

Implantable and Wearable Wireless Medical Devices

J.-C. Chiao

Professor

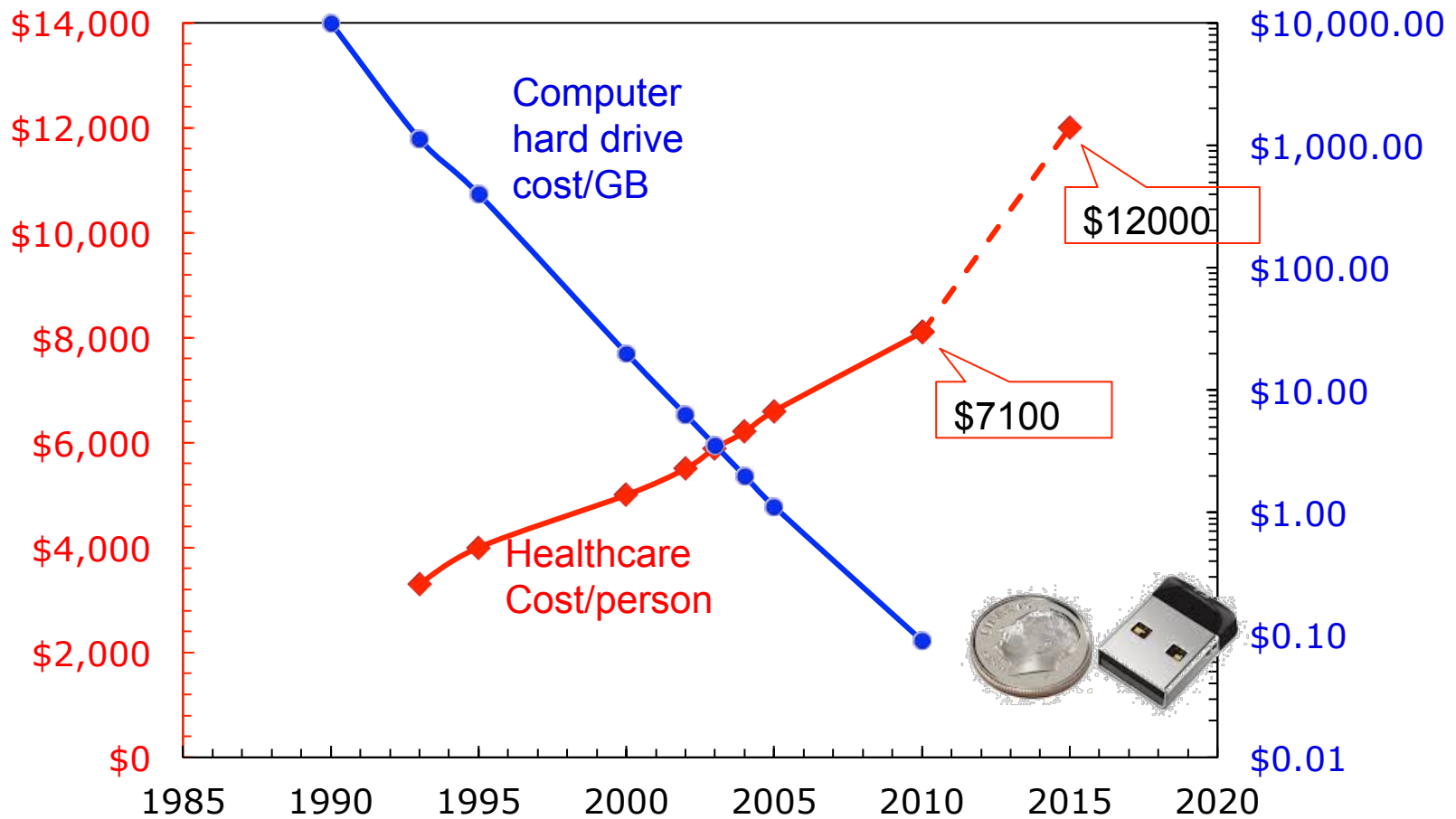
Electrical Engineering, University of Texas – Arlington

Adj. Associate Professor

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www.uta.edu/faculty/jcchiao

Healthcare per person spending



Sources: Wells Fargo Insurance Services, <http://www.mkomo.com/cost-per-gigabyte>

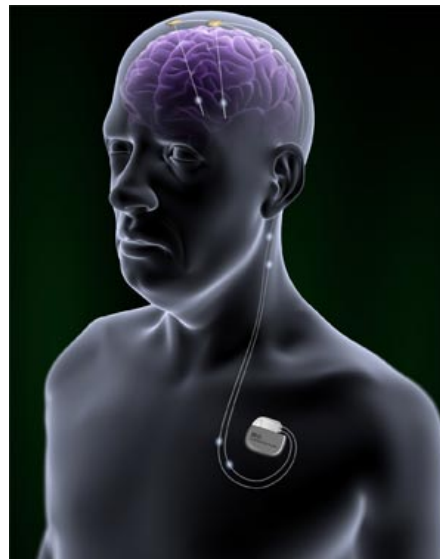
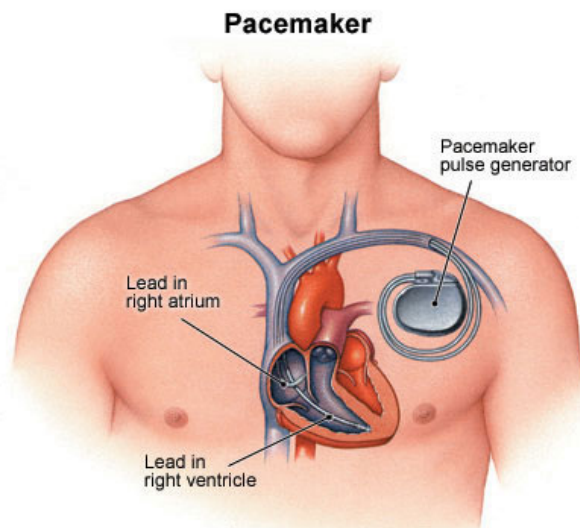
Electronic Implants



Pacemaker

Implantable cardioverter-defibrillator (ICD)

Neurostimulator



Technical Challenges

- Applications
- Size
- Power source
- Implementation
 - Functional
 - Clinical
 - Personal

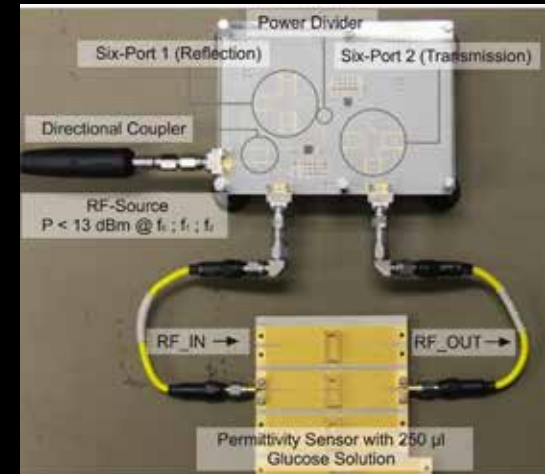
Electromagnetics

- Communication
- Power delivery
- Noninvasive interrogation

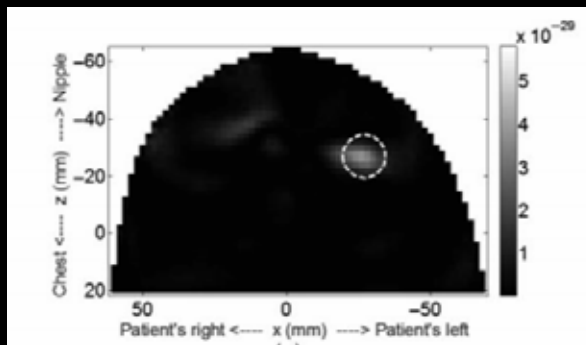
Millimeterwave liquid sensing

Millimeterwave probing of cancer cells

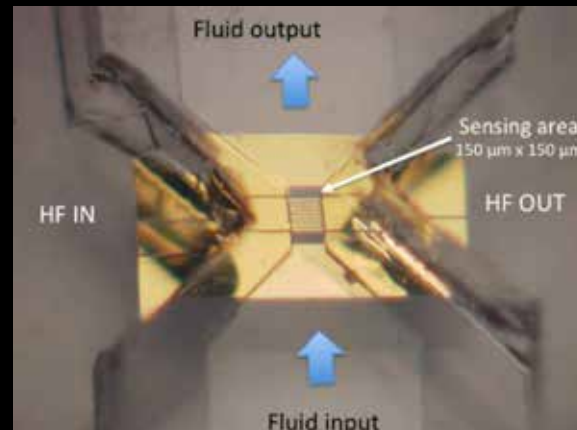
Microwave imaging



IMS, Max Hofmann, 2013



T-AP, Elise Fear 2015



T-MTT, Katia Grenier, 2012

Electromagnetics

- Communication
- Power delivery
- Noninvasive interrogation
- Direct manipulation of tissues

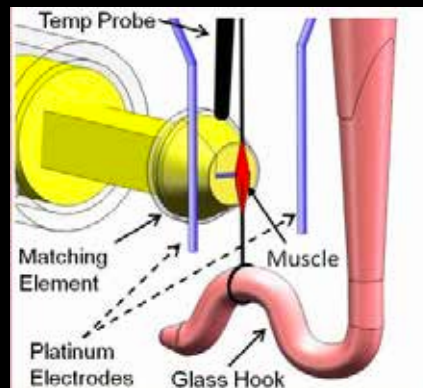
Decrease sweat glands

Microwave hyperthermia for cancer

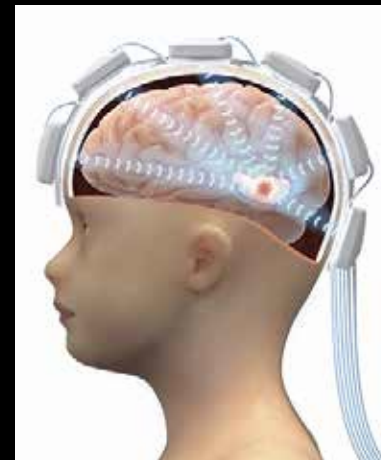
Millimeterwave stimulation



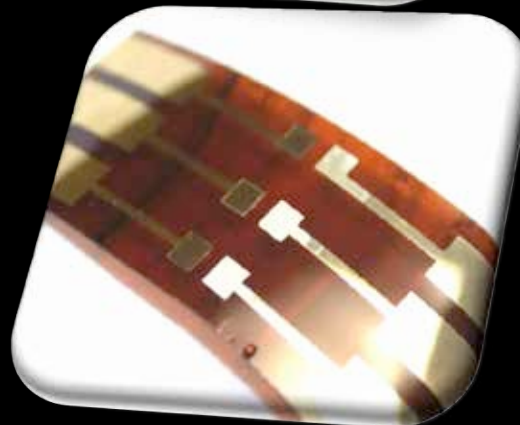
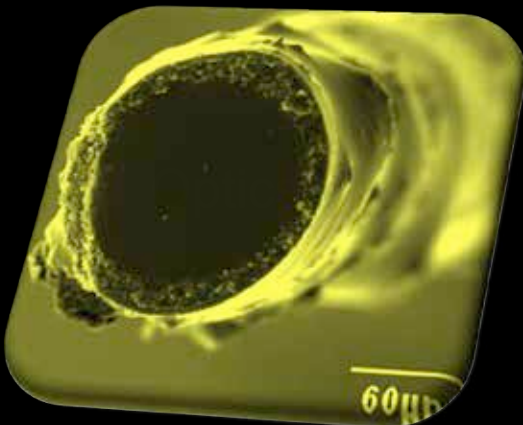
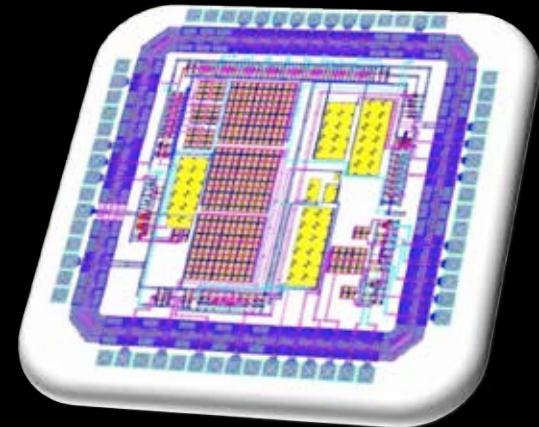
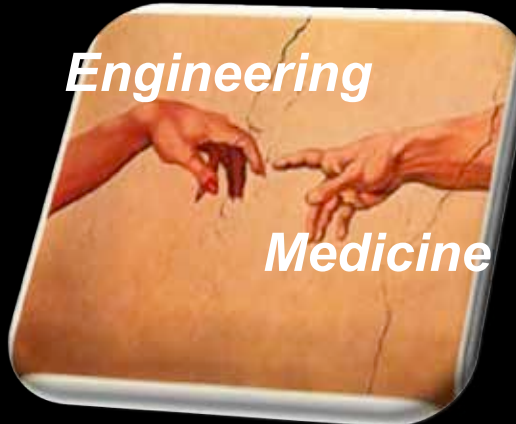
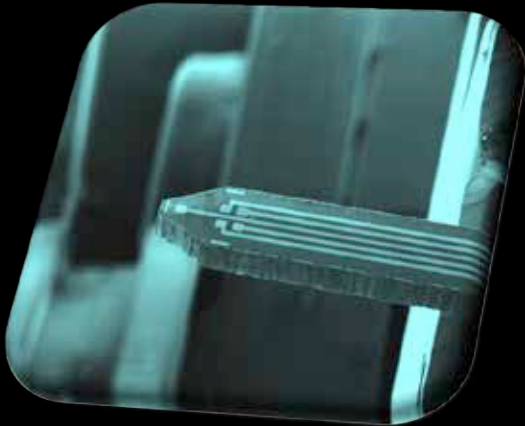
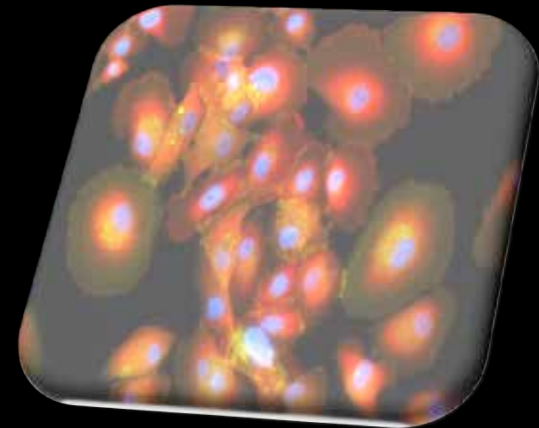
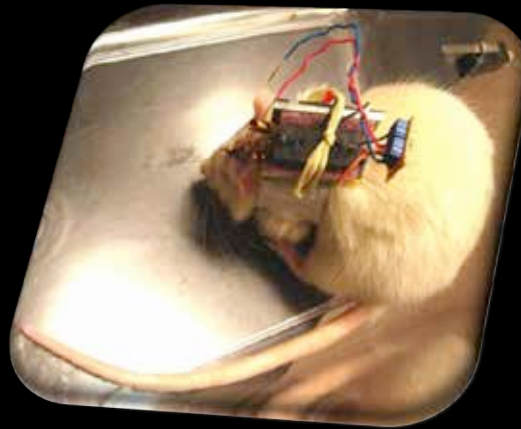
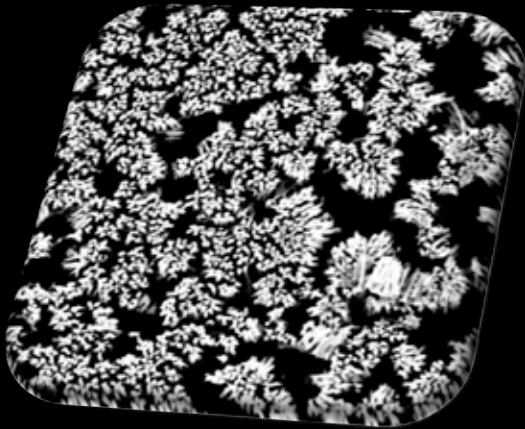
MiraDry 2013



