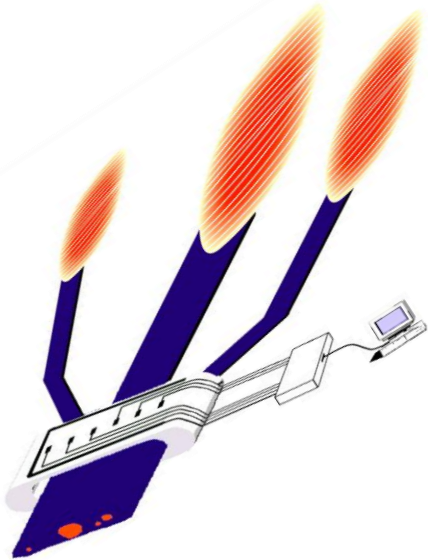


Engineering Prosthetic Systems to Repair the Nervous System



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USA

Neural Prostheses In a Nutshell

Success Story

Problems that will be solved

Problems that can be solved

More Difficult Problems

Basic Mechanisms, New Tools

Obstacles:

Future Directions:

Auditory Prosthesis

Obstructive Sleep Apnea

Pain

Bladder Control

Retinal Prostheses

Neural Interface with brain

Neural Interface with the PNS

Autonomic Nervous System Disorders

Spinal Cord Injury and Paralysis

Stroke (Disphagia, motor-sensory, ...)

Epilepsy

Cognitive Prostheses: hippocampus, Alzheimer,..)

Neurooptics: Optogenetics and optical stimulation

Modelling

Functional Genomics

Hermeticity

Biocompatibility

Selectivity

Electrodes and Materials

Hybrid Technology

Closed-Loop System for Obstructive Sleep Apnea

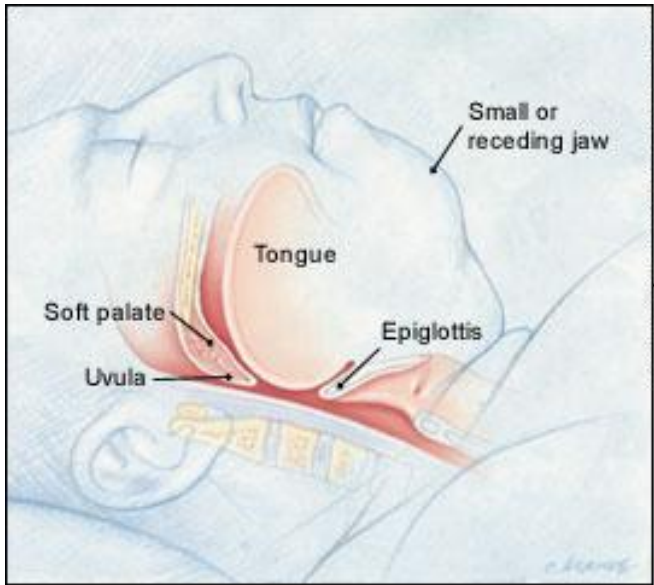
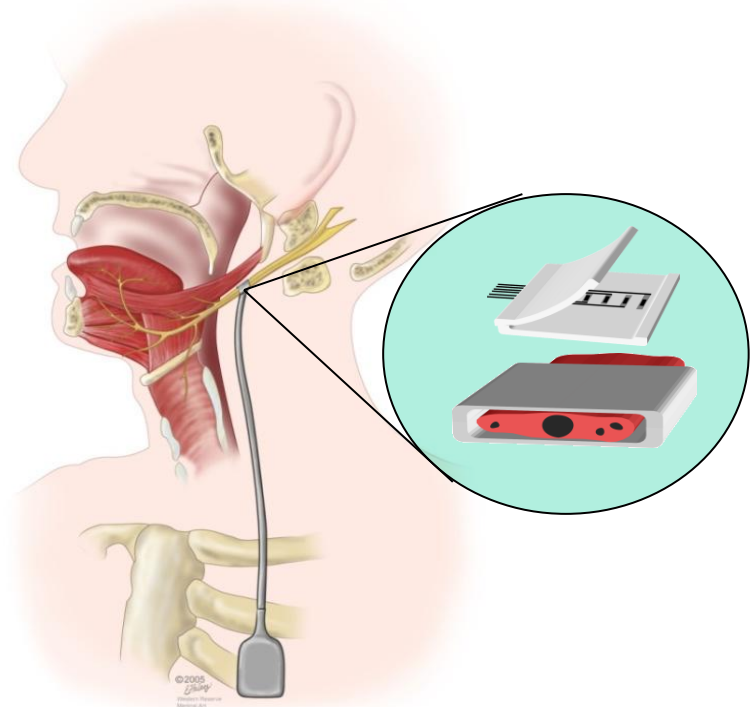
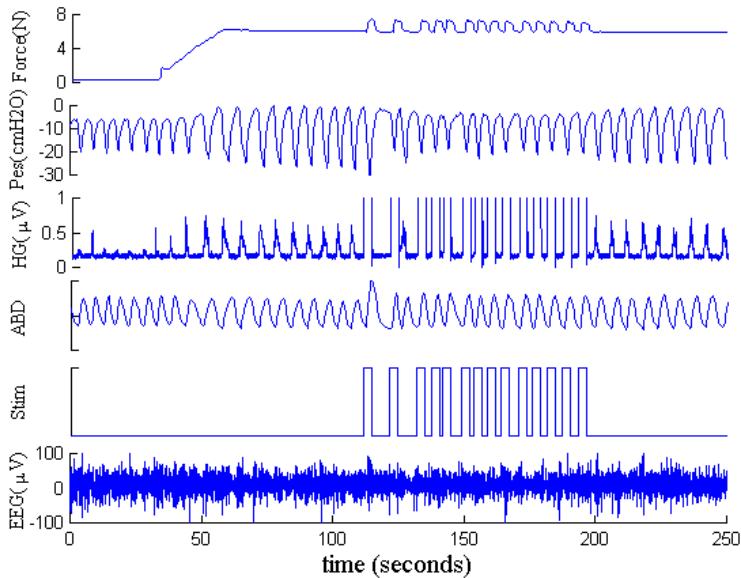


