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# Introduction to Biomedical Engineering Cardiac Bioelectricity

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## Part 7. Cardiac implantable devices

<http://efimov.cwru.edu/teaching>

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## References

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Handouts and slides are at my WEB-site:

<http://efimov.cwru.edu/teaching>

Username: member

Password: member

Homework reading: Terence D. Valenzuela, et al, Outcomes of Rapid Defibrillation by Security Officers after Cardiac Arrest in Casinos, Volume 343:1206-1209, 2000



## Approaches to the Heart Disease Therapy

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- Healthy life-style and diet: the best, but often too late :o(
  - Invasive therapy: cardiac surgery, angioplasty or ablation procedure: excellent outcome, but not always possible :o(
  - Pharmacological (drug) antiarrhythmic therapy: a chain of disappointments in clinical trials of 1980-90s...
  - Device therapy: impressive results, yet still has unresolved questions...
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## Types of Implantable Devices

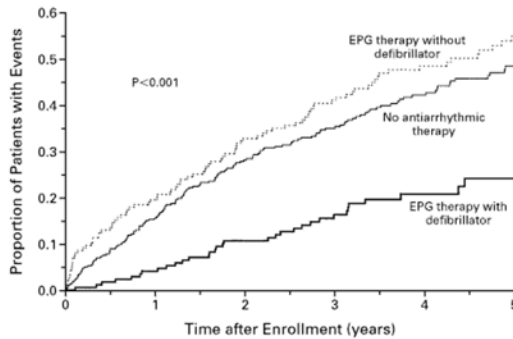
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- Fully implantable artificial heart (replaces the heart)
  - Left ventricular assist device (takes over part of the function)
  - Implantable pacemaker (controls heart rhythm)
  - Implantable defibrillator (jump-starts the heart in case of cardiac arrest)
  - Implantable ECG monitors (precise diagnostics of rare events)
  - Implantable drug delivery systems (yet to be produced)
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## Kaplan–Meier Estimates of the Rates of Overall Mortality According to Whether the Patients Received Treatment with a Defibrillator



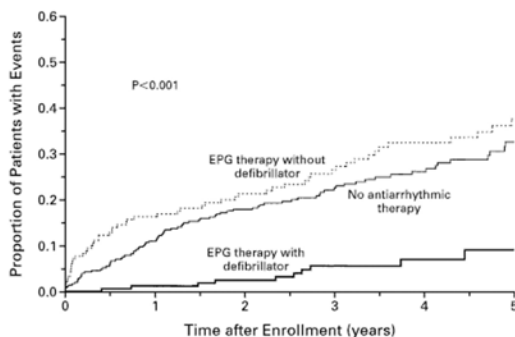
The P value refers to two comparisons: between the patients in the group assigned to electrophysiologically guided (EPG) therapy who received treatment with a defibrillator and those who did not receive such treatment, and between the patients assigned to electrophysiologically guided therapy who received treatment with a defibrillator and those assigned to no antiarrhythmic therapy.

Buxton et al, New Engl J Med, Volume 341:1882-1890, 1999

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## Kaplan–Meier Estimates of the Rates of Cardiac Arrest or Death from Arrhythmia According to Whether the Patients Received Treatment with a Defibrillator



The P value refers to two comparisons: between the patients in the group assigned to electrophysiologically guided (EPG) therapy who received treatment with a defibrillator and those who did not receive such treatment, and between the patients assigned to electrophysiologically guided therapy who received treatment with a defibrillator and those assigned to no antiarrhythmic therapy.

