled Sensor



Fearnot, et al.

Manufacturer Overview

- Biotec, S.P.A., Bologna, Italy
- Biotronik, GmbH & Co., Berlin, Germany
- Cardiac Pacemakers Inc., St. Paul, MN
- Cook Pacemakers Corporation, Leechburg, PA
- Ela Medical, Rougermont, France
- Intermedics Inc., Angleton, TX
- Medtronic Inc., Minneapolis, MN

Manufacturer Overview

- Siemens Ltd., Solna, Sweden
- Sorin Biomedica, Saluggia, Italy
- St. Jude Medical, Inc, St. Paul, MN
- Telectronics Pacing Systems, Englewood, CO
- Vitatron Medical B.V., Dieren, The Netherlands.

Manufacturer Overview

METHODS	PHYSIOLOGIC PARAMETERS	EXAMPLES	
		MODELS	MANUFACTURERS
Impedance sensing	Respiratory rate Minute ventilation	Biorate Meta Chorus RM Legend plus Precept	Biotec Telectronics Ela Medical Medtronic Inc. CPI
	Stroke volume, prejection period, right ventricular ejection time		
Ventricular evoked response and output pulse parameter sensing	Evoked QT interval Evoked R-wave area ("gradient") Trailing edge of output pulse	TX, Quintech, Rhythmx Prism CL	Vitatron Telectronics
Vibration sensing	Body movement	Activitrax, Legend Sensolog, Sensorhythm Relay, Dash Excel Ergos Swing	Medtronic Inc. Siemens Intermedics CPI Biotronik Sorin
Special sensors on pacing electrode	<i>Physical Parameters</i> 1. Central venous temperature	Kelvin 500 Nova MR Thermos Model 2503 RS4	Cook Pacemakers Intermedics Biotronic Medtronic Inc. CPI
	<i>Chemical Parameters</i> 1. pH 2. Mixed venous oxygen saturation 3. Catecholamine levels		Medtronic Inc. Siemens

Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 144.

Telemetry

- “Telemetry involves the transmission of information from the pulse generator to an external programmer.”
- Battery voltage and impedance, stimulus current, voltage, and energy, lead resistance, intracardiac electrograms, and stored histograms of pace and sensed data retrievable from telemetry

Telemetry



Biotronik Home Monitoring®

Transmitters

Transmitter 1-9 of 9

Search Display 10 20 50 1-9 of 9

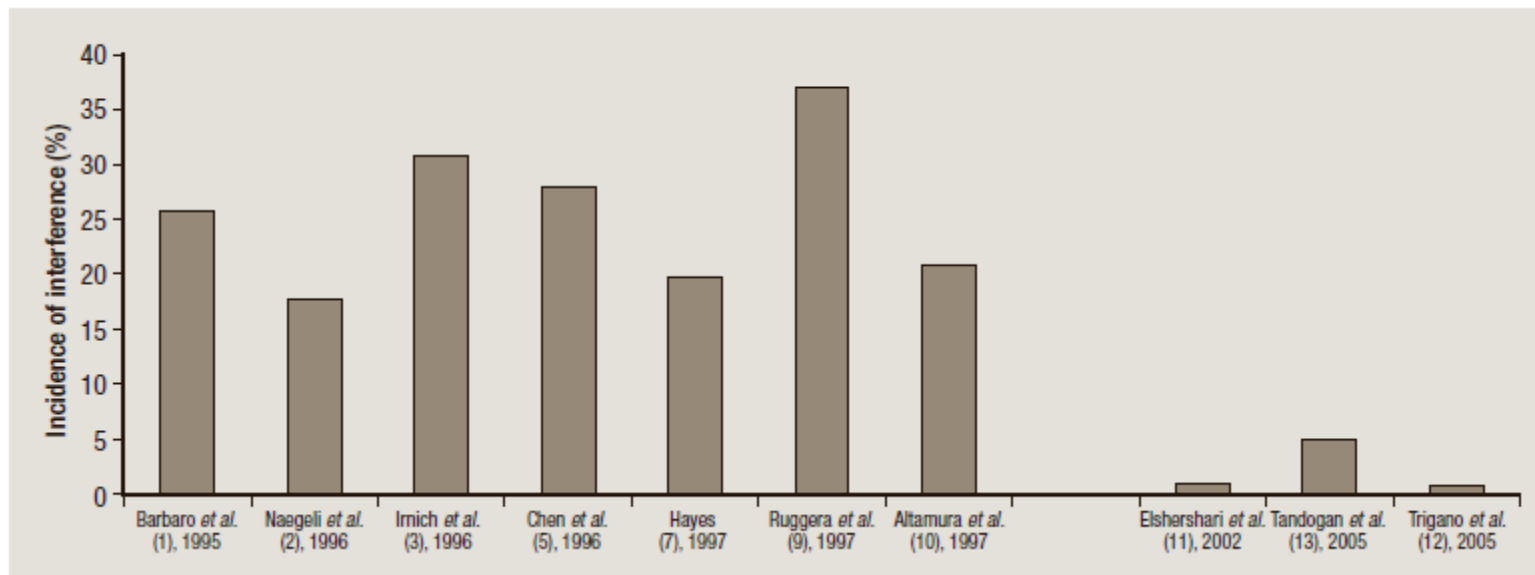
Transm. SN	Patient ID (last Message)	Implant SN (last Message)	Last message	Callback	
44846216	Anne Coldren	79883093	Aug 08, 2005 08:59 AM	<input type="button" value="✕ Cancel request"/>	Request by Dr. Max Mustermann on 01/24/2006
44846226	Bill Mahoney	79883094	Aug 04, 2005 6:39 PM	ON	LED ON until 01/27/2006
44846319	David Labraccio	79883095	May 11, 2004 06:50 AM	<input type="button" value="✓ Request callback"/>	
44846218	Martin Lorence	79883277	Feb 21, 2004 06:50 AM	<input type="button" value="✓ Request callback"/>	
44846316	Jefferson Langley	79884001	Aug 04, 2003 6:39 PM	<input type="button" value="✓ Request callback"/>	
44846317	Joe Hurley	79884012	Jul 15, 2003 11:58 AM	<input type="checkbox"/>	
44846221	Nelson Hings	79884018	Aug 08, 2002 08:59 AM	<input type="checkbox"/>	
44846516			Feb 21, 2002 06:50 AM	<input type="button" value="✓ Request callback"/>	
44846512			Jul 15, 2001 11:58 AM	<input type="checkbox"/>	

Medtronic CareLink® Network Monitoring Device



Improving SNR

- Federica Censi, et al. studying the effects of electromagnetic interference on pacemakers.



- RF feedthrough filters

References

- Ellenbogen KA, Kay GN, Wilkoff BL. Clinical Cardiac Pacing. W.B. Saunders Company. Philadelphia. 2005. pg 3—276.
- Fearnot, NE et al. Heart Rate Correlation, response time, and effect of previous exercise using advanced pacing rate algorithm for temperature-based rate modulation. PACE (11): 1846-1852, 1988.
- Kristensson B, et al. Holter-monitored heart rhythm during atrioventricular synchronous and fixed-rate Ventricular pacing. PACE (9): 511, 1986.
- Censi, F, et al. Interference between mobile phones and pacemakers: a look inside. Ann Ist Super Sanita, 2007. Vol. 43, 3: 254—259.
- Hayes, DL and Vliestra RE. Pacemaker Malfunction. Ann Internal Medicine. 1993; 119: 828—835.