Implantable IC

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- General Background
- New Application – Silicon Neuron
- Case Study – Pacemaker
- Conclusion

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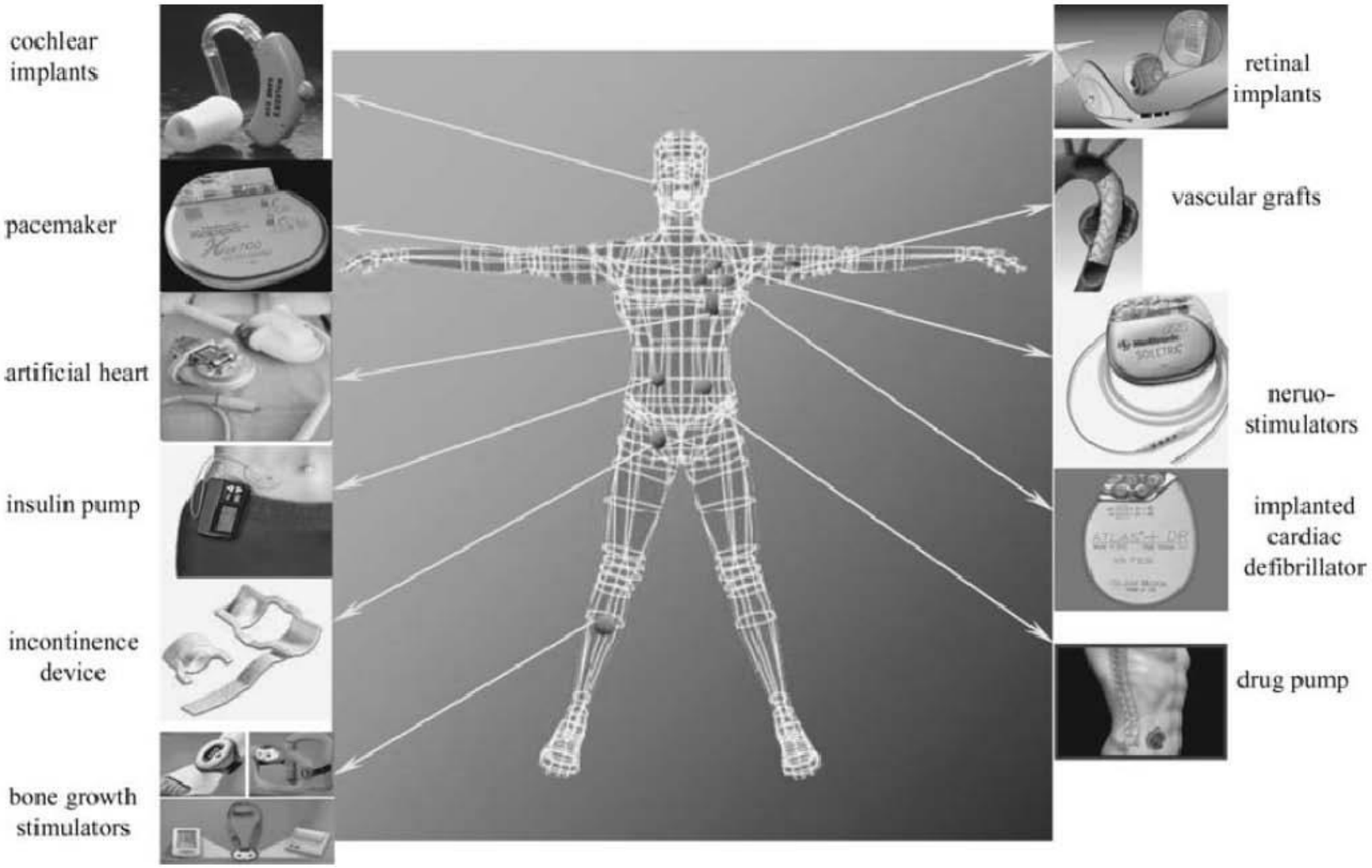
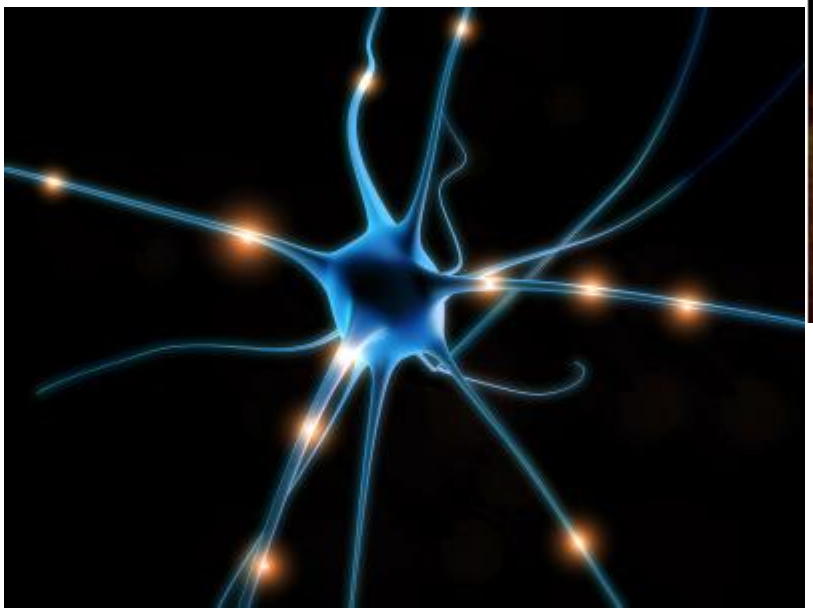
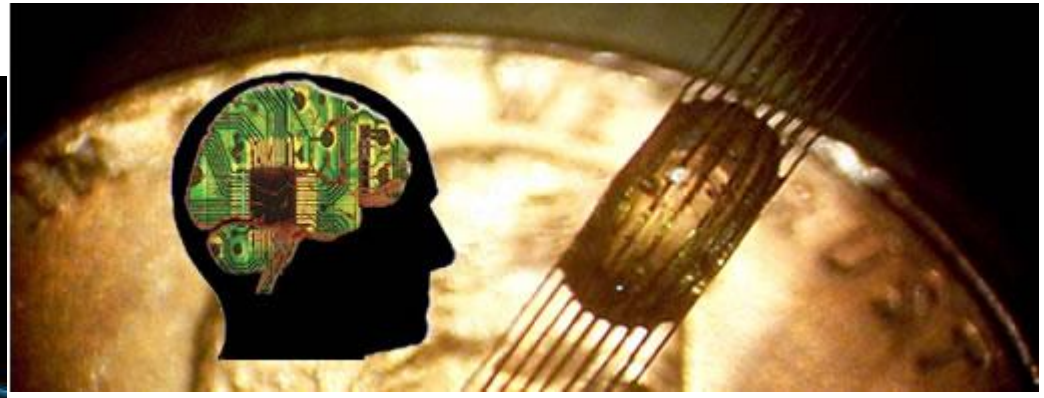
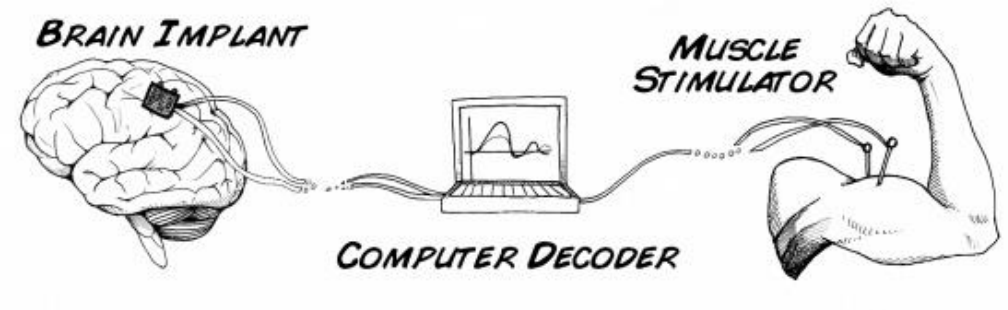
IC Applications in Health Care