Buxton et al, New Engl J Med, Volume 341:1882-1890, 1999

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## Cardiac implantable devices

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- Implantable Pacemaker (treatment of bradycardia)
  - Implantable Cardioverter Defibrillator (treatment of tachycardia and fibrillation)
  - ECG Loop Recorders (Implantable Holter monitor)
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## Indications for Implantable Cardiac Pacemaker

- Complete Heart Block (AV node does not conduct impulses)
- Sinus Bradicardia (slow SA node)
- Following AV node ablation (treatment for atrial arrhythmias)

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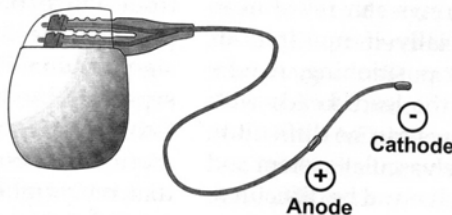


## Unipolar and bipolar pacing

**Unipolar**



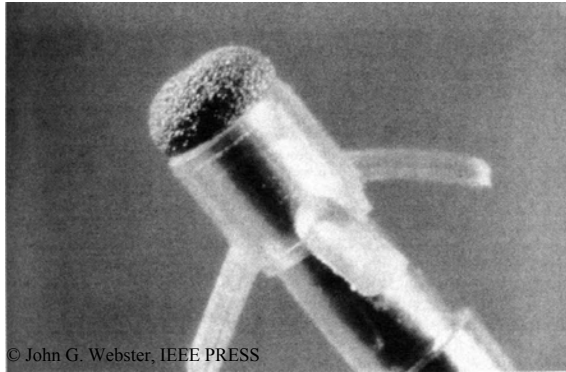
**Bipolar**



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## Passive Implantable Lead

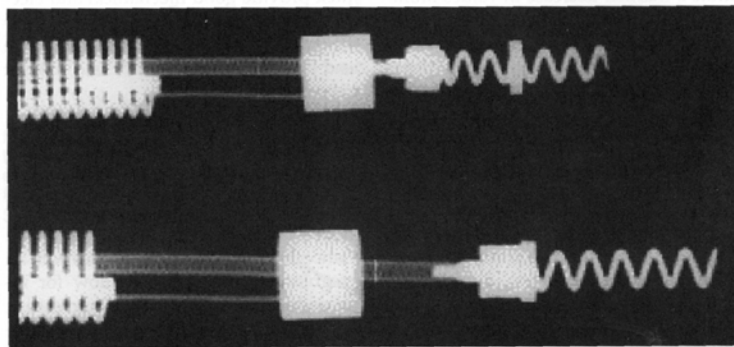


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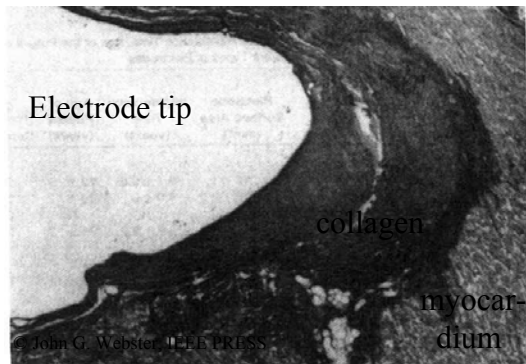
## Active Fixation Pacing Lead



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## Encapsulation of implantable lead results in additional resistive isolation of the lead

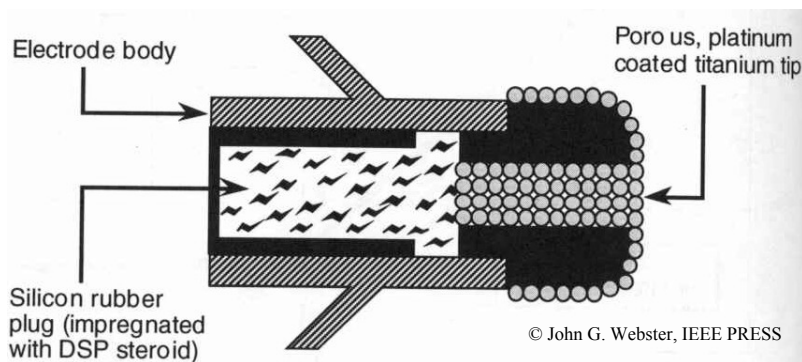


Implantation causes local inflammation process, which results in collagen network formation around implantable lead. Worsening of sensing and pacing efficacy results.