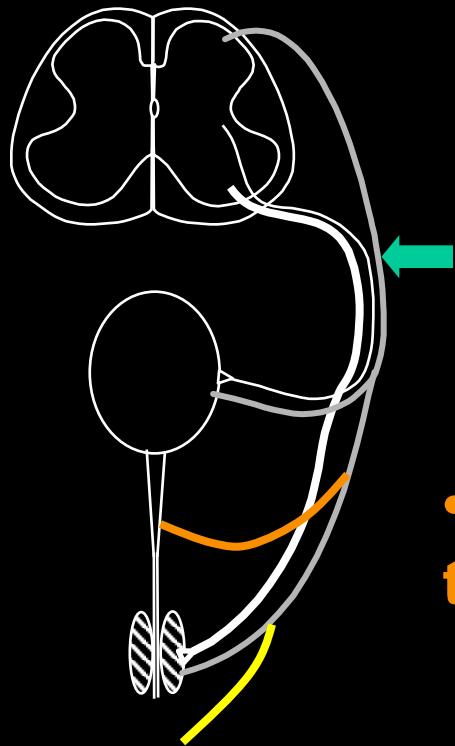
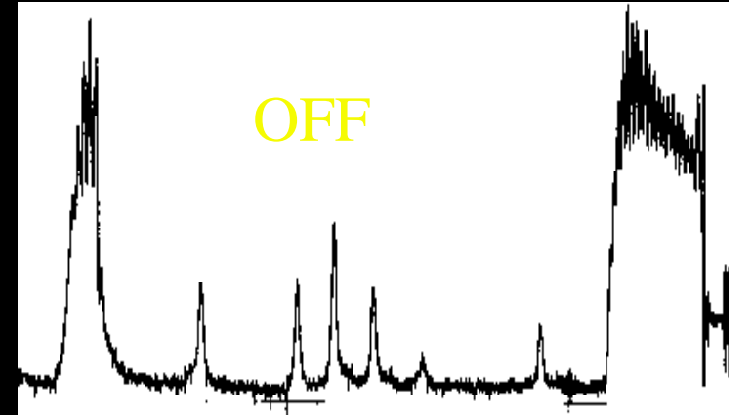
Illustration © 1999 Christy Krames

8 Million Americans with untreated severe OSA



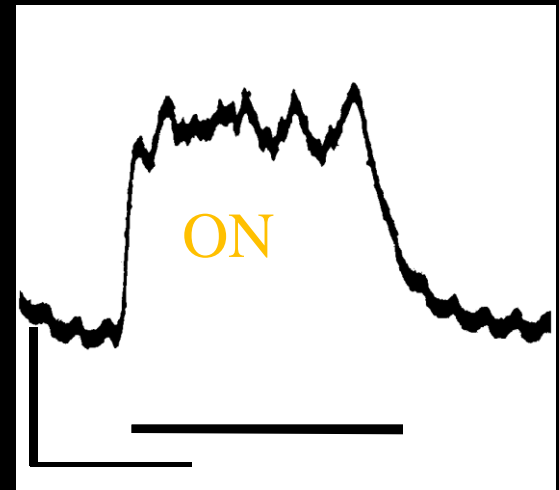
Bladder Control: Continence and Micturition