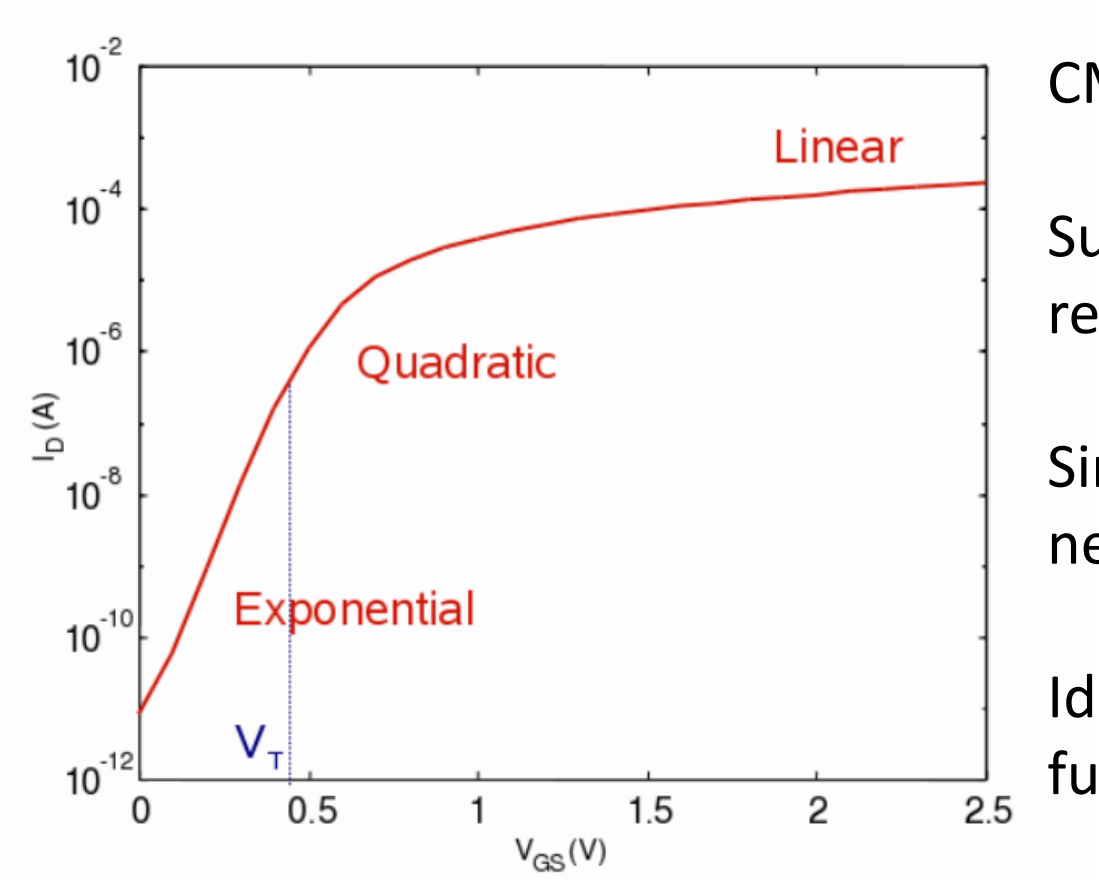
Neuroprothetics







Silicon Neuron



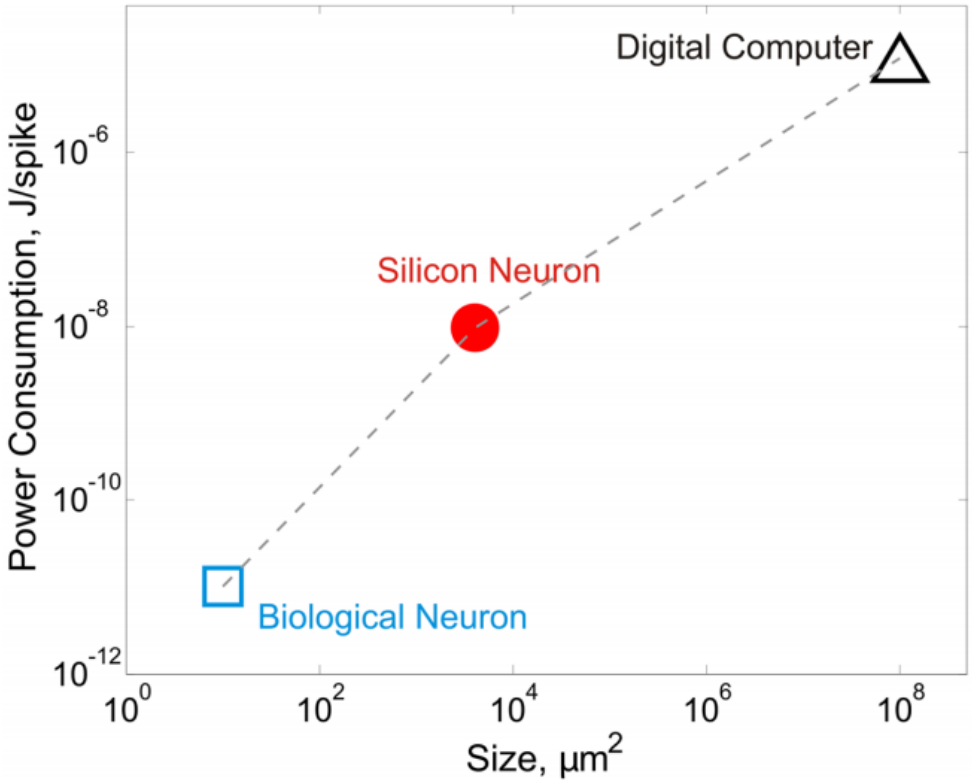
CMOS

Subthreshold operation region

Similar I-V relationship to neural-ion channels

Ideal analogs to of neural function

Silicon Neuron

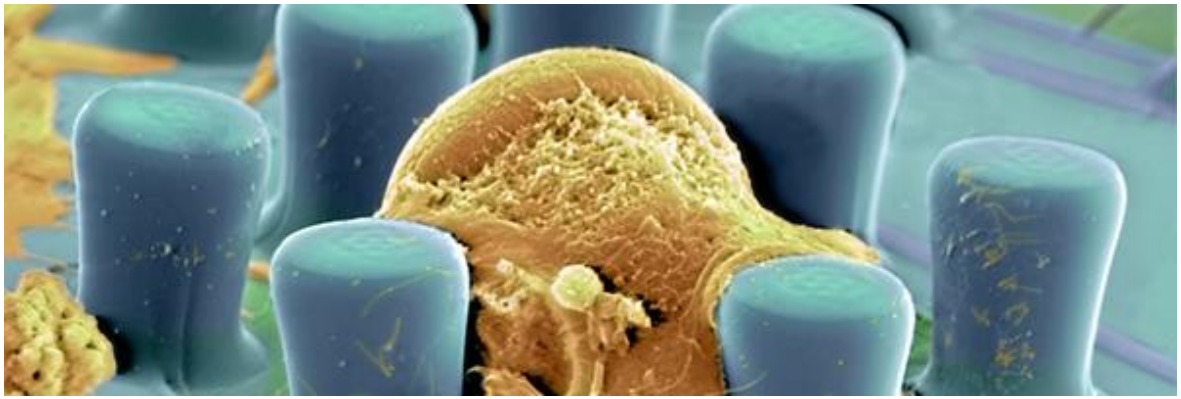


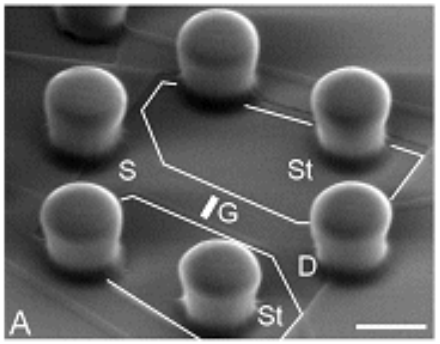
Digital neural simulation: precise
Reproducible and re-programmable outputs