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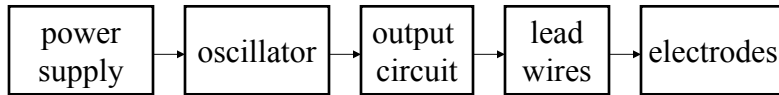
## Steroid-eluting lead design is used to prevent inflammation and resulting encapsulation



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## Asynchronous cardiac pacemaker (VOO)



Constant voltage pacing:  $\sim 5.0$  V,  $\sim 0.5$  msec

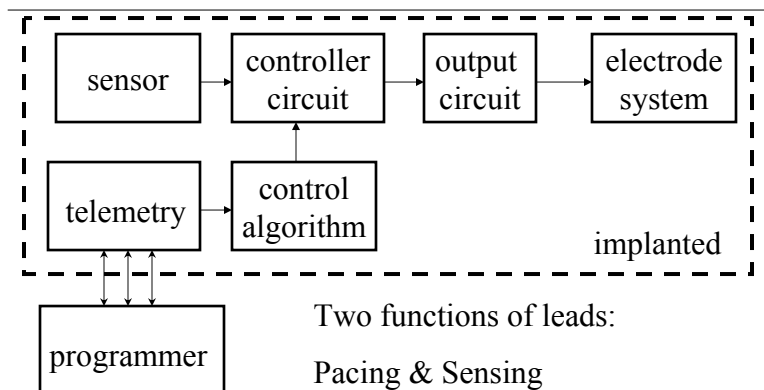
Constant current pacing:  $\sim 10$  mA,  $\sim 1$  msec

Rate: 60-150 bpm

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## Rate-responsive pacemaker (DDDR)



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## Pacemaker Nomenclature (NBG Code)

I	II	III	IV
Chamber(s) paced	Chamber(s) sensed	Response to sensing	Programmability, rate modulation
O = None	O = None	O = None	O = None
A = Atrium	A = Atrium	T = Triggered	P = Simple programmable
V = Ventricle	V = Ventricle	I = Inhibited	M = Multiprogrammable
D = Dual (A+V)	D = Dual (A+V)	D = Dual (T+I)	C = Communicating R = Rate modulation

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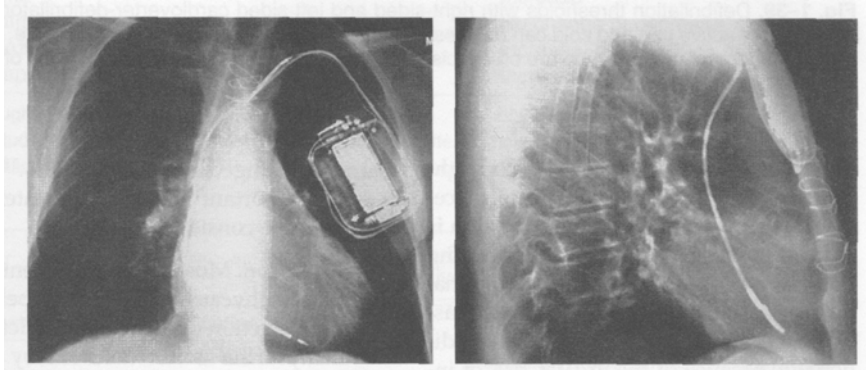
## Examples

- VVIR – Pace ventricle, sense ventricle, inhibit on sensed beat, rate responsive (problems with atrium)
- DDDR – Pace both chambers, sense both chambers, inhibit on V or trigger on A, rate responsive (problem with AV node)
- AAIR – pace atrium, sense atrium, inhibit on sensed beat, rate responsive (problems with low atrial signal)