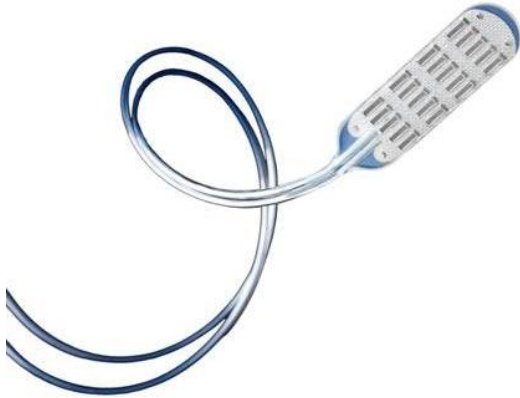
- stimulate sensory 1 to abolish contractions



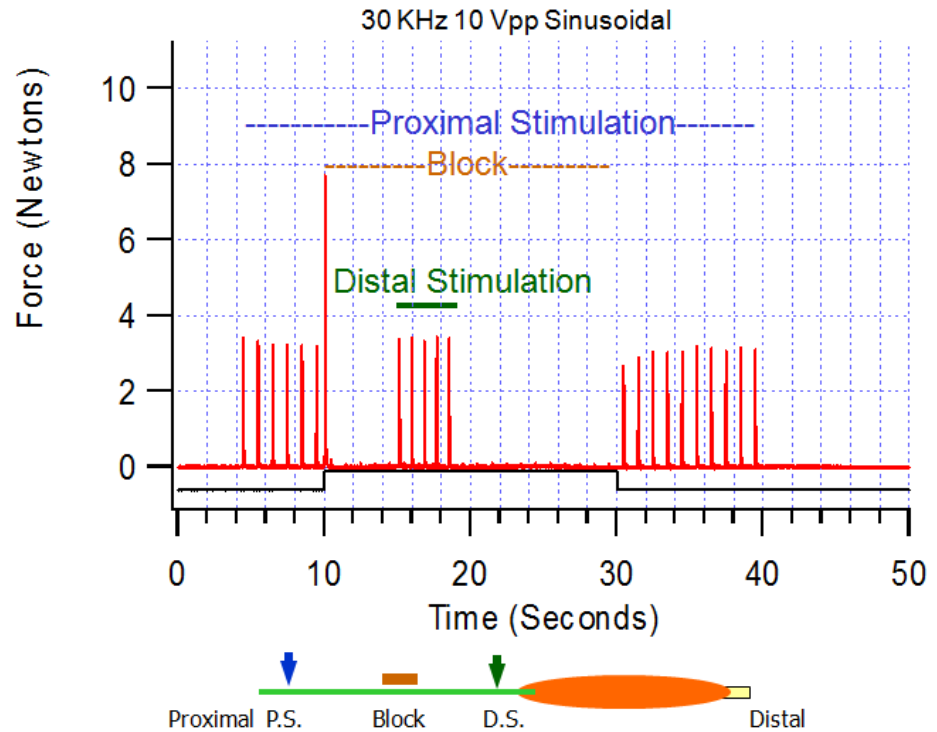
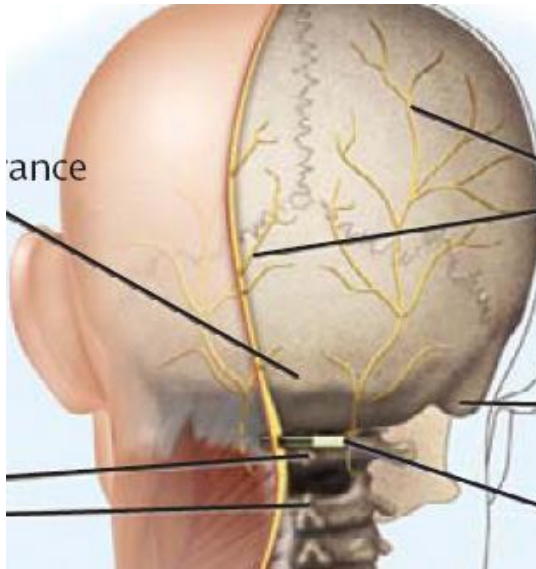
1 2

- stimulate sensory 2 to induce micturition





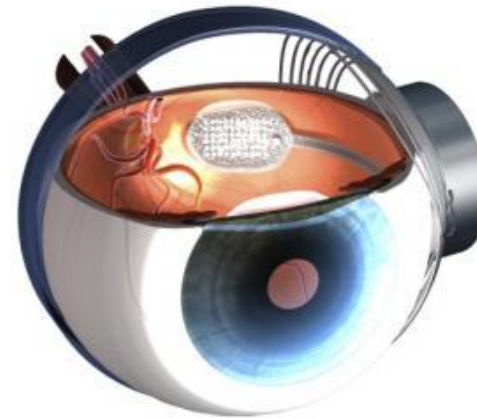