Indira Chatterjee, 2011

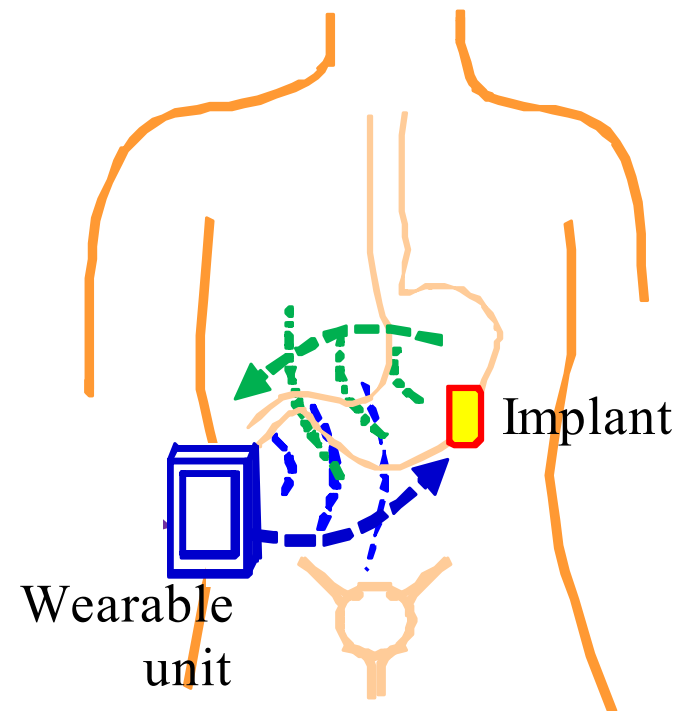


Andreas Fhager, 2016

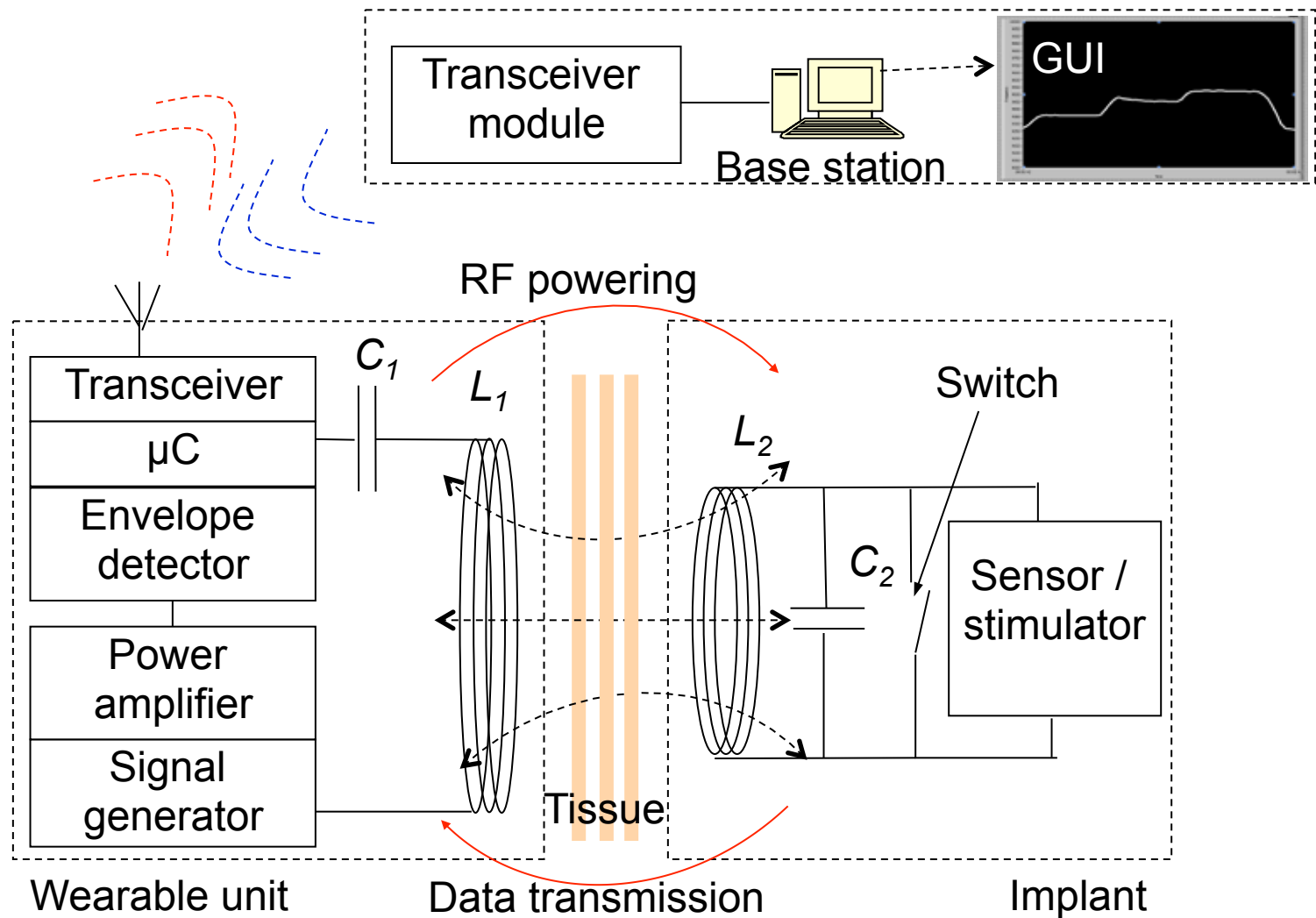


- APRITM Automatic Pain Recognition and Inhibition
 - A closed-loop wireless system between body and computer
- BESTTM Batteryless Endoluminal Sensing Telemeter
 - GERD monitoring
 - Gastrostimulation

Wireless Implant System Configuration



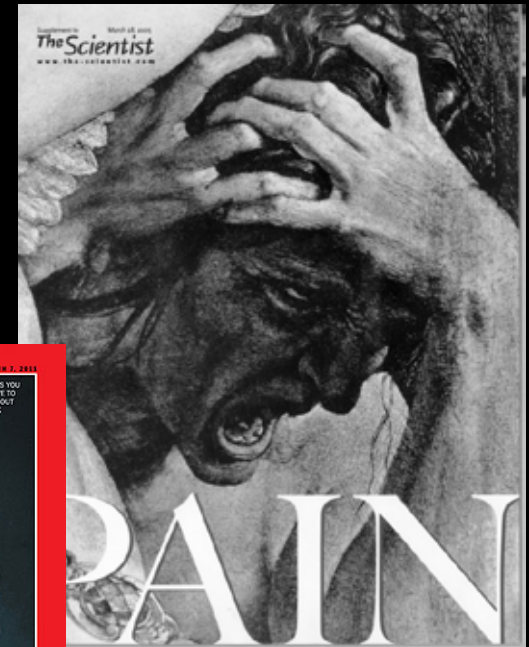
Wireless Implant System Configuration



Integrated Pain Management System

Chronic pain

Cancer
Arthritis
Back
Neuropathic



Dr. Yuan Bo Peng, MD, Psychology, UTA

Chronic Pain

25% American suffers from chronic pain

40 million physician visits per year

\$50B are lost due to workday loss

\$100B in medical expenses are due to chronic pain

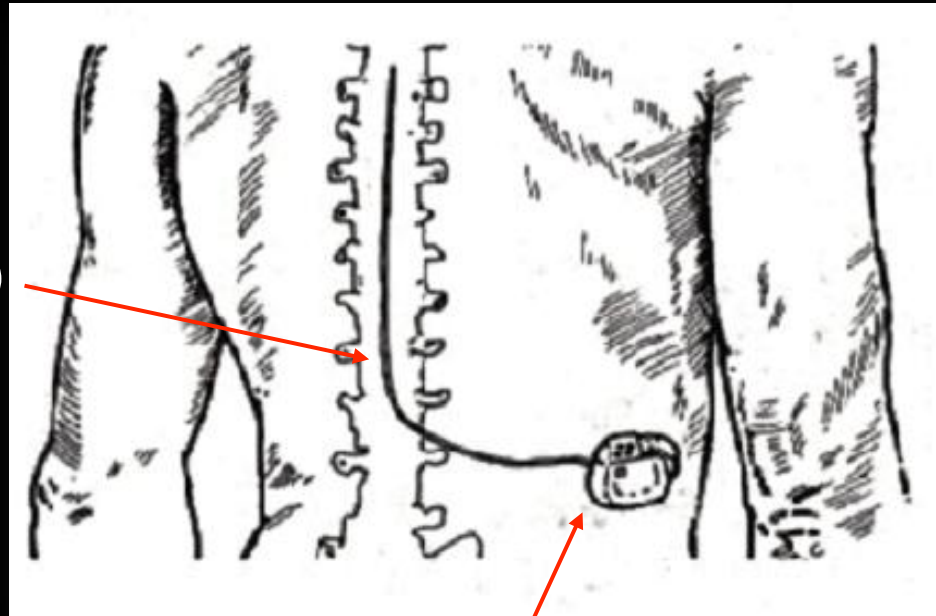
Implantable morphine pump

Addiction, overdose, noncontrollable



Neurostimulator: Open loop pain management system

Electrode catheter (lead)



IPG: Implantable pulse generator

- High frequency voltage spike trains
- Single frequency trains and envelopes are usually employed; multiple frequencies are feasible
- Single voltage spikes $\sim 100 \mu\text{s}$, 1-5 V



How to optimize?

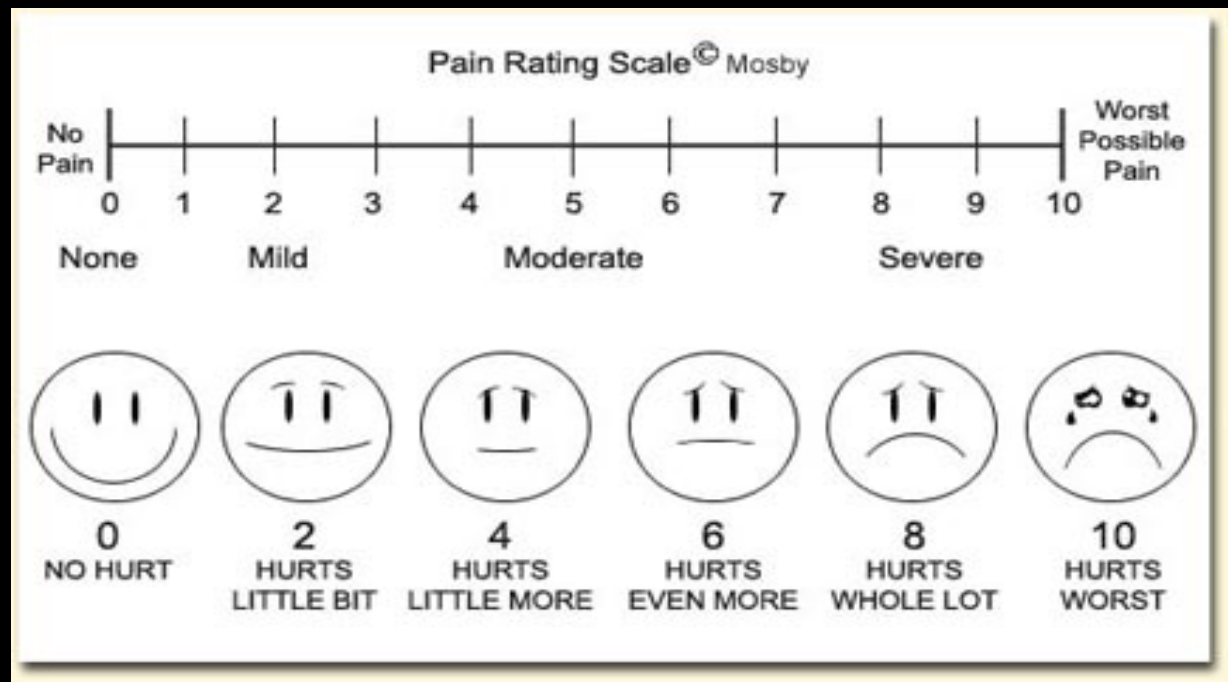
Pains: indicate illness and danger

Current system: open loop

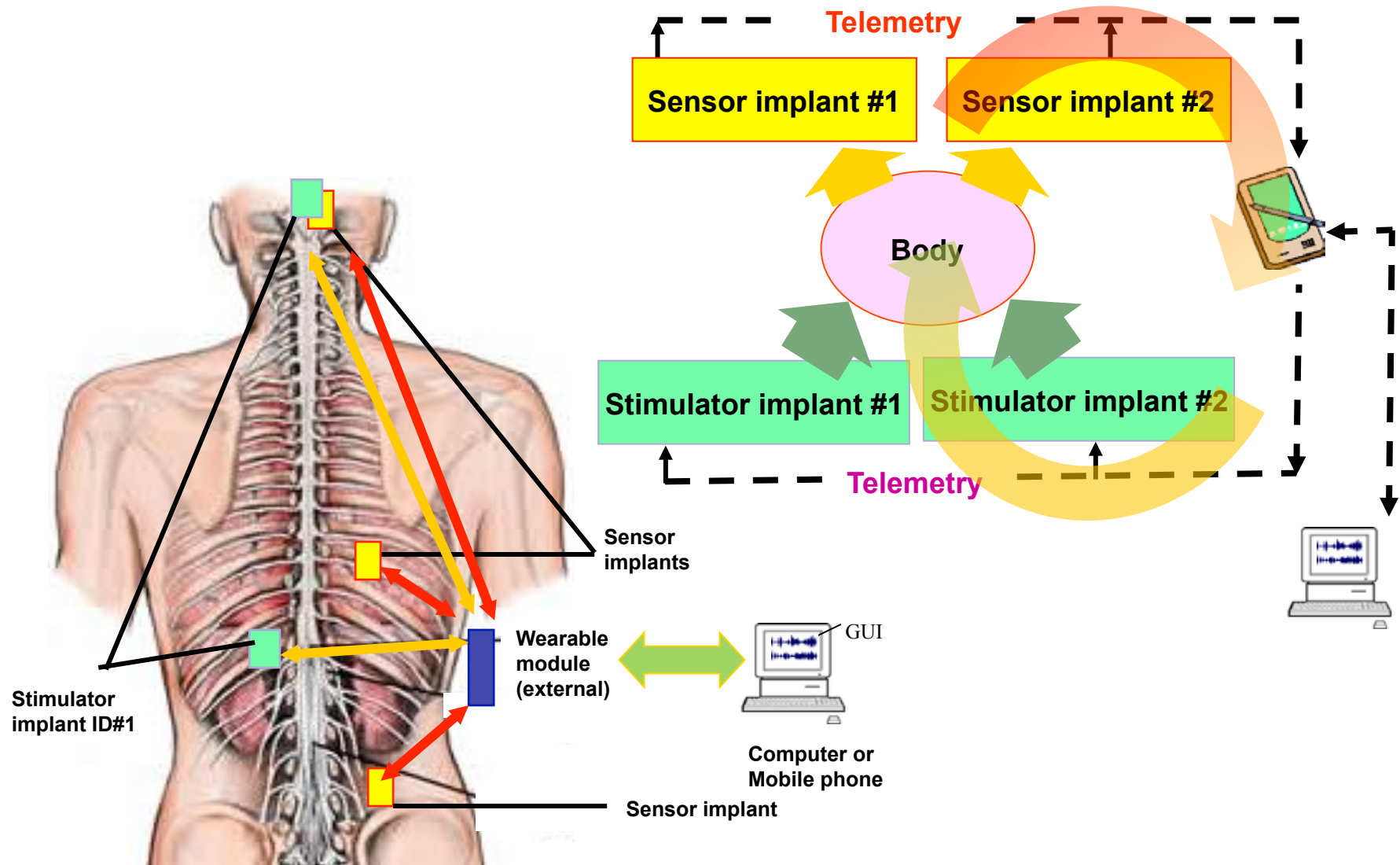
Manual control

What is “pain”?