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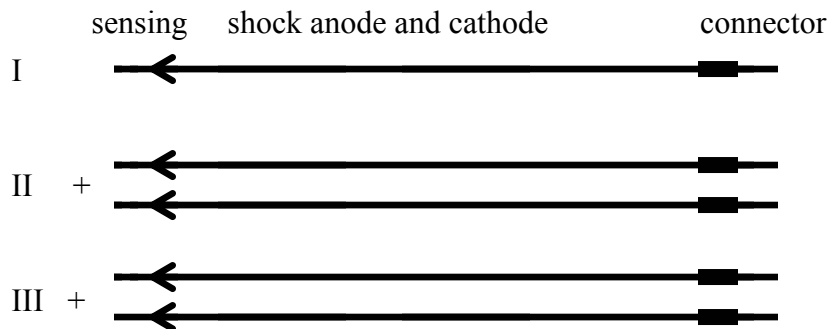
## Implantable cardioverter-defibrillator



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## Three types of ICD lead configurations:



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## Indications for Implantable Cardioverter-Defibrillators (ICD)

- History of Ventricular Tachycardia (VT)
- History of Ventricular Fibrillation (VF)

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- Defibrillation: Application of a large electric shock to terminate VF and reset normal sinus rhythm
  - Cardioversion: Application of a large appropriately synchronized electrical shock to terminate VT and reset normal sinus rhythm

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## Important Considerations

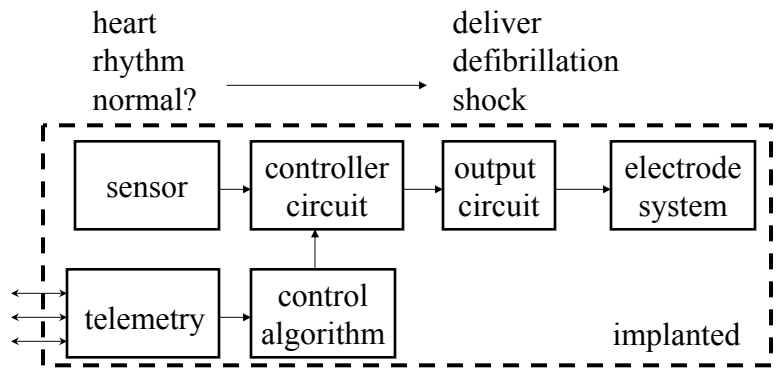
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- Most people will not survive the first episode of VT/VF  $\Rightarrow$  better methods are needed to identify people at risk of sudden cardiac death !!!
  - 50% chance of surviving second episode without ICD
  - 98% chance of survival the second episode with ICD

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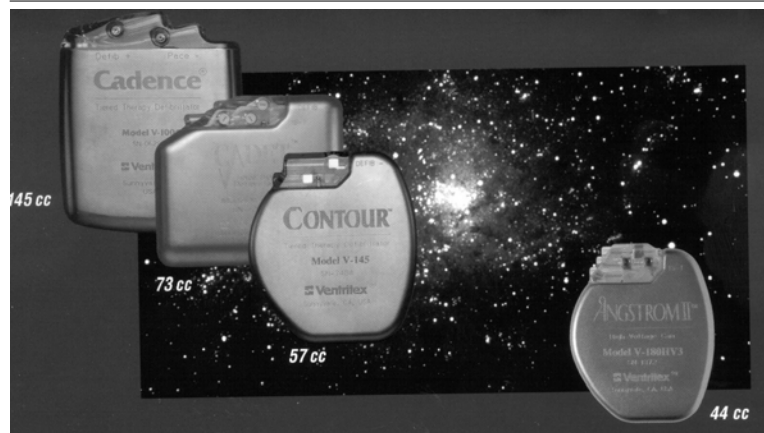
# Implantable Defibrillator



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## ICD development during 1980-2000