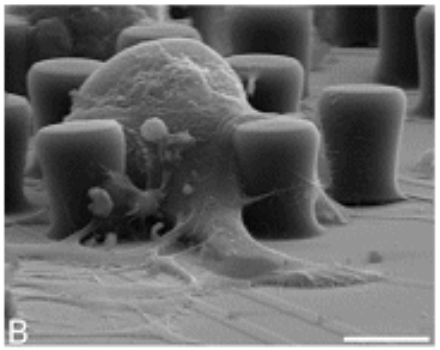
Biological neuron:
inherently analog
need real time simulation

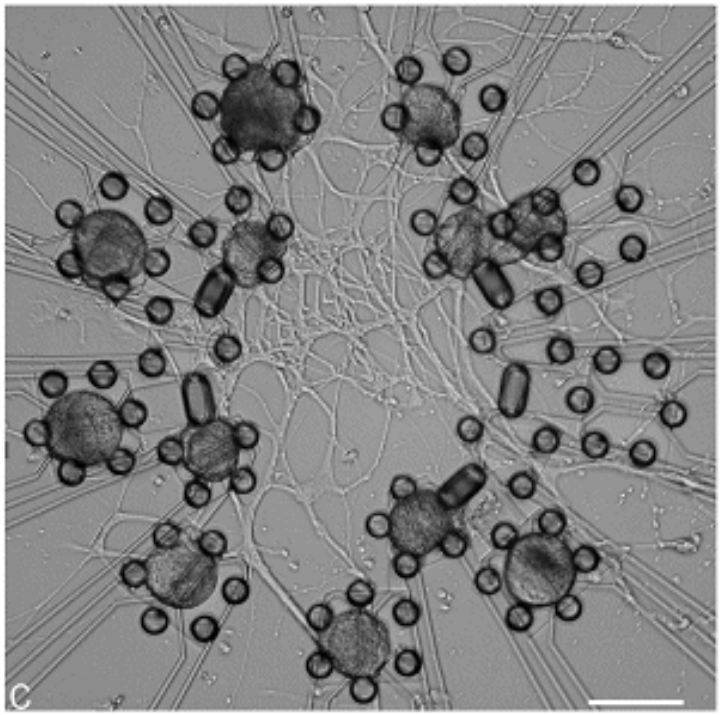
SiNs:
Intermediate computation medium

Neuron sillicon chip

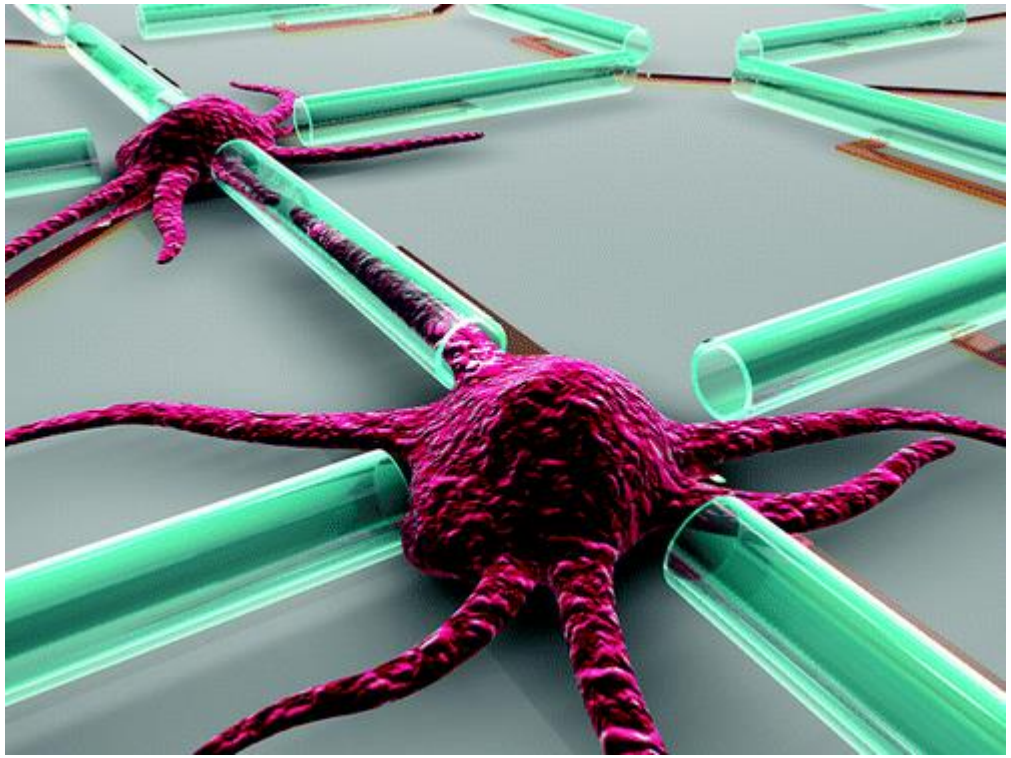








Neuron silicon chip



Neuron grow in semiconductor tubes

Interfaces between neurons and semiconductors

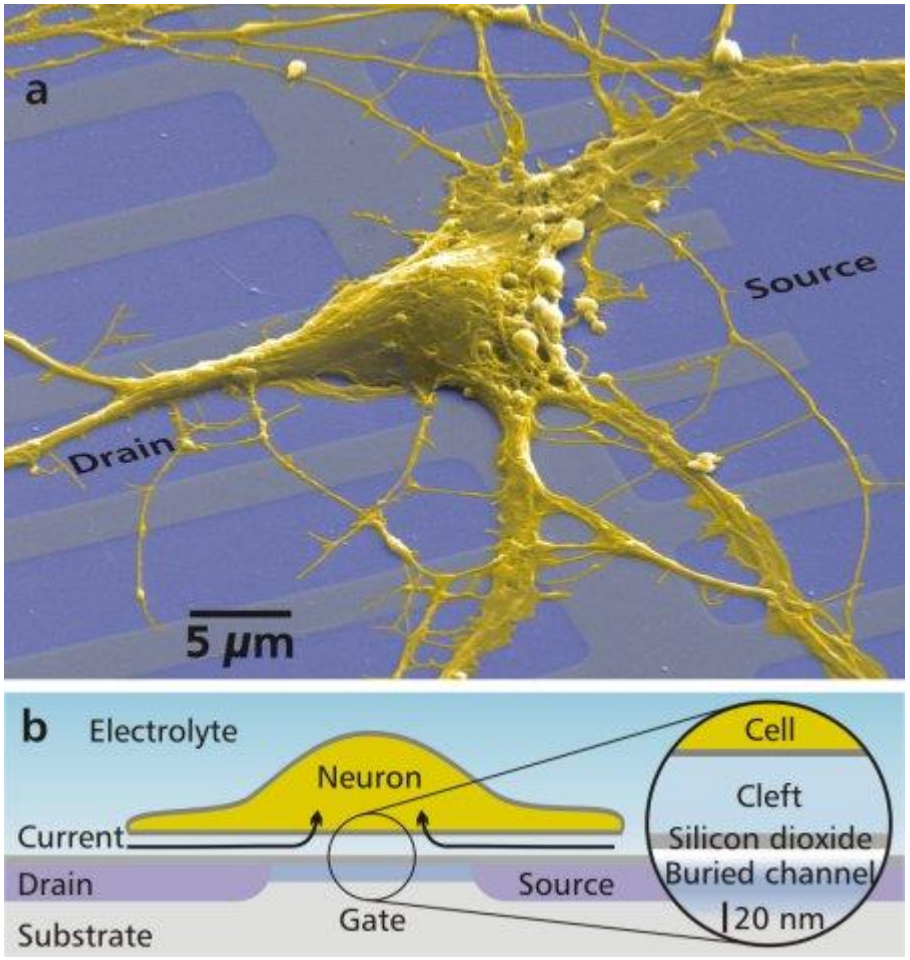
Bridge the broken nerves

Insulate the nerves

Transmit electrical impulses

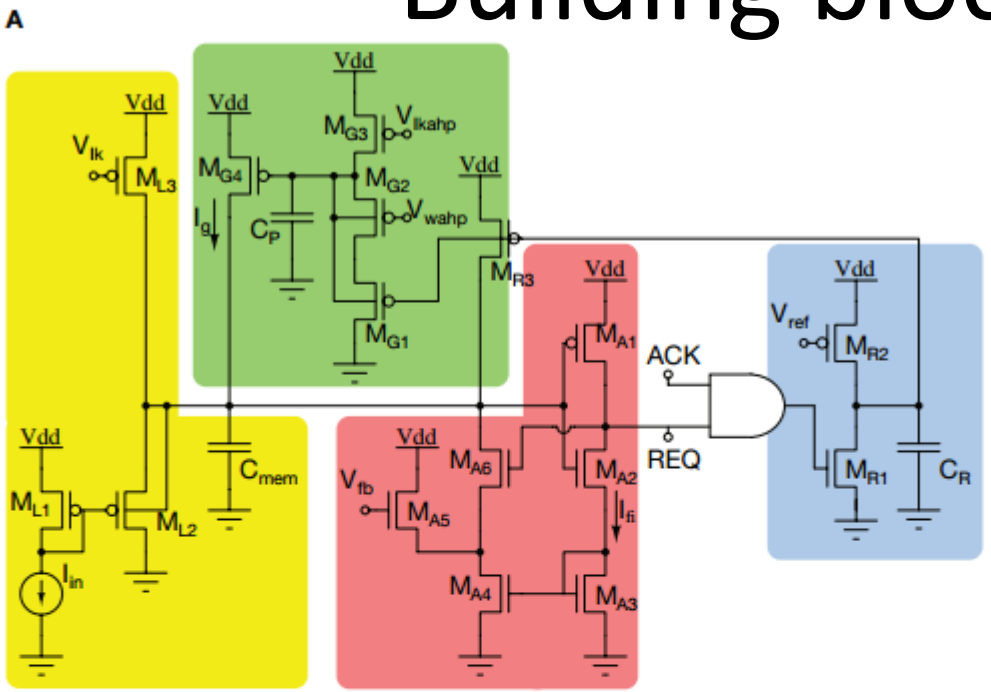
Paralysis