Digitize pain

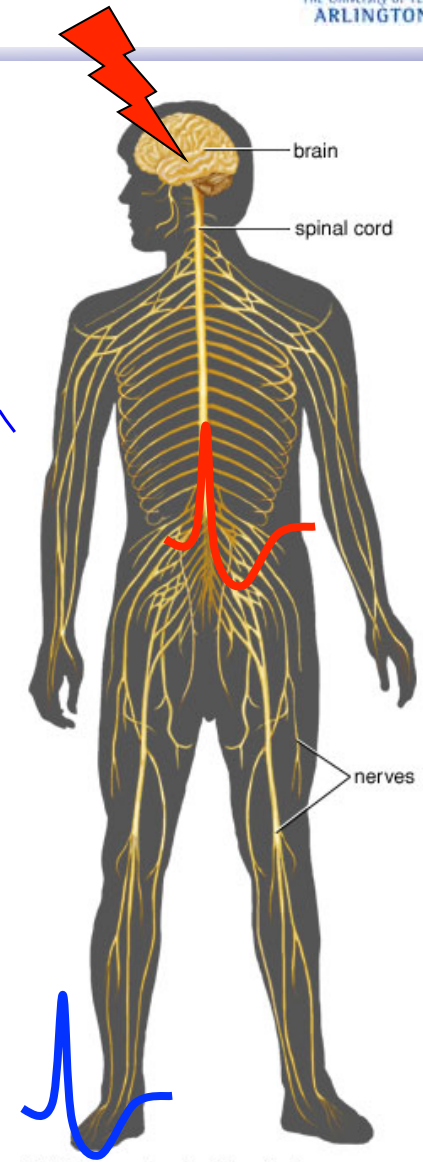
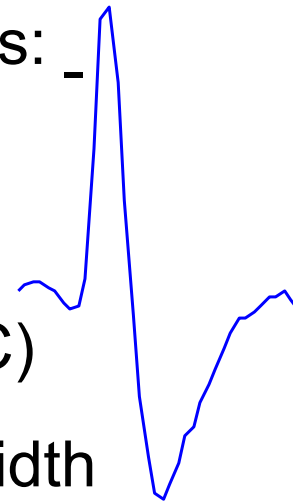


Integrated Sensor and Stimulator Implants



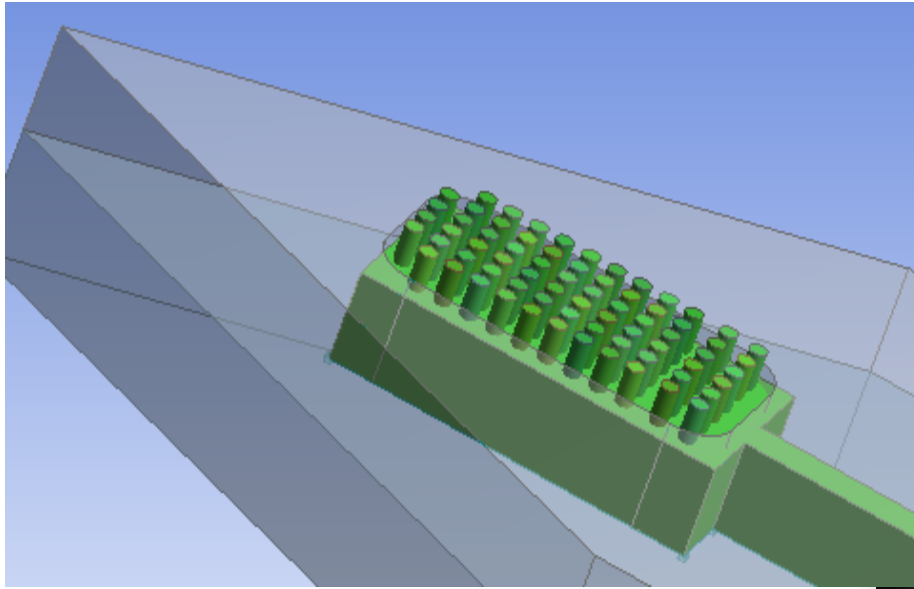
Neural signals: action potentials (APs)

- Communication between neurons: nociceptors
- Ions flow through cell membrane
- Nociceptive afferent fibers (A δ , C)
- Spike like, 500Hz – 3kHz bandwidth

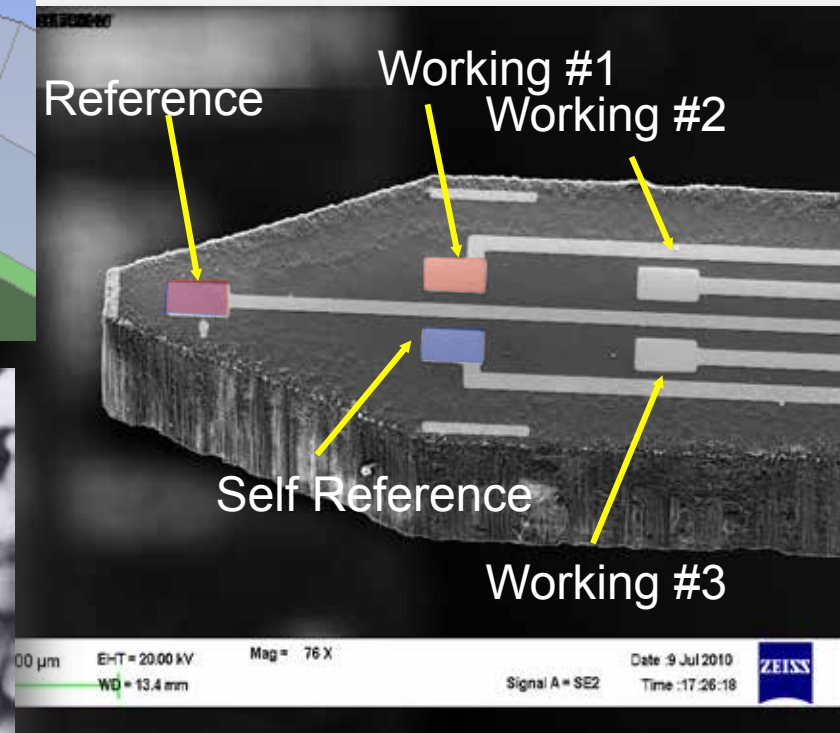


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Integrated Neurotransmitter Probe

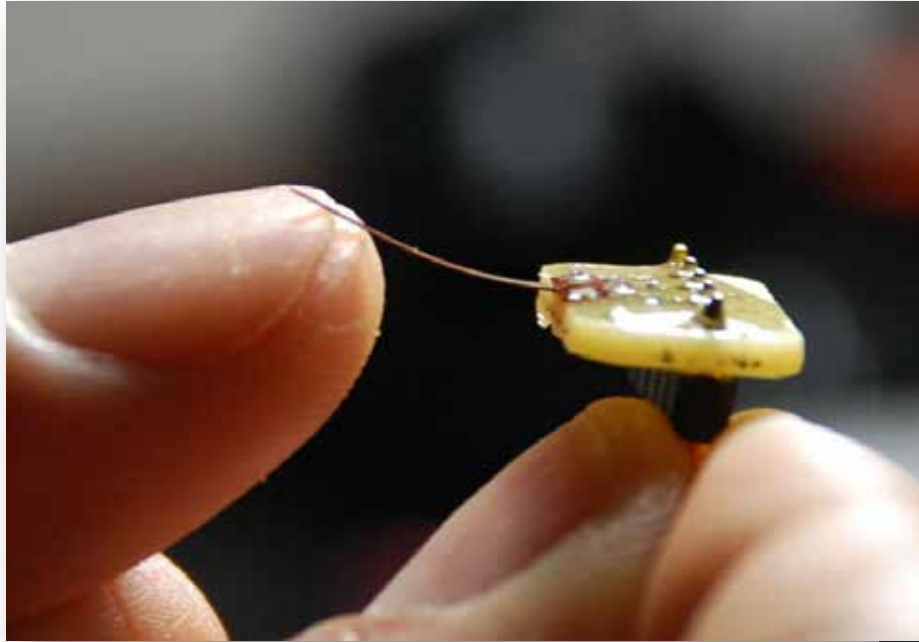


Glutamate + Noises

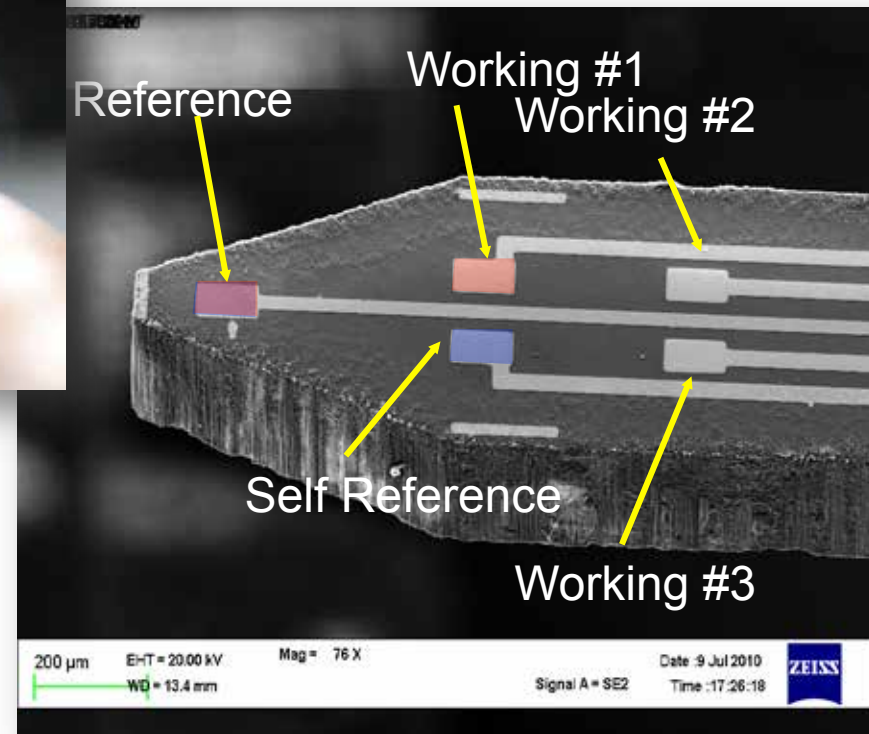


Noises

Integrated Neurotransmitter Probe

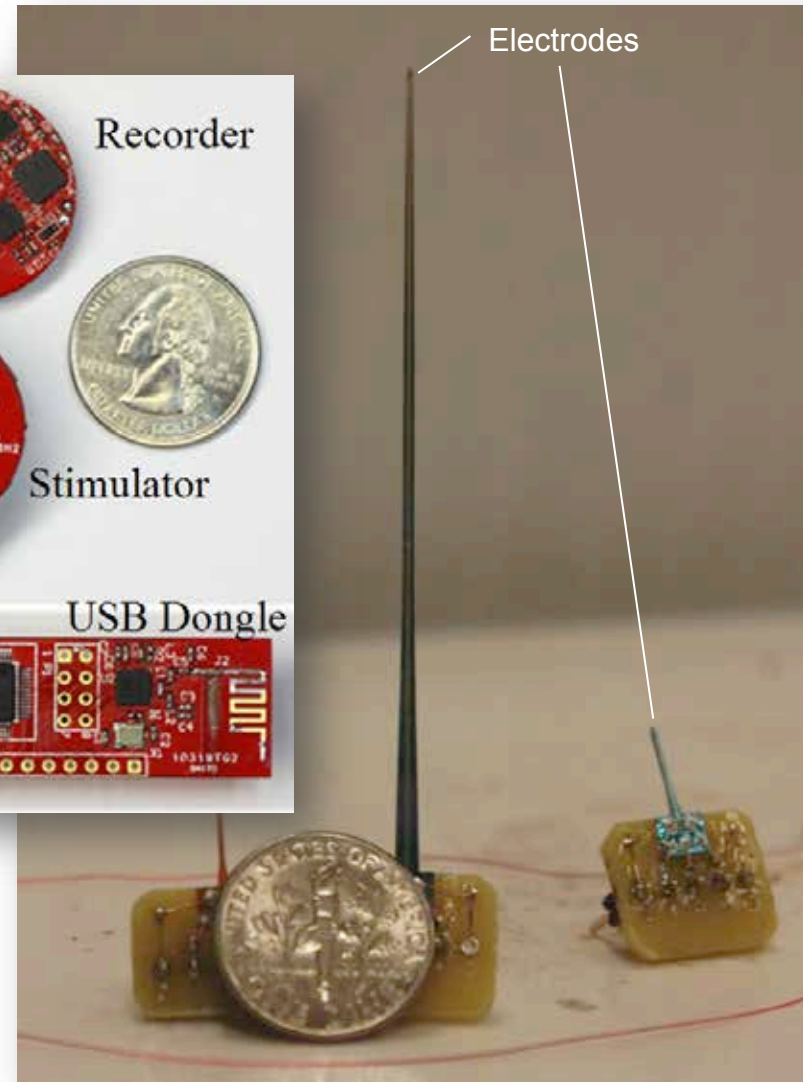
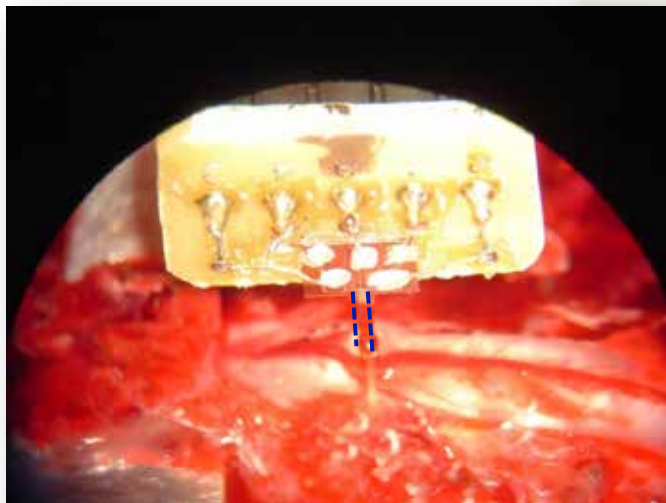
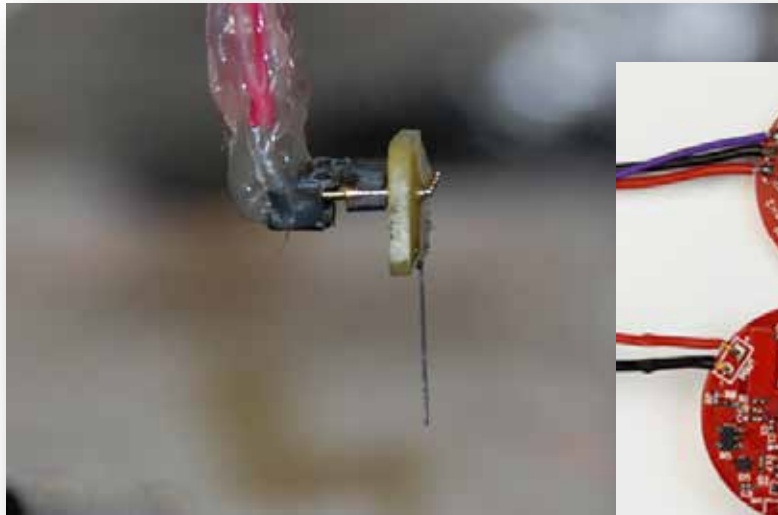


Glutamate + Noises

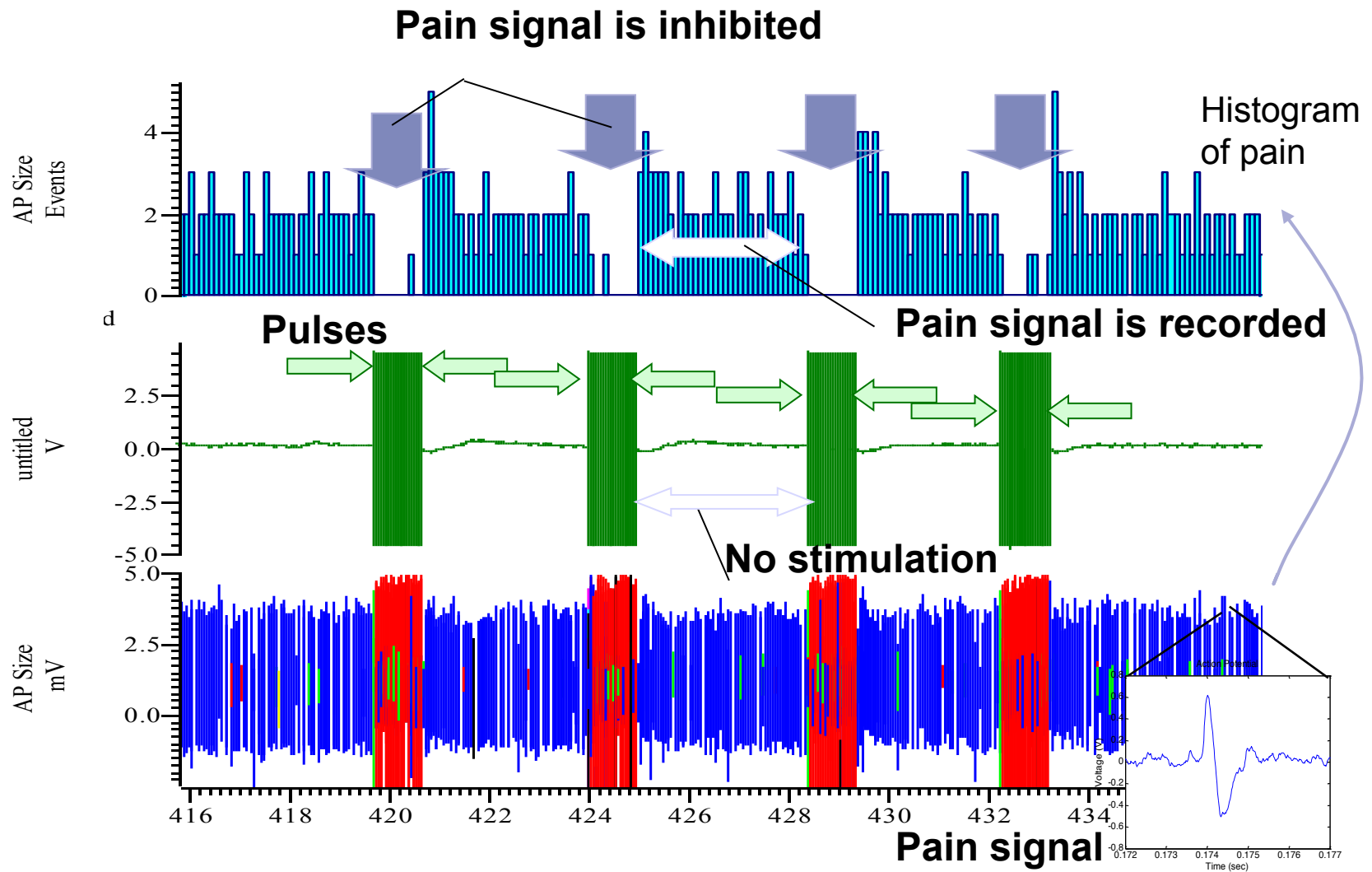


Noises

Integrated Neurotransmitter Probe

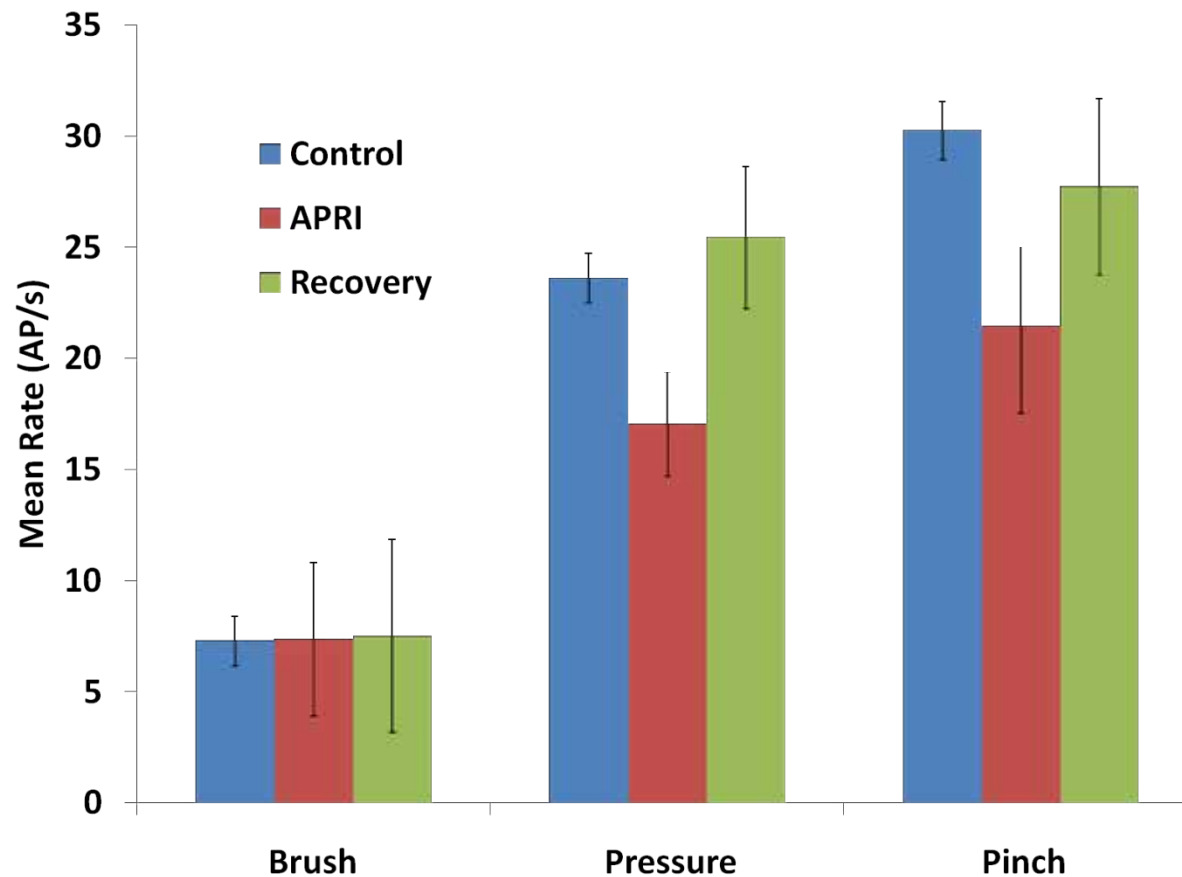


Pain inhibition: signals recognition

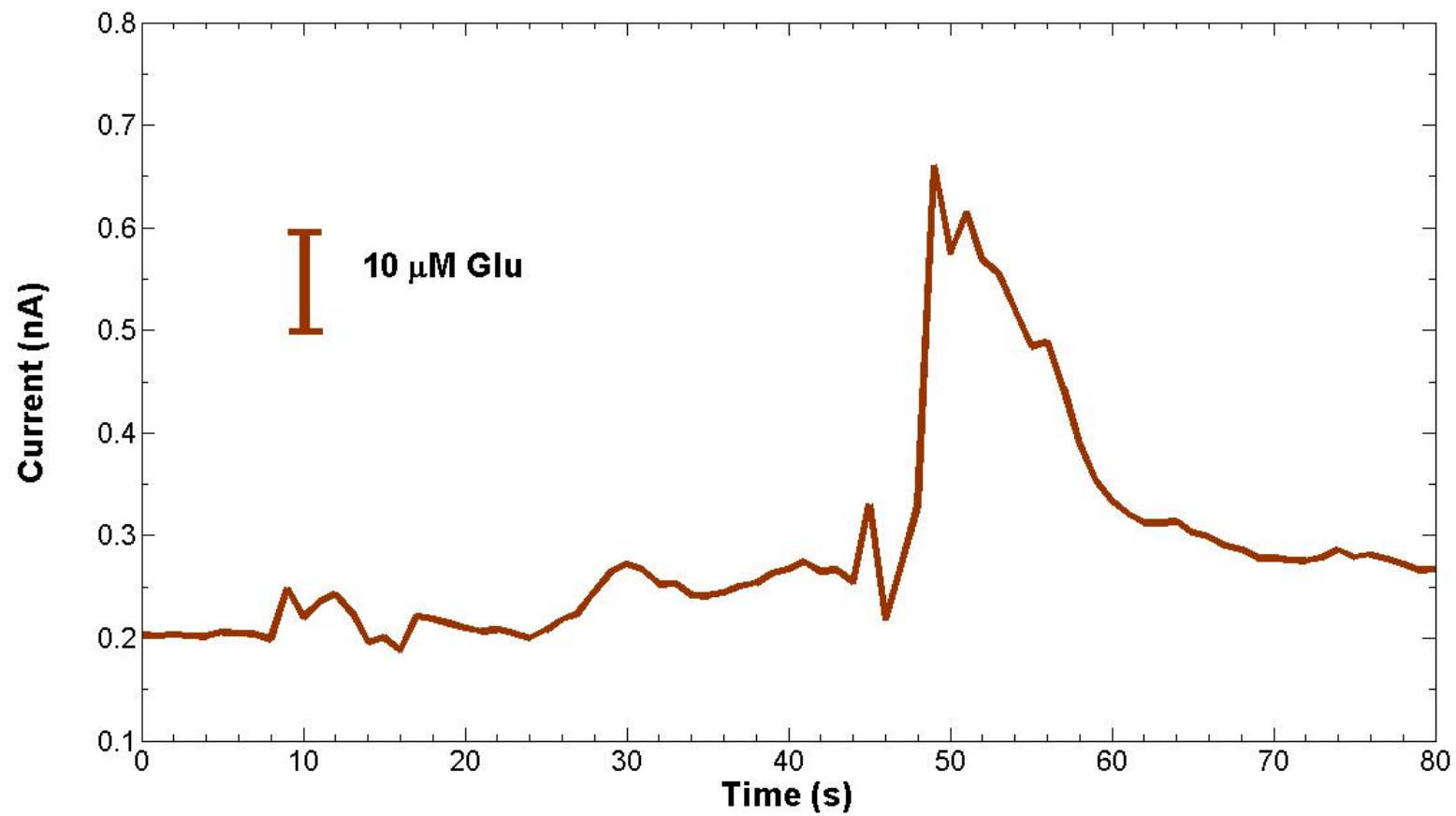


On-demand feedback for pain reduction

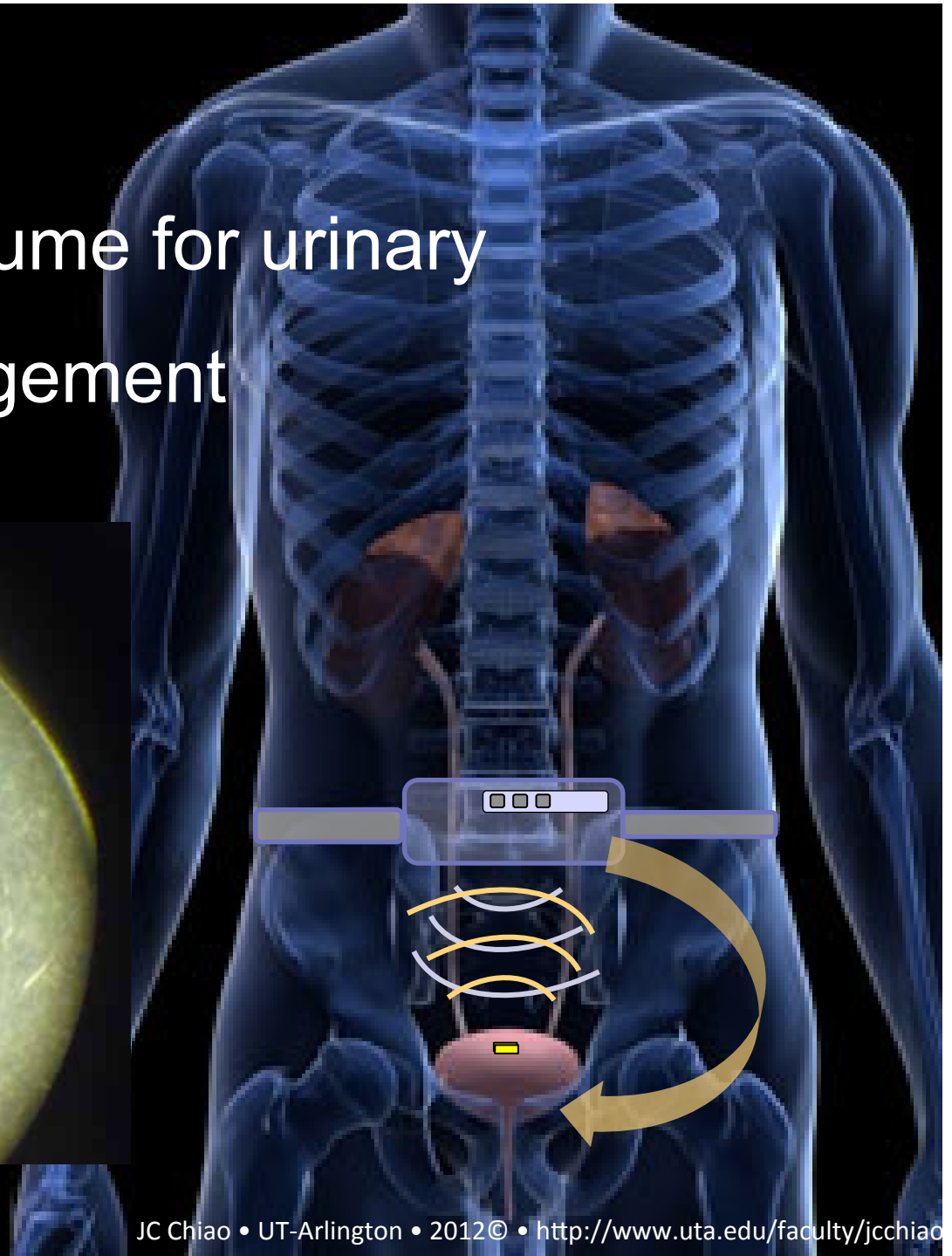
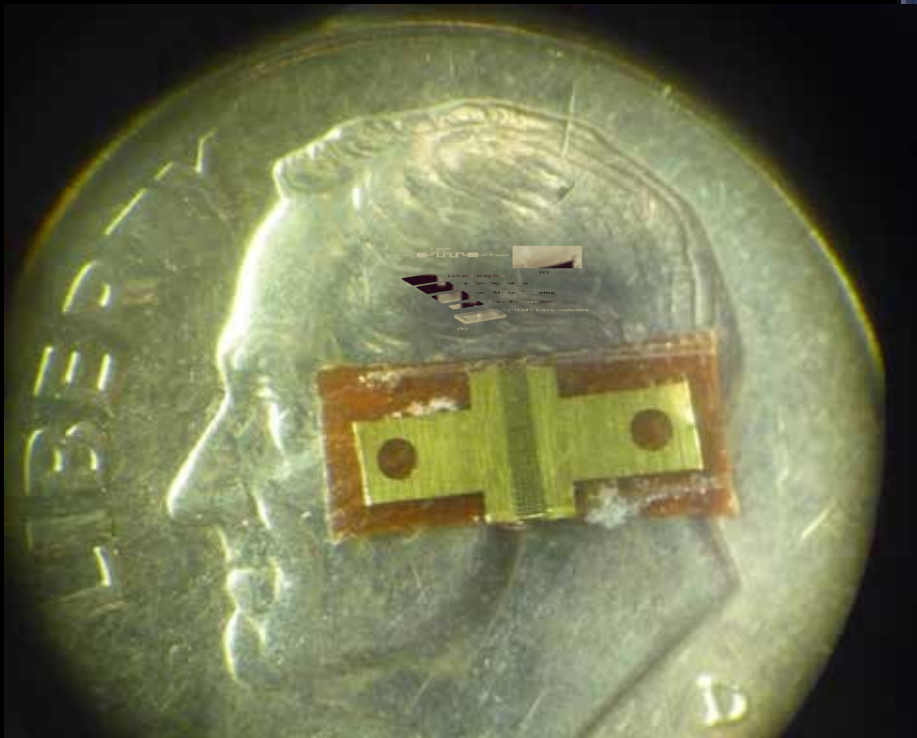
Statistical results