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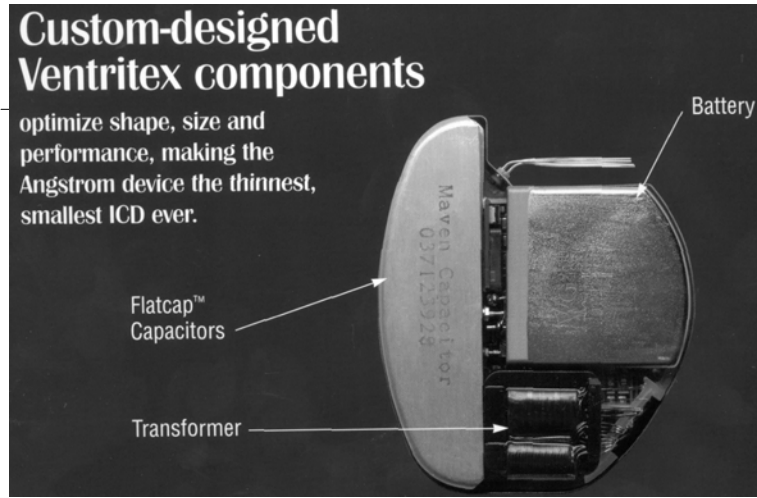
## Custom-designed Ventritex components

optimize shape, size and performance, making the Angstrom device the thinnest, smallest ICD ever.

Flatcap™  
Capacitors

Transformer

Battery



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## More efficient electronic packaging

means a customized shape without compromised performance.

Passives

Reed Switch

SRAM

Charge Module

Telemetry Coil

Protect Module

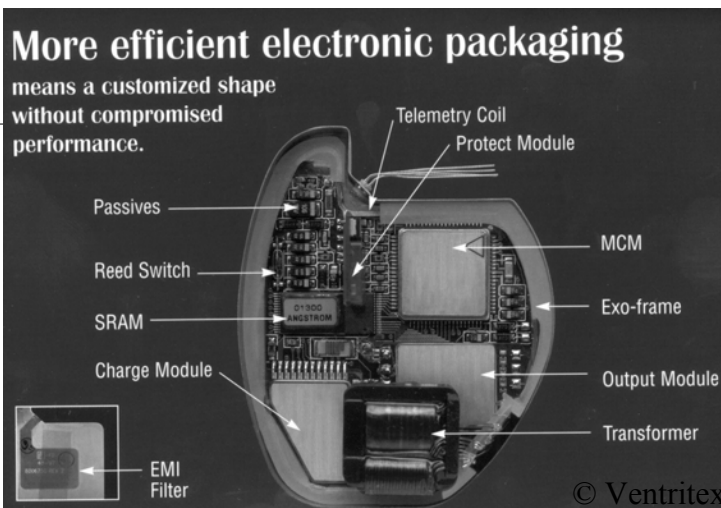
MCM

Exo-frame

Output Module

Transformer

EMI  
Filter

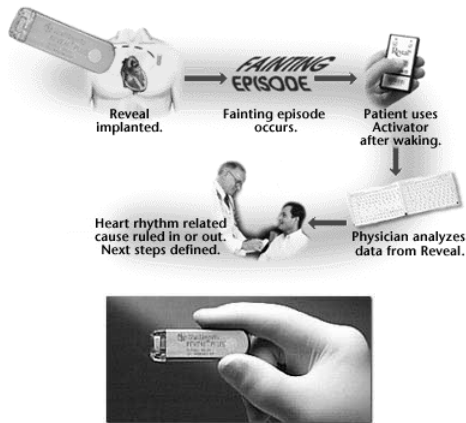


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## Implantable subcutaneous loop recorder



The Reveal Insertable Loop Recorder continuously monitors the rate and rhythm of the heart. It works much like a black box in an airplane, whereby vital information is recorded during the actual fainting episode and can be played back later for detailed analysis. The Reveal Insertable Loop Recorder can continuously record the heart's rate and rhythm for up to 14 months.

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Next :

# TEST

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