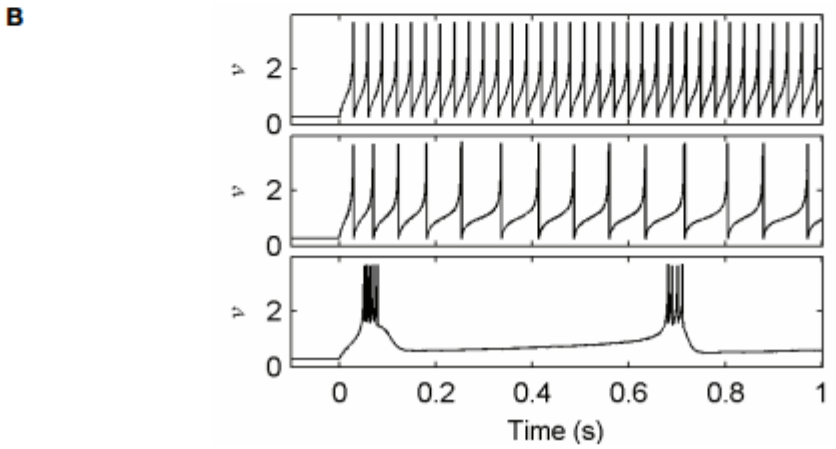
Neuron silicon chip



Signal transmission from nerve cell to FET

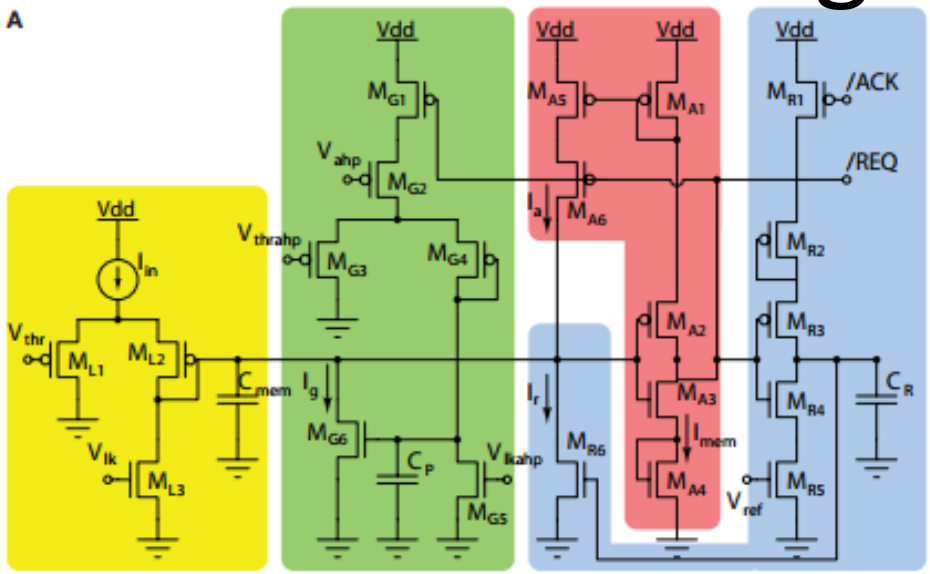
Building blocks

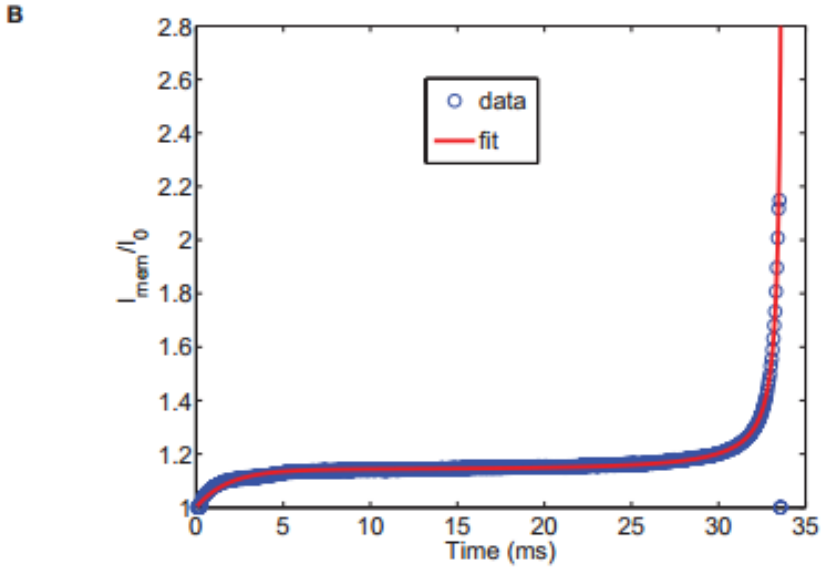




The log-domain LPF neuron

Building blocks





The DPI neuron

Challenge of building SiN on VLSI chips

- Subthreshold CMOS highly susceptible to mismatch in transistor threshold voltage
- Current factors caused by fabrication imperfections and temperature variations
- Need for high degree of biological realism

Next generation

low-power system-on-chip applications (SoC) led to low-power subthreshold SoC circuits

-> Reduction in threshold voltage variation

Tri-gate process-> scale problem

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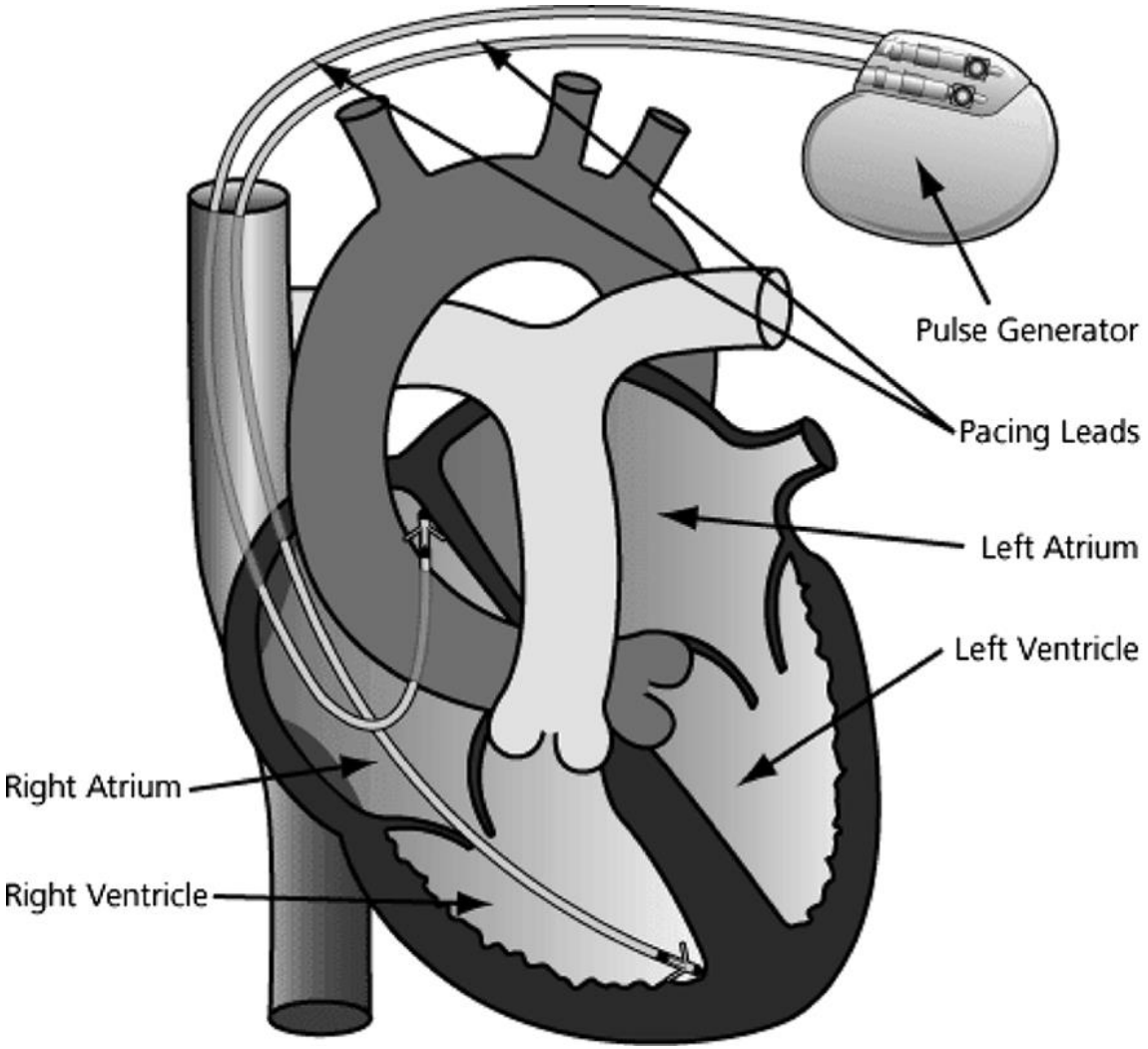
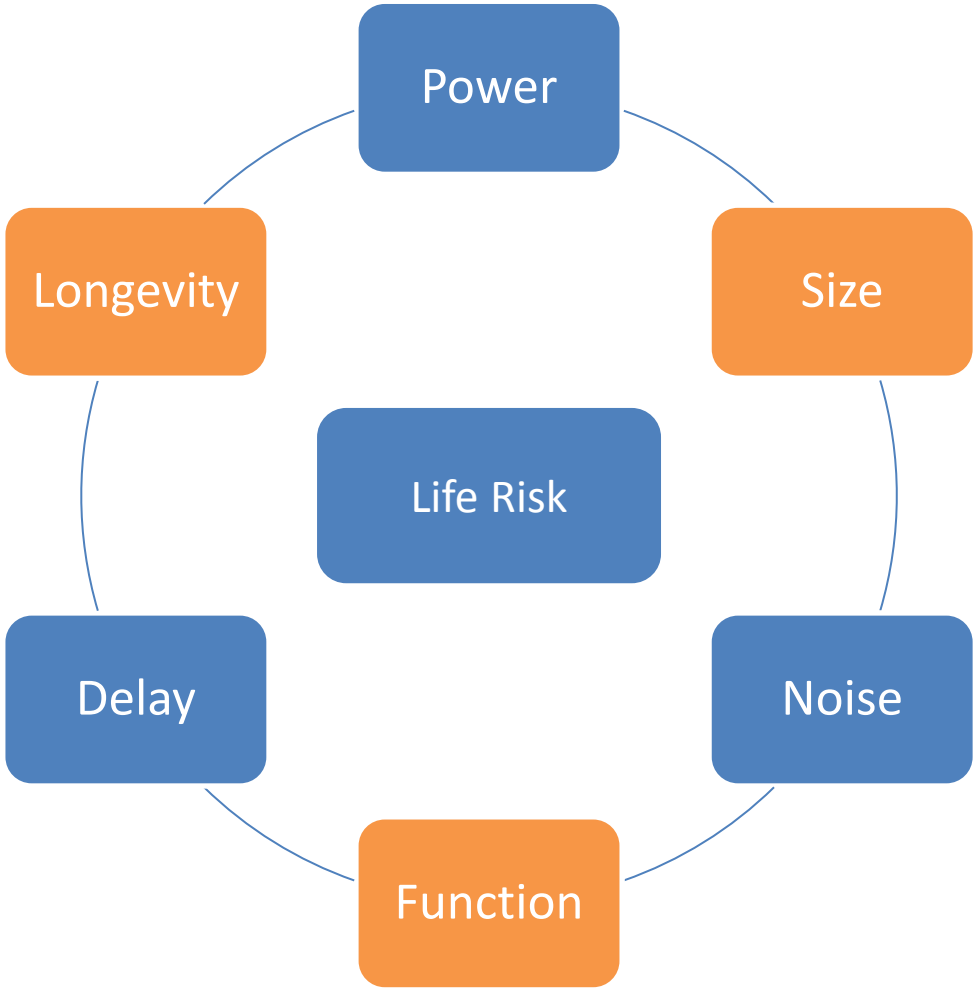
Pacemaker



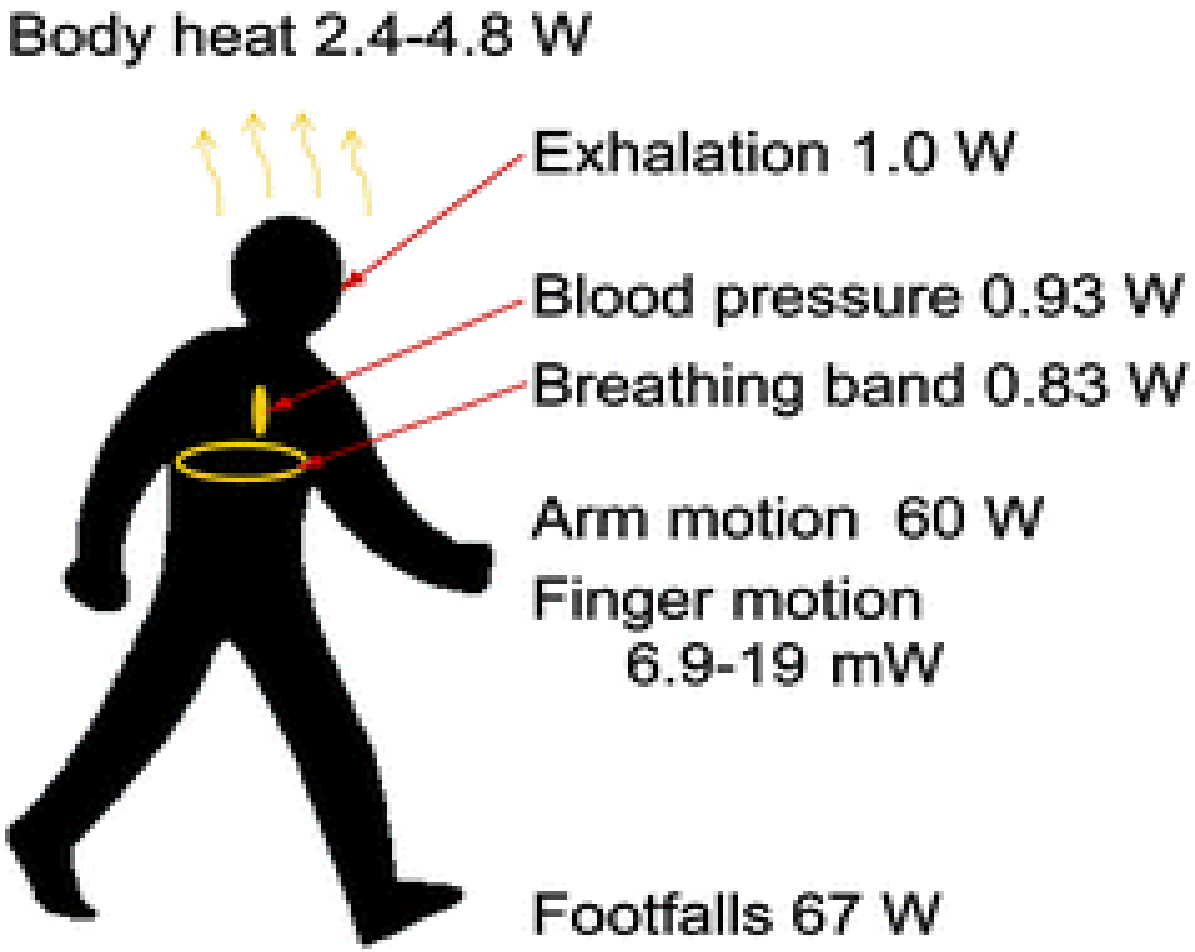
~1.5 inch

Picture of an actual Implantable Pacemaker

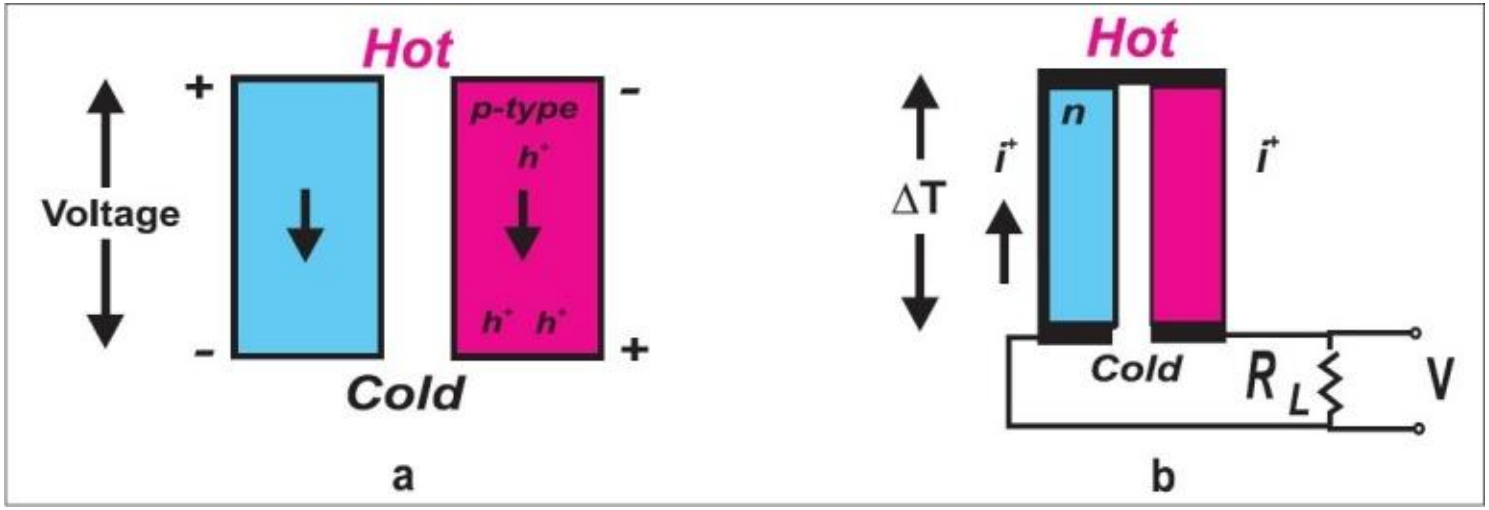
Special Considerations



Body Energy Harvesting



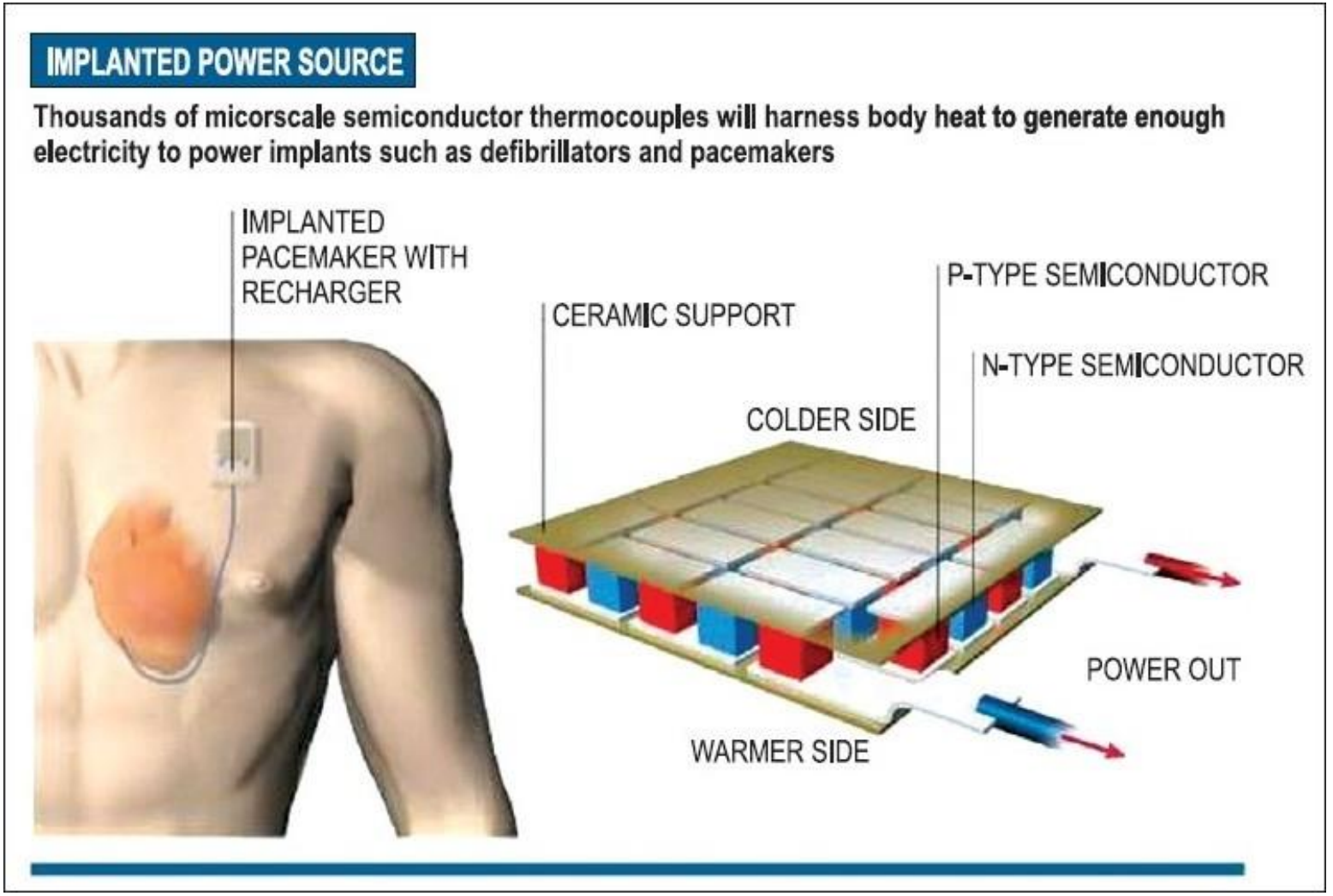
Power Generation Using Body Heat



Generation of positive/negative charges due to difference in temperature

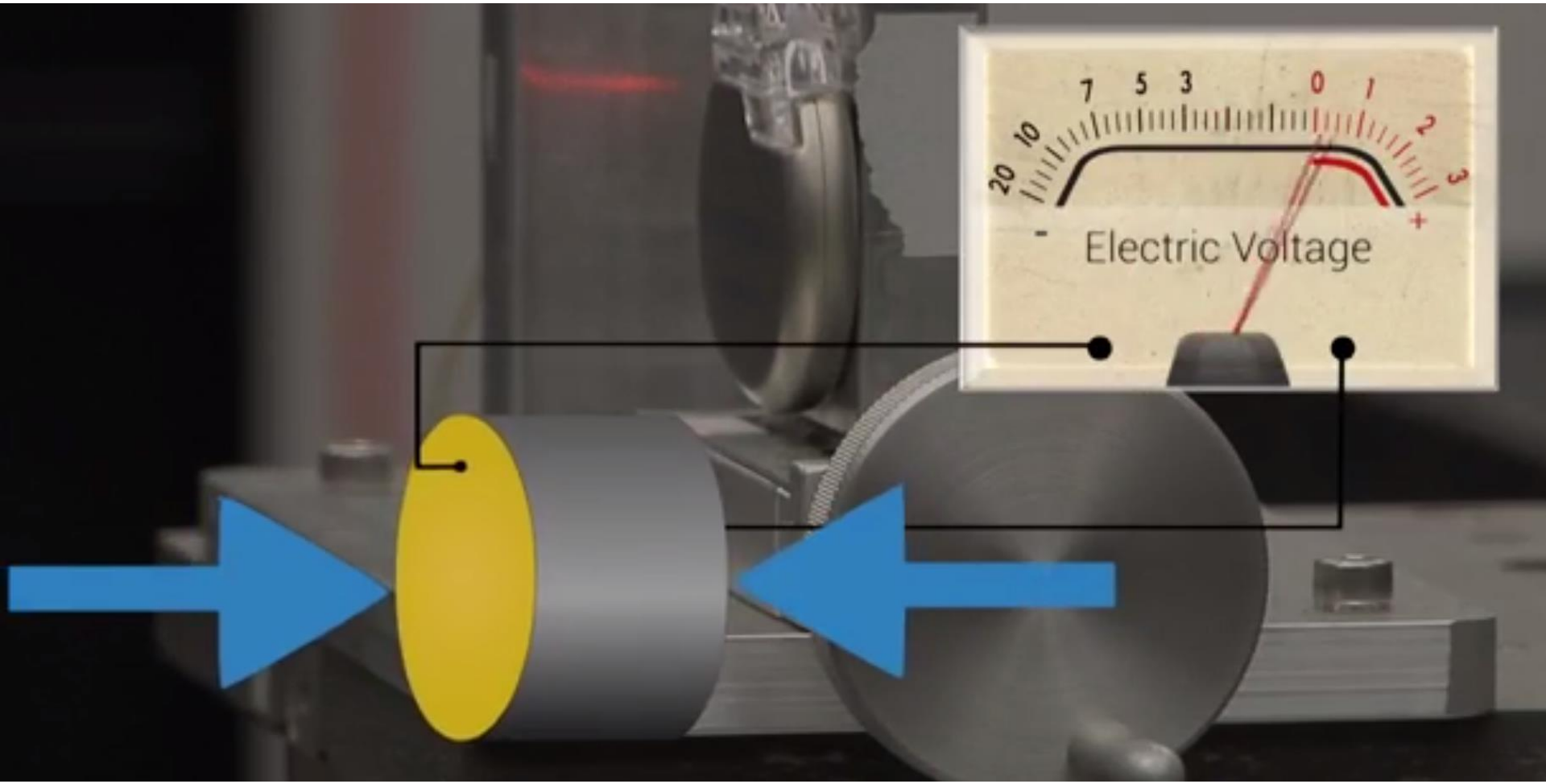
Generation of positive/negative potentials due to difference in temperature

Power Generation Using Body Heat



Biothermal battery: PN junction array

Power Generation Using Vibration



The Heart Alone Could Power New Pacemaker

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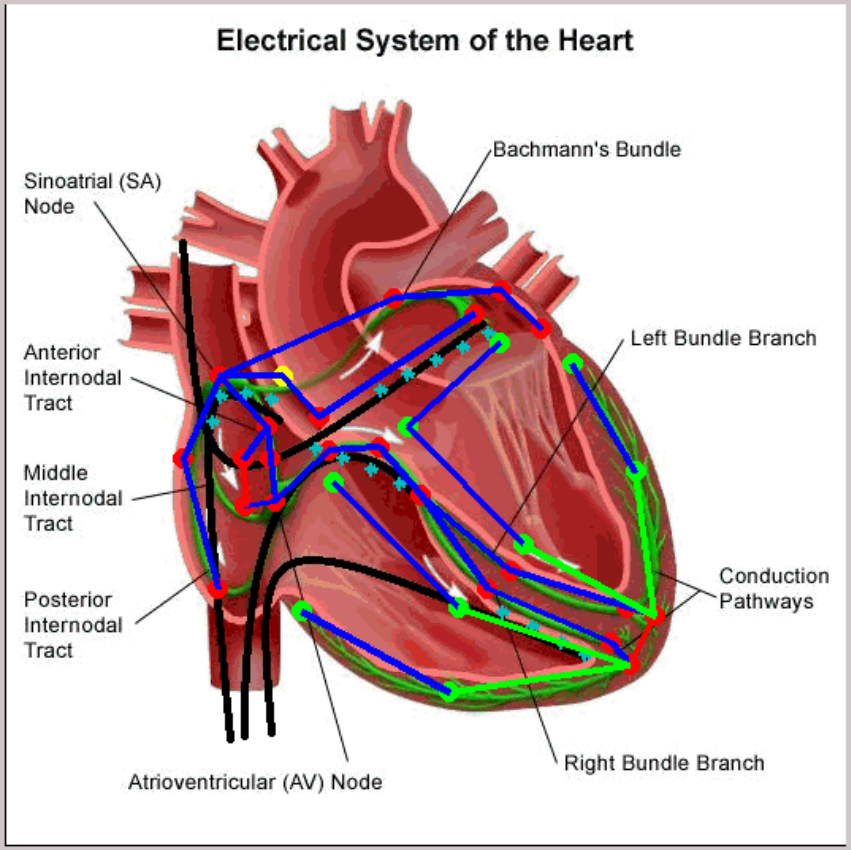
Background

- # of codes: 80,000 lines

- Need a systematic way to evaluate safety of pacemaker software

Penn Virtual Heart Model Simulator V2.0

File Edit View Insert Tools Desktop Window Help



display image

500

Run

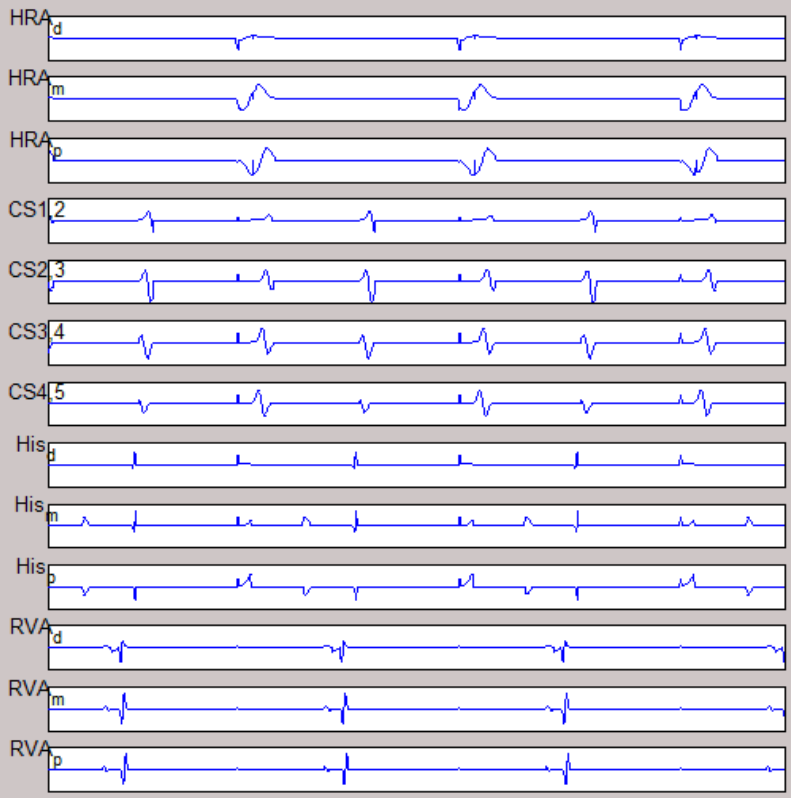
Save model | Load model | Show EGM | Add node | Add path | Add probe

Pace panel

Formal model

Electrograms

File Edit View Insert Tools Desktop Window Help

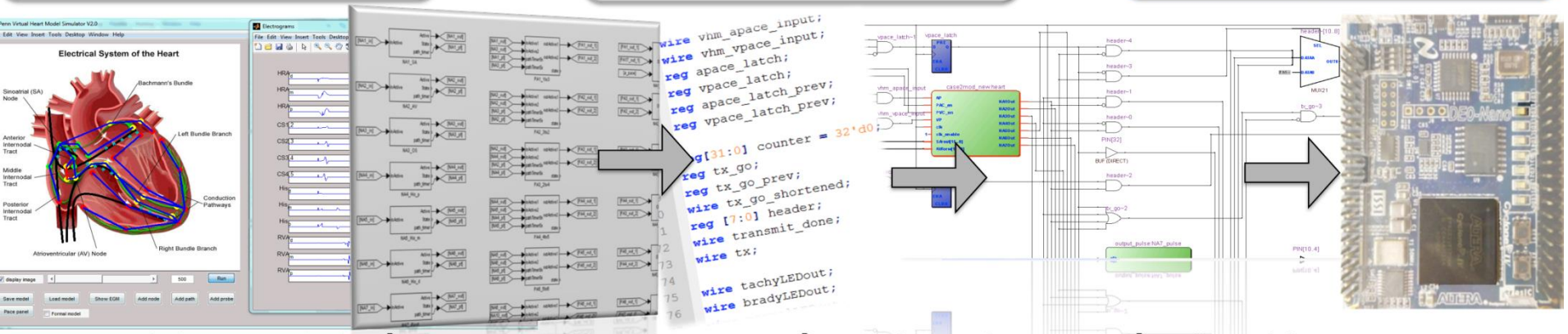


Heart Model

Heart Model Assembly (Heart → Model)

HDL Generation (Model → Code)

FPGA Synthesis (Code → Hardware)



Heart Model in Simulink → VHDL Code Generation → Synthesis for FPGA → Closed-loop testing

Conclusion

- New applications

- Having its limitations
  - power
  - testing

References

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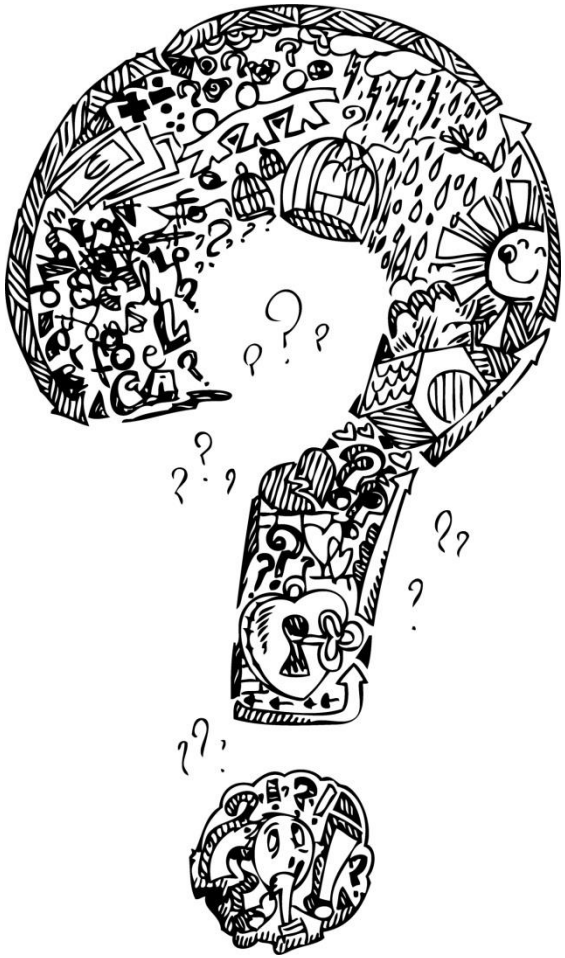
Questions



Video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University of Michigan