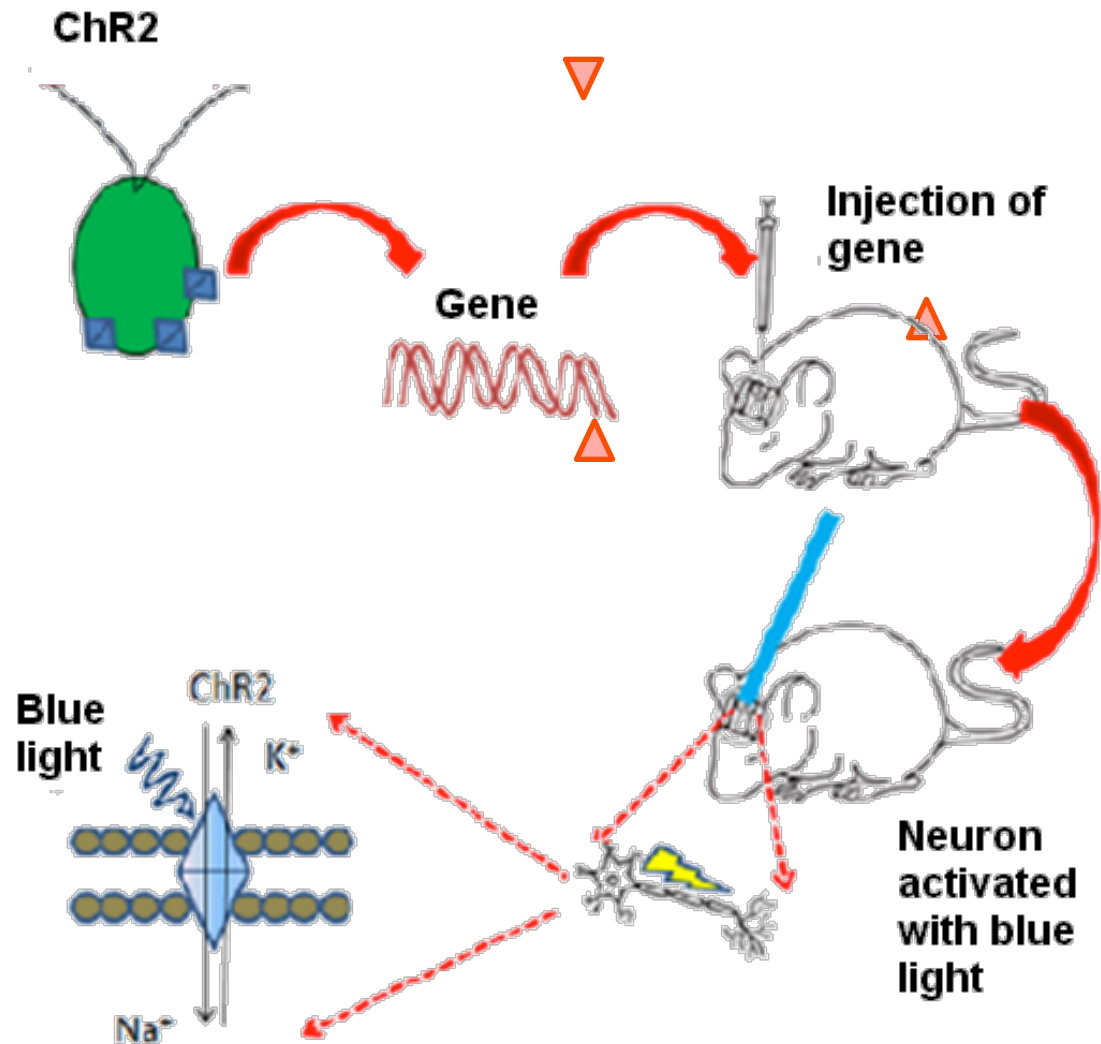
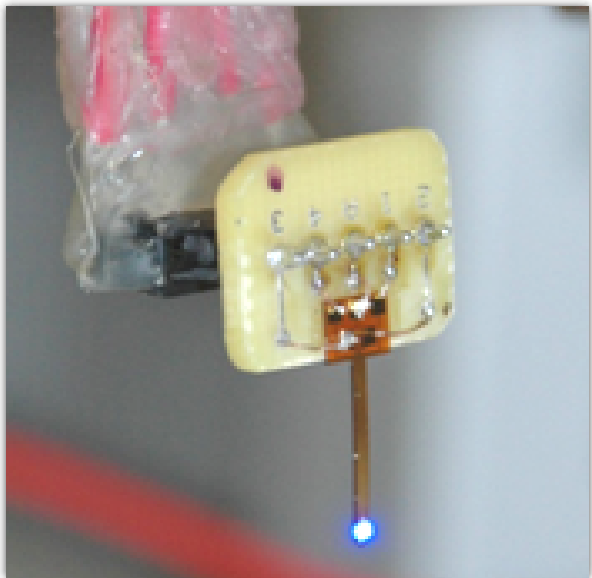
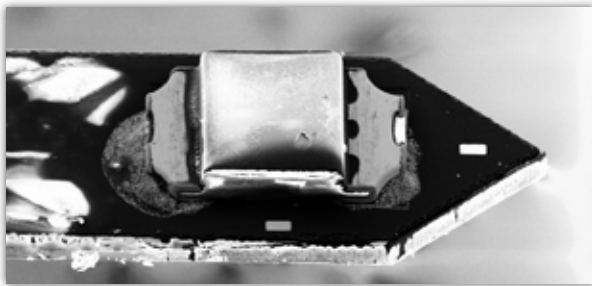
Glutamate responses to pain



Monitor bladder volume for urinary incontinence management



Wireless μ Optrode for Optogenetic Stimulation and Electrical Recording



- APRITM Automatic Pain Recognition and Inhibition
 - A closed-loop wireless system between body and computer
- BESTTM Batteryless Endoluminal Sensing Telemeter
 - GERD monitoring
 - Gastrostimulation

Batteryless Implants

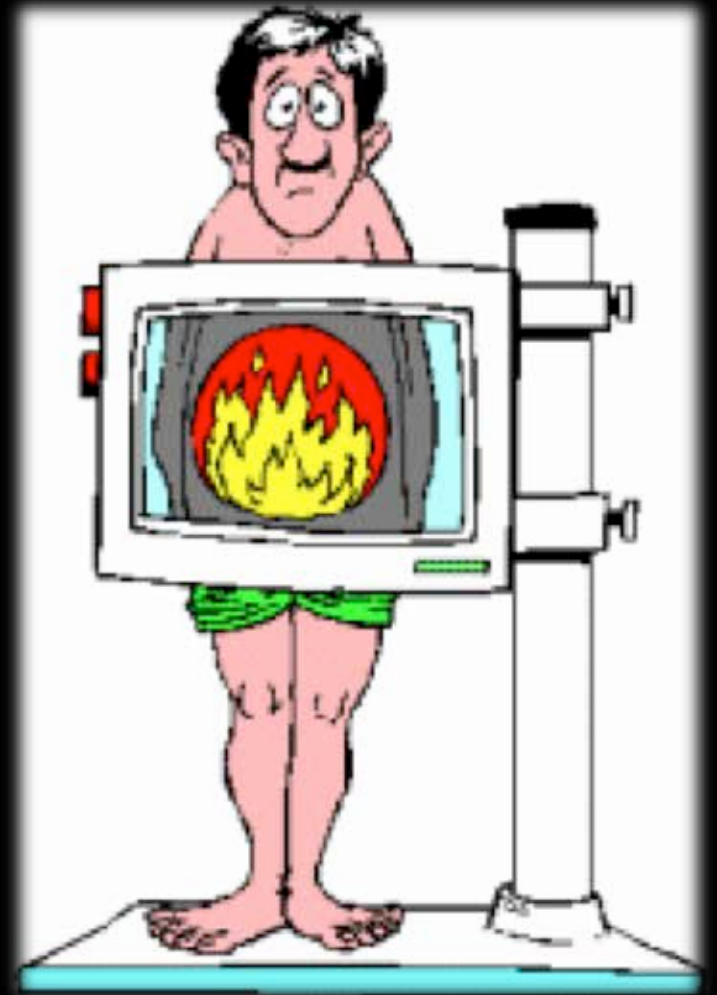
BEST™ Batteryless Endoluminal Sensing Telemeter

Dr. Shou Tang, Dr. Tom Abell, Dr. Chris Lahr,
Univ. of Mississippi Medical Center

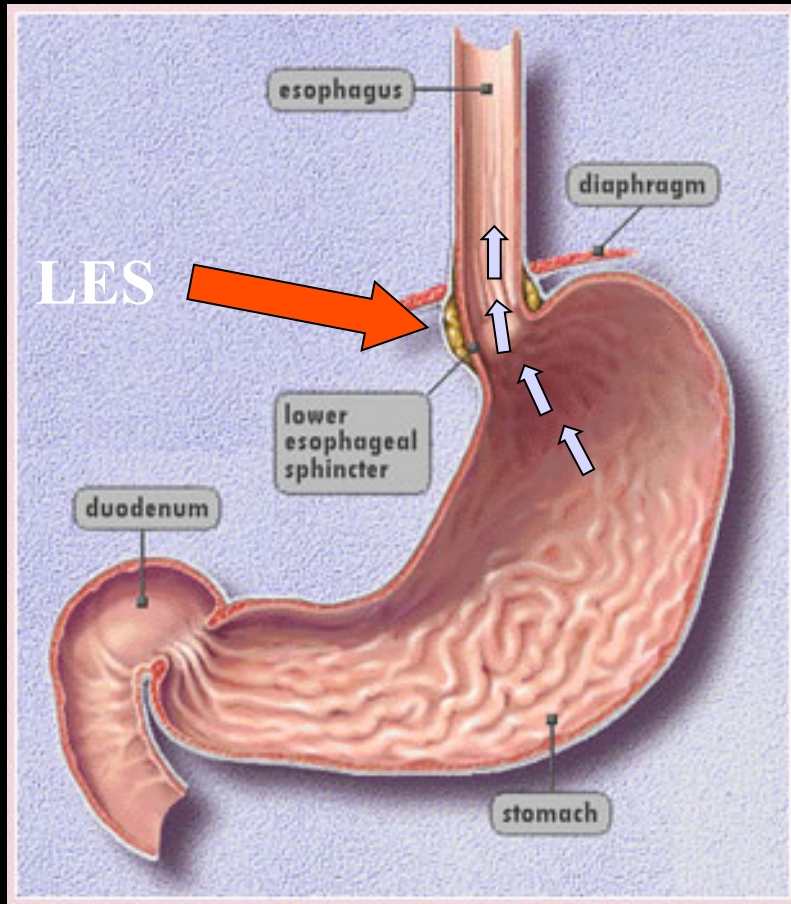
Dr. Stuart Spechler,
UT-Southwestern; VA-Dallas

Dr. Greg O' Grady,
University of Auckland, New Zealand

Dr. Rajeev Jian
THR-Presbyterian Hospital of Dallas



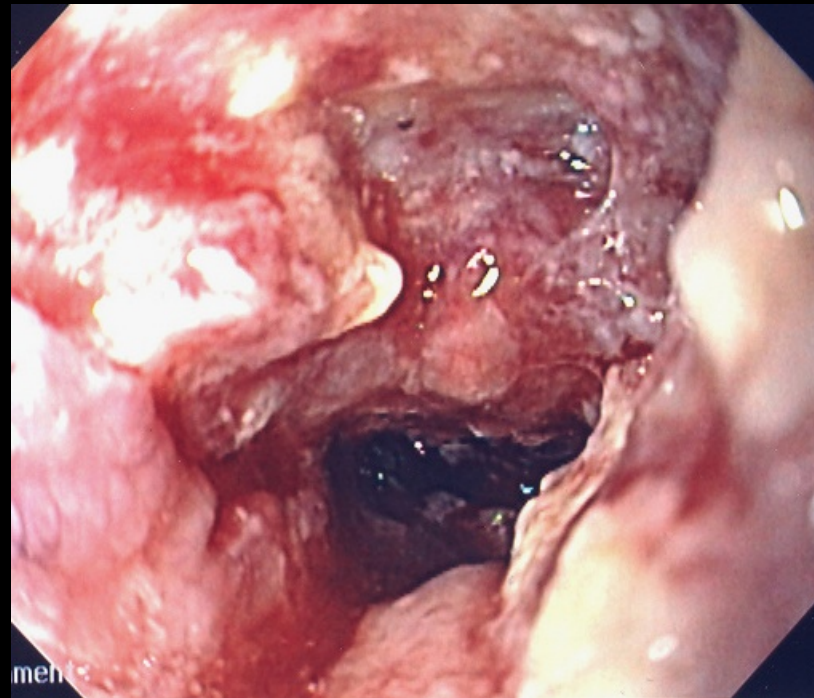
Gastroesophageal Reflux Disease (GERD)



www.GERD.com

GERD symptoms

- Heartburn
- Barrett's Esophagus
- Esophageal cancers



Gastroesophageal Reflux Disease (GERD)

Esophageal cancer

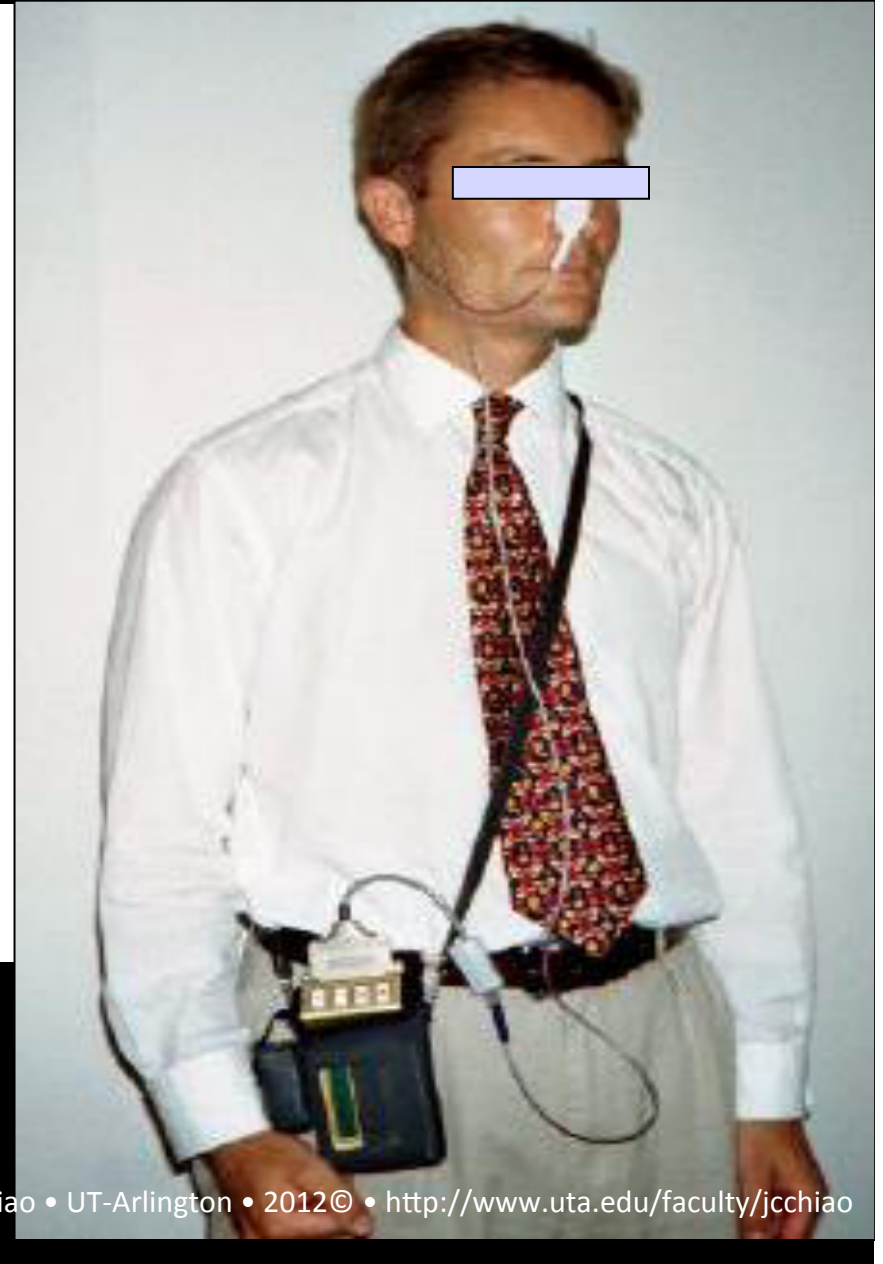
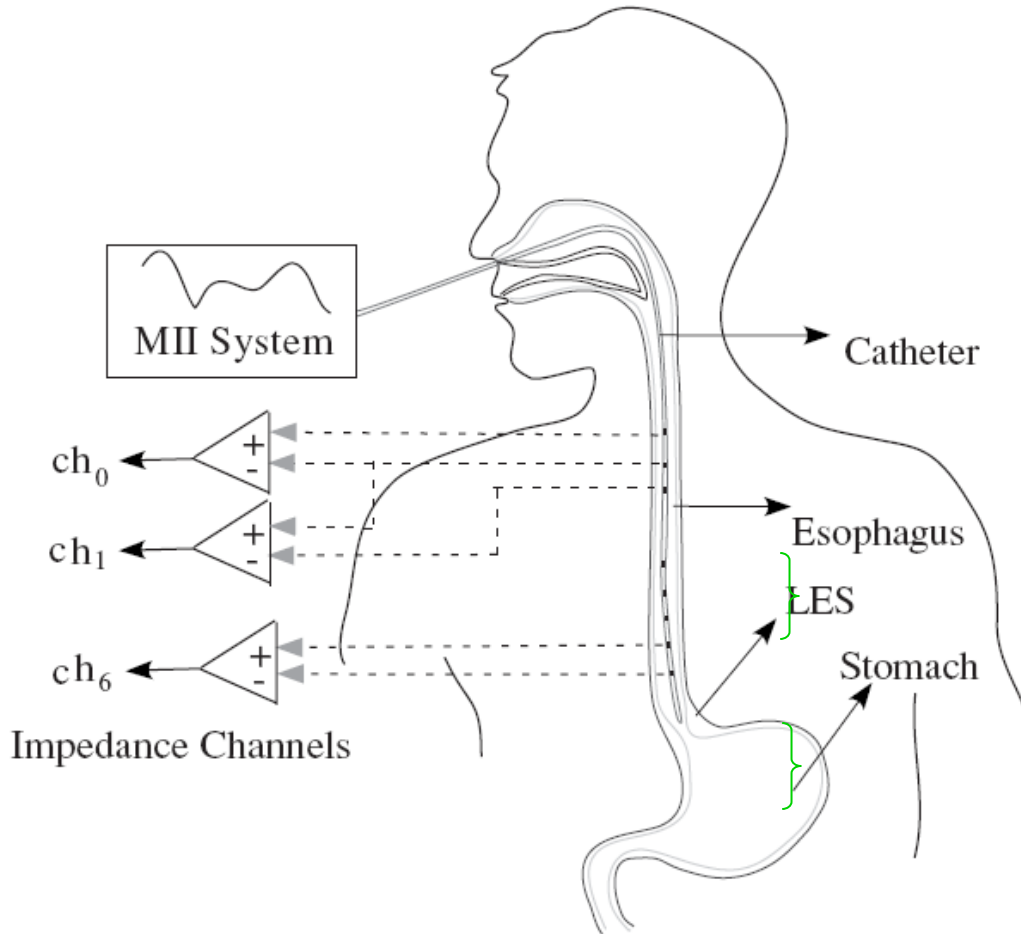
350% growth in the past 25 years

Fastest growing cancer in the developed world

Often **not curable**

19 million people in USA may have
GERD

Multichannel Esophageal Monitoring – Tethered

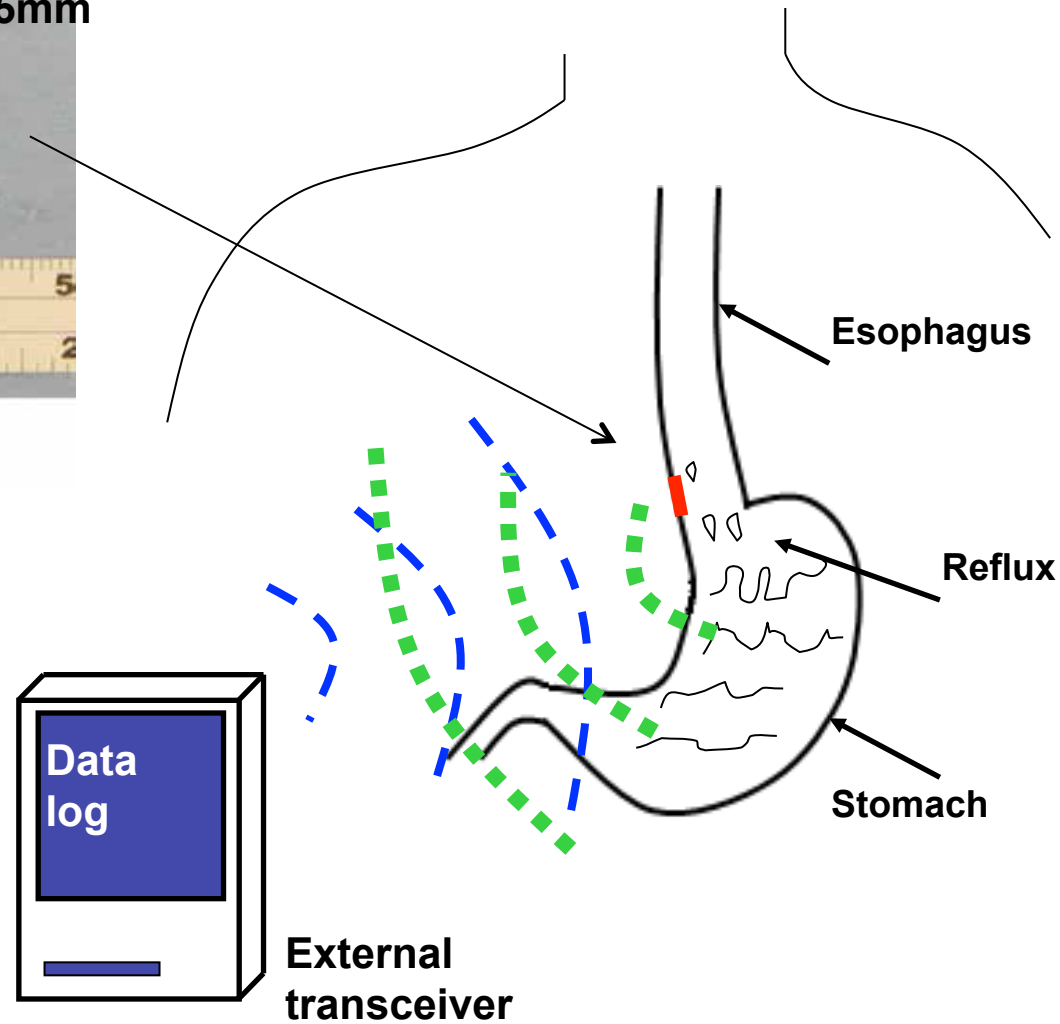


Uncomfortable

Patients limit daily activities

BEST™

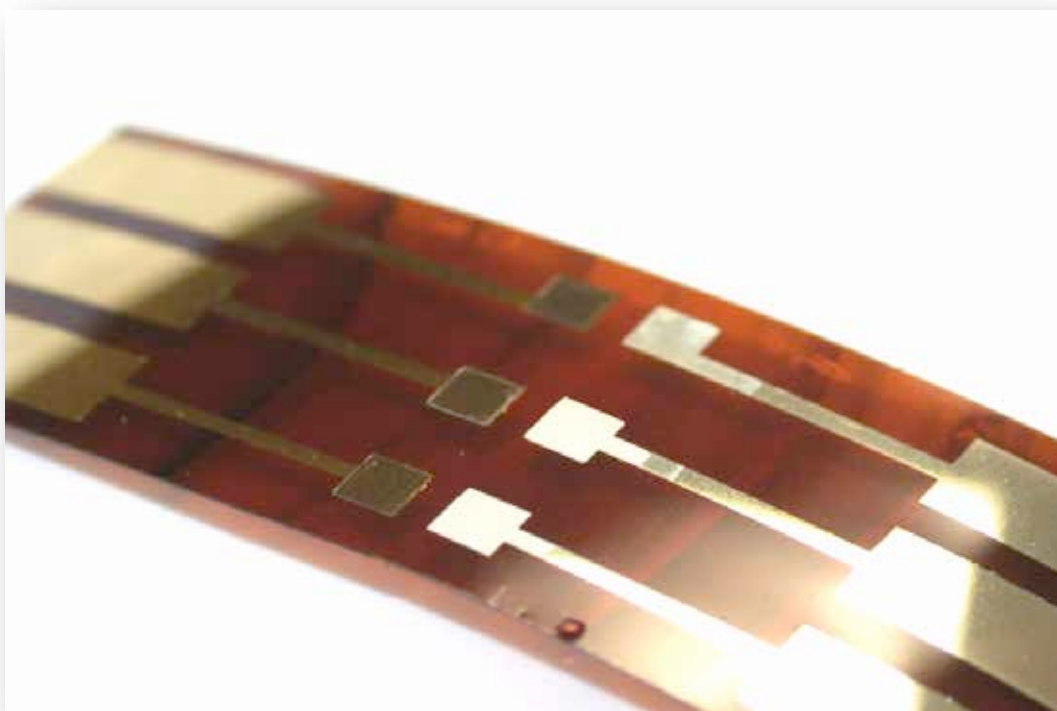
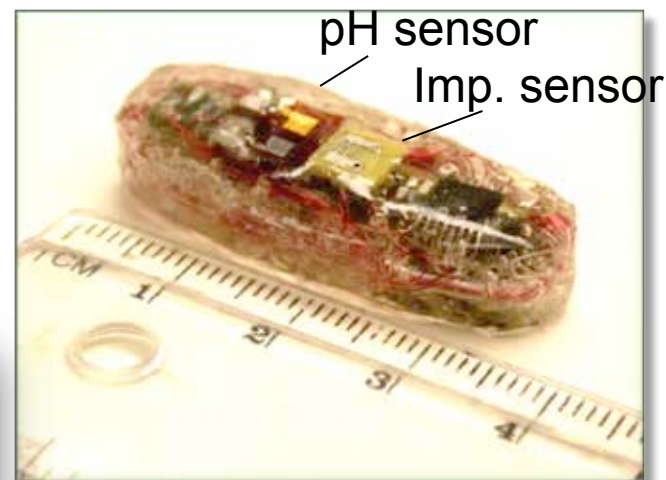
Batteryless Endoluminal Sensing Telemeter



Impedance and pH Sensors with Episodes

Dual sensors: Impedance and pH

Flexible sol-gel IrOx pH sensor



Impedance and pH Sensors with Episodes

Four sensors

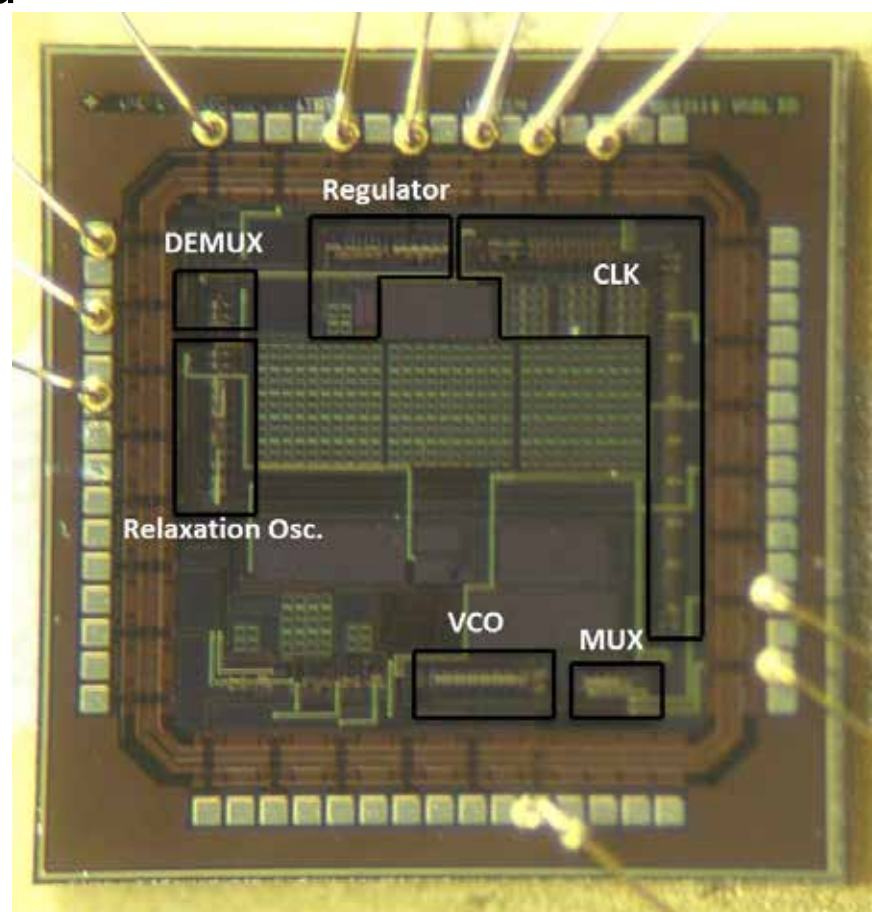
Time/Frequency multiplexed

FSK modulation

AMI 0.5 μ m (C5N)

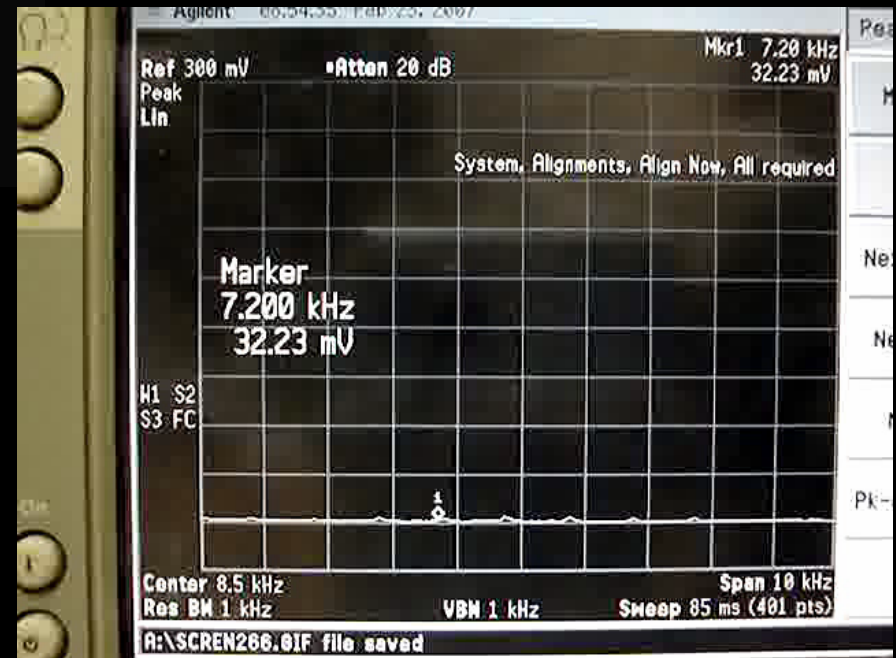
1.95mm x 1.95mm

Less than 37 μ A

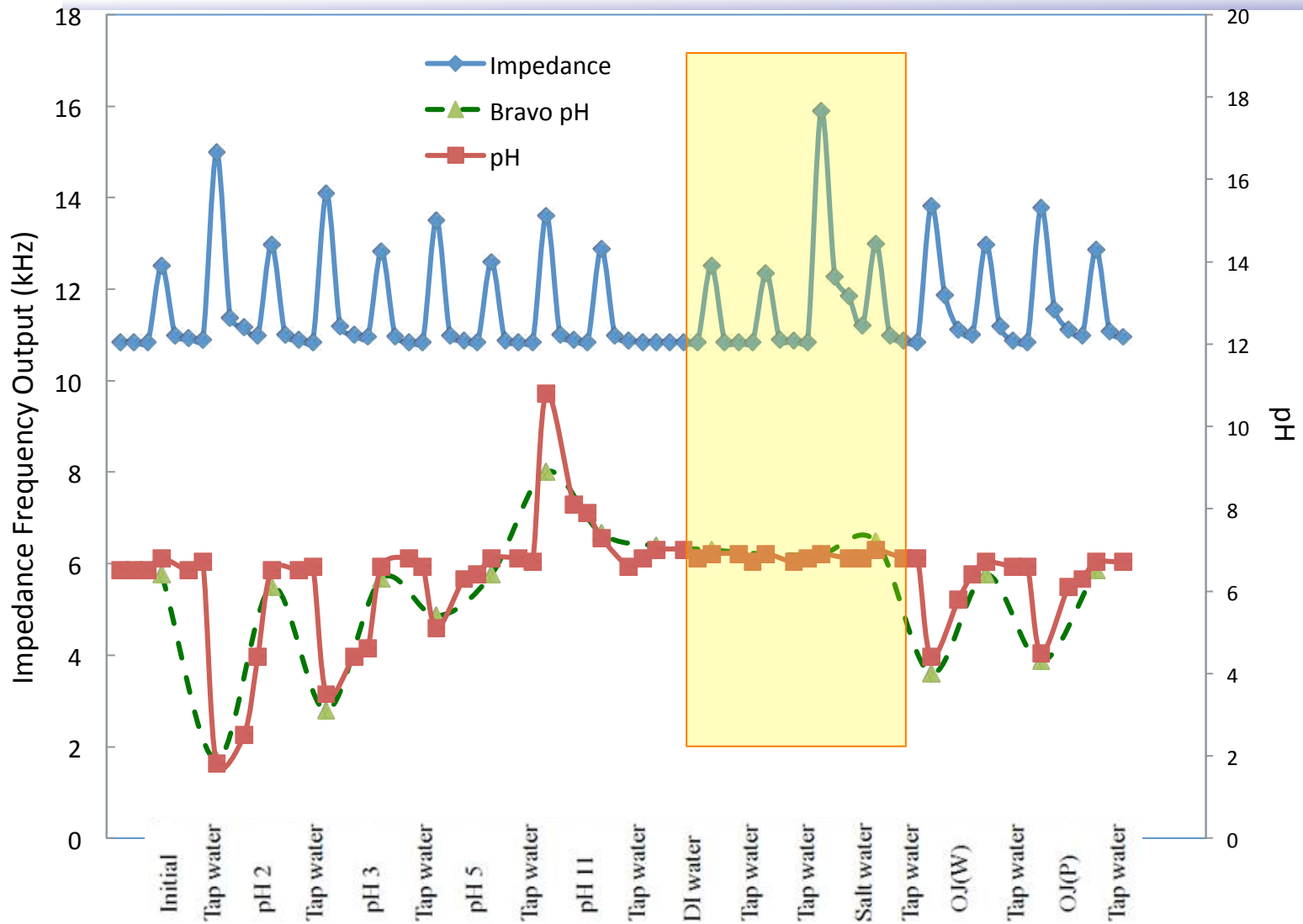


In vivo Experiments

Total Video Converter
<http://effectmatrix.com>



Impedance and pH Sensors with Episodes



- APRI™ Automatic Pain Recognition and Inhibition
 - A closed-loop wireless system between body and computer
- BEST™ Batteryless Endoluminal Sensing Telemeter
 - GERD monitoring
 - **Gastrostimulation**

Gastroparesis

Vagus nerve is damaged

- Stomach does not work properly
- Food moves slowly/stops moving
- Nausea and vomiting

171M patients in 2000

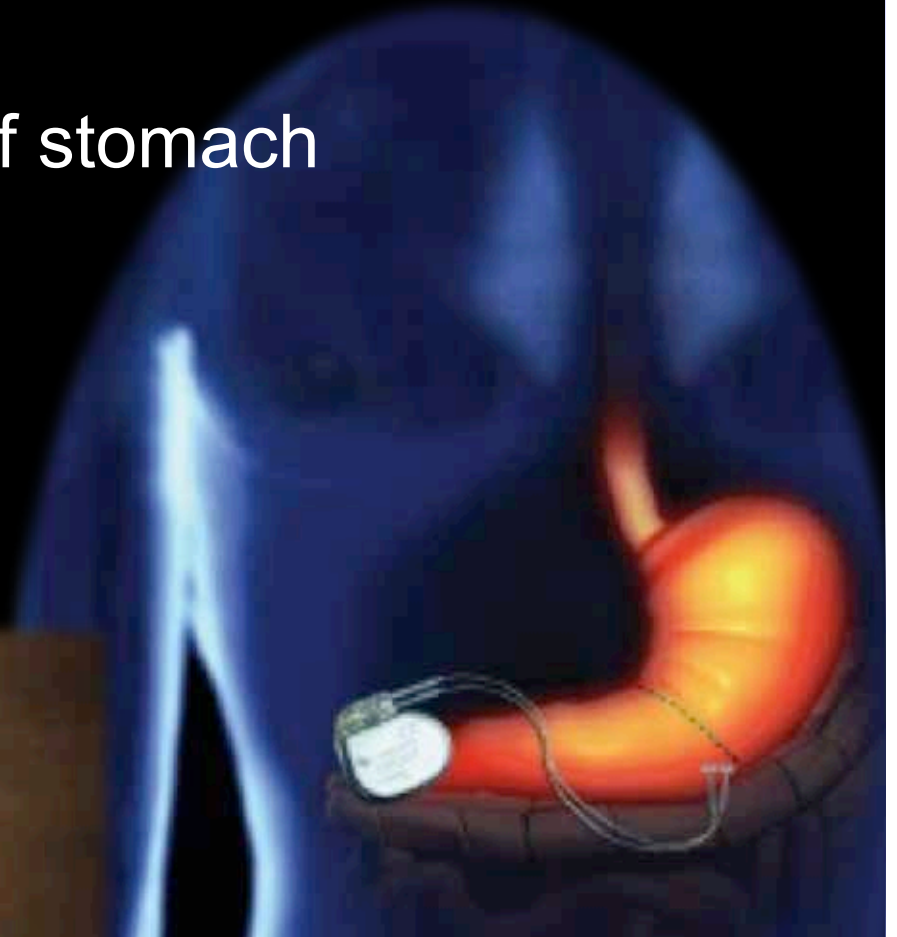
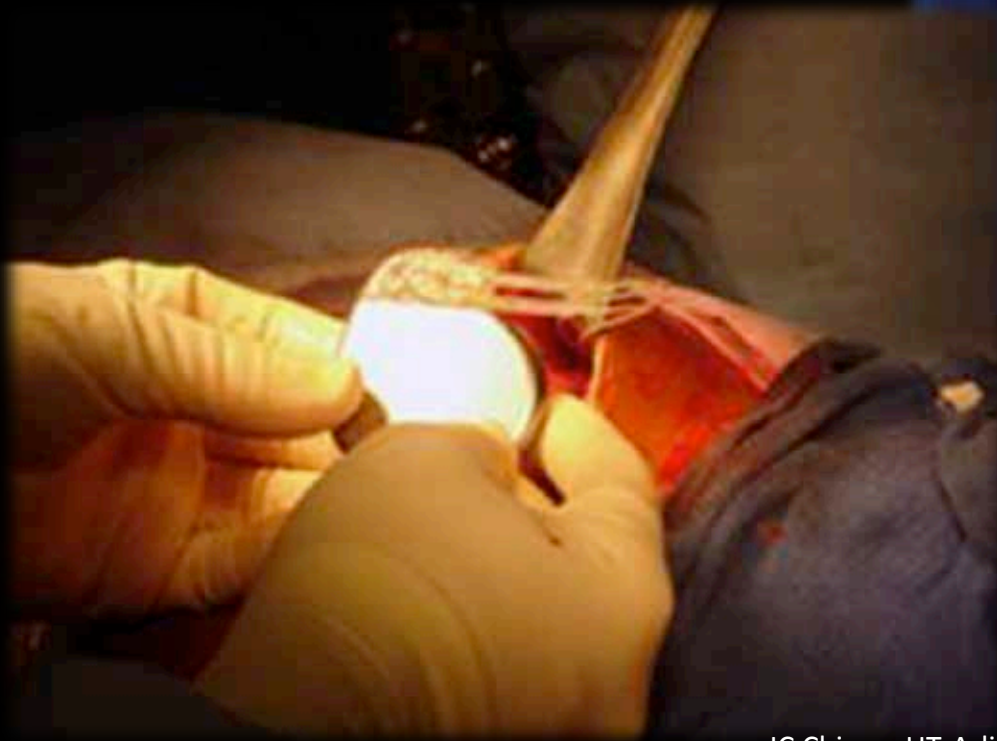
Predicted 366M patients in 2030

Co-morbidity of diabetes mellitus, whether type-I or II, is considerable to be as high as **50%**



Gastroparesis: stimulation of stomach

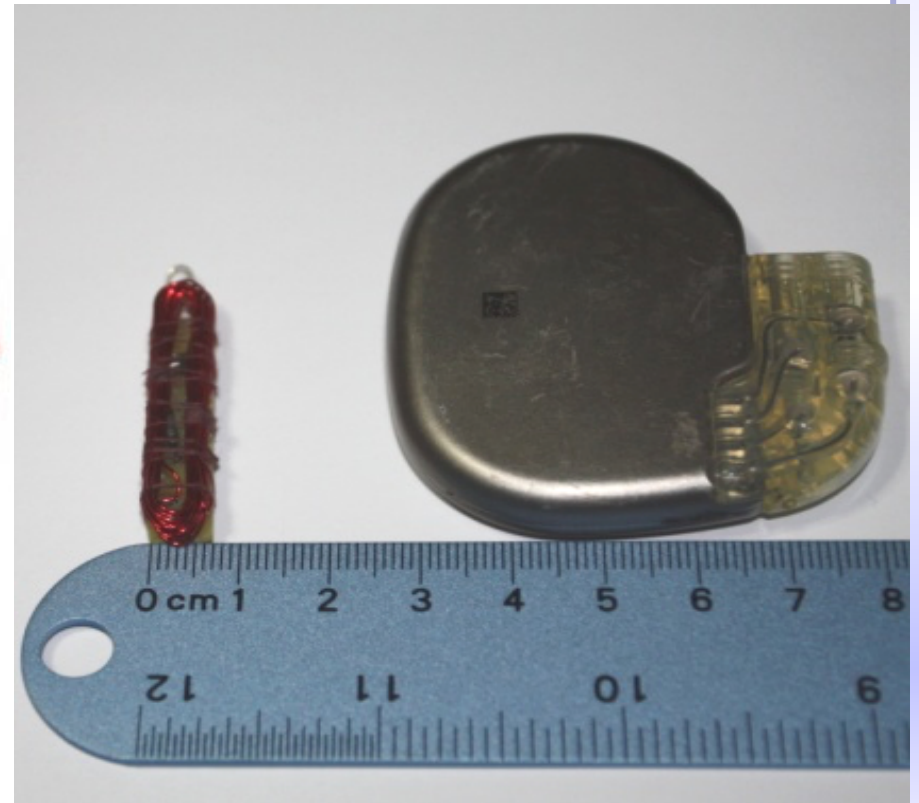
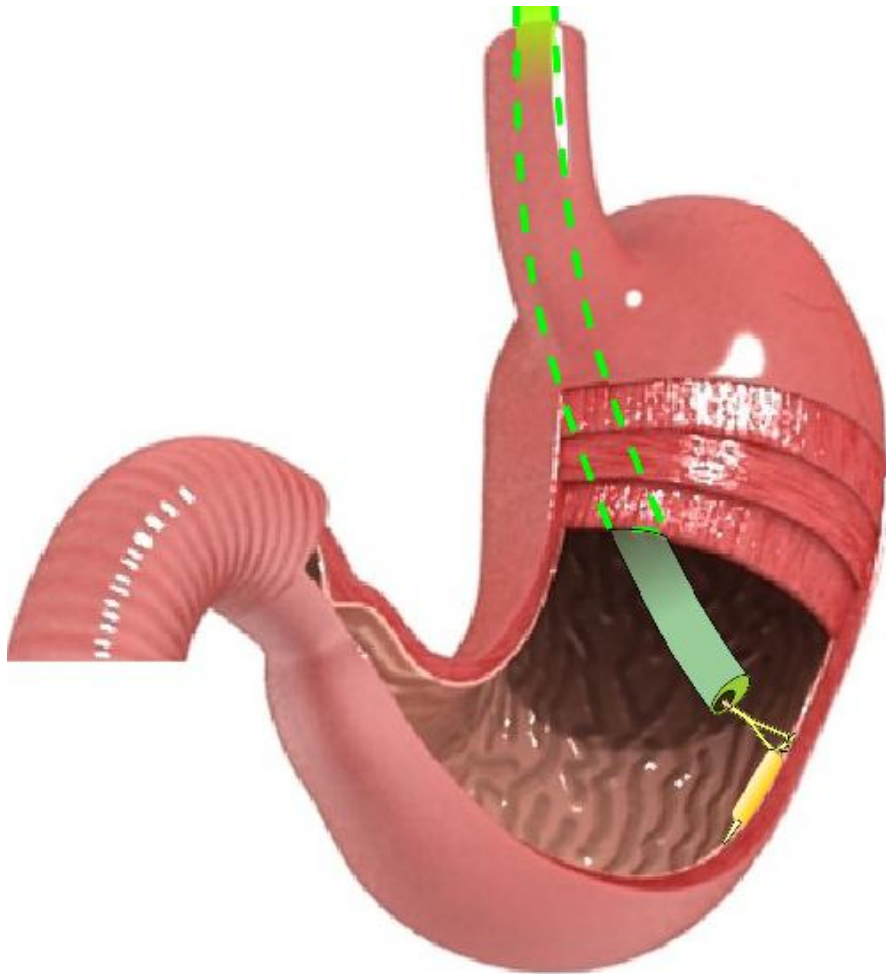
- 1–4 hour surgery
- Hospitalization for 3–4 days
- Replacement after 3–6 years



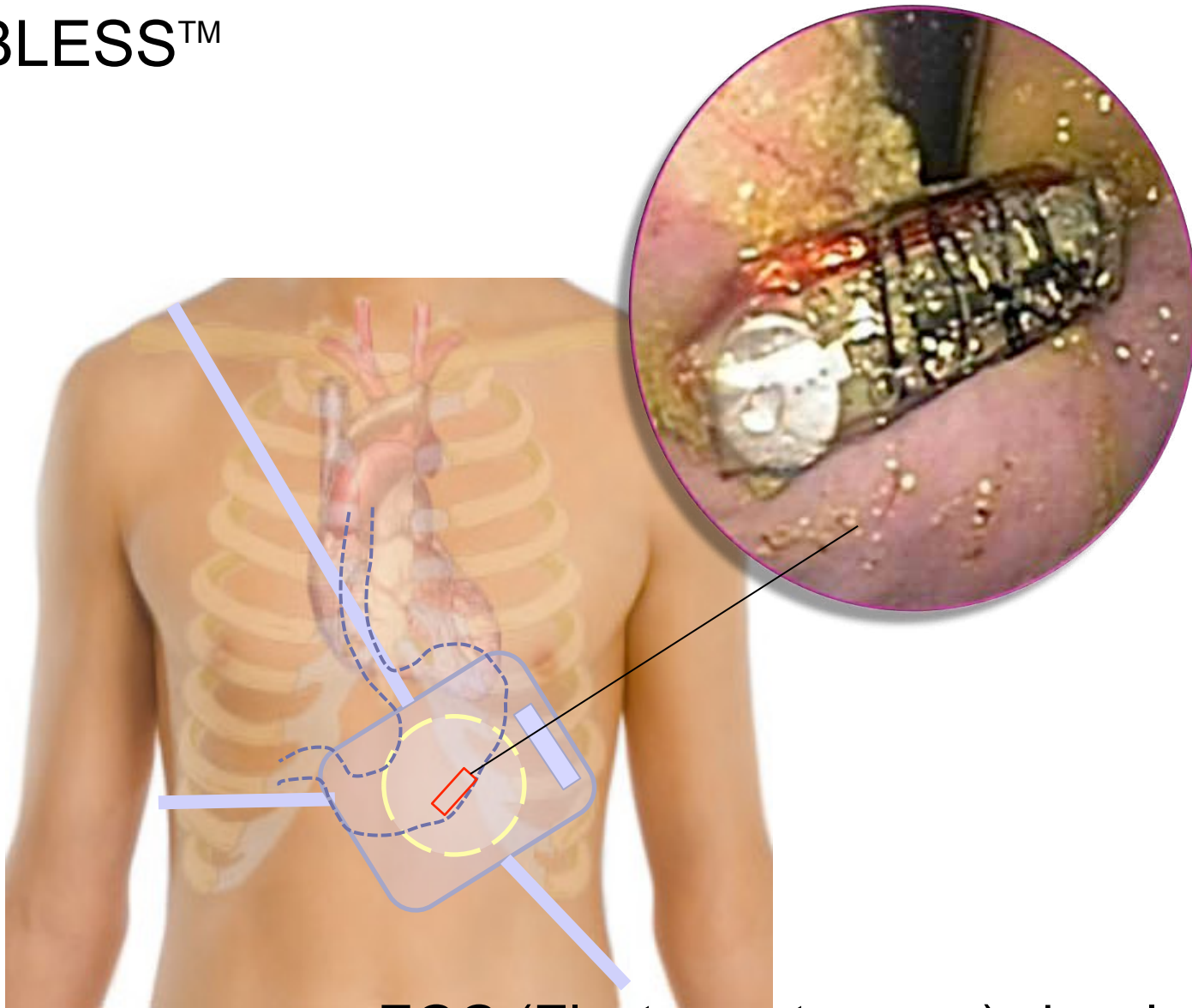
Courtesy of Medtronic

BLESS™

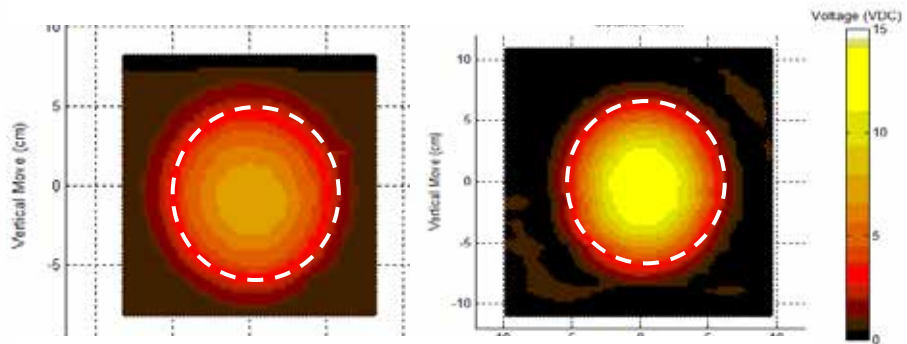
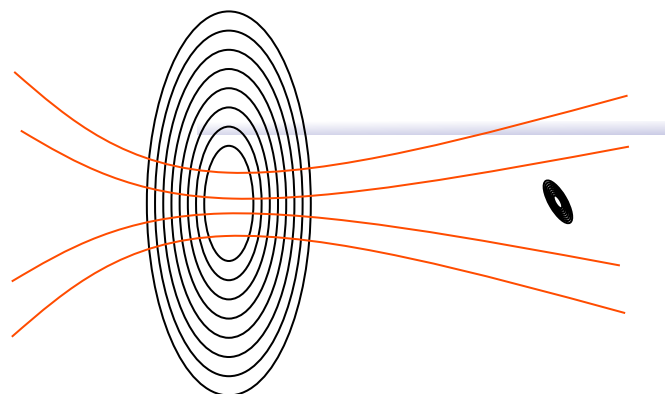
BatteryLess EndoScopically-implantable Stimulator



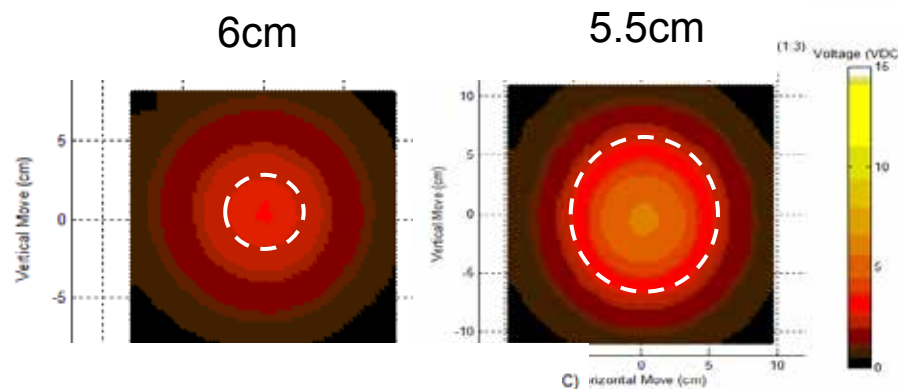
BLESS™



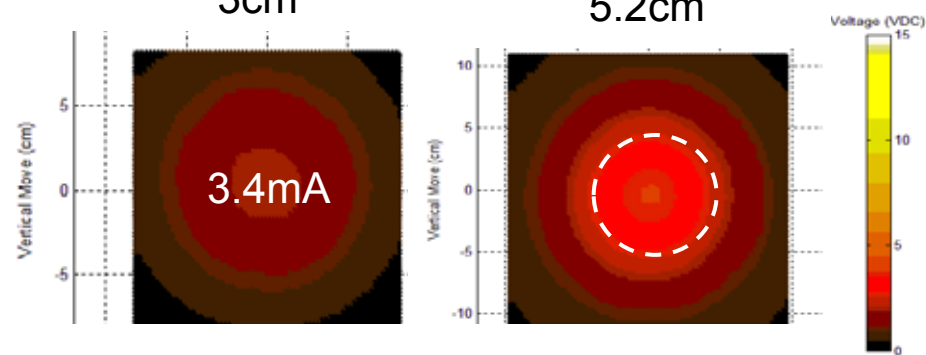
EGG (Electrogastrogram) signals modified



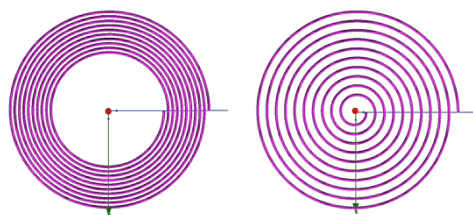
4cm



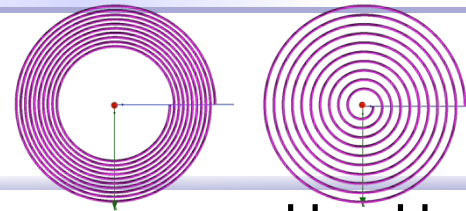
8cm



10cm

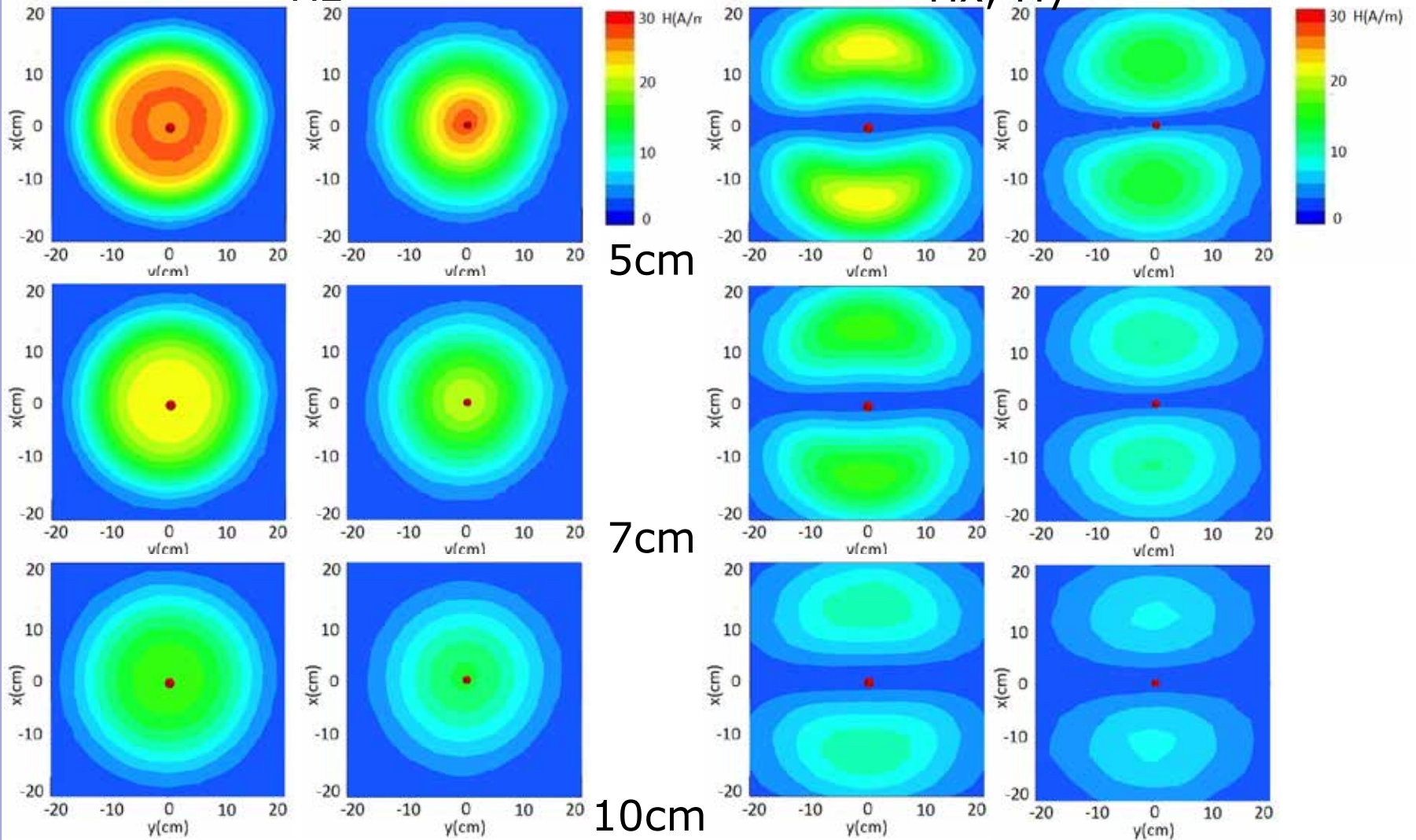


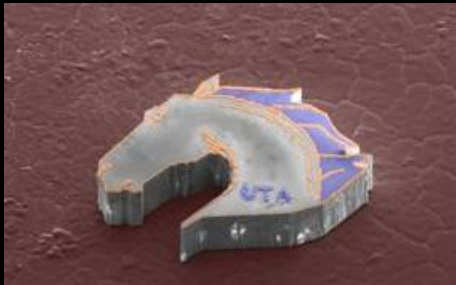
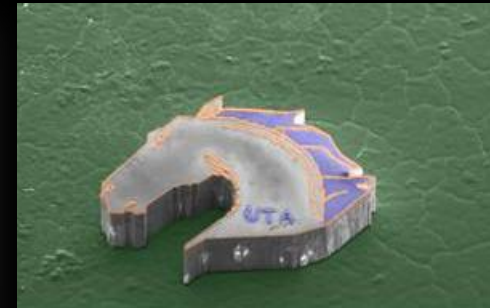
Field distributions



H_z

H_x, H_y





<http://www.uta.edu/faculty/jcchiao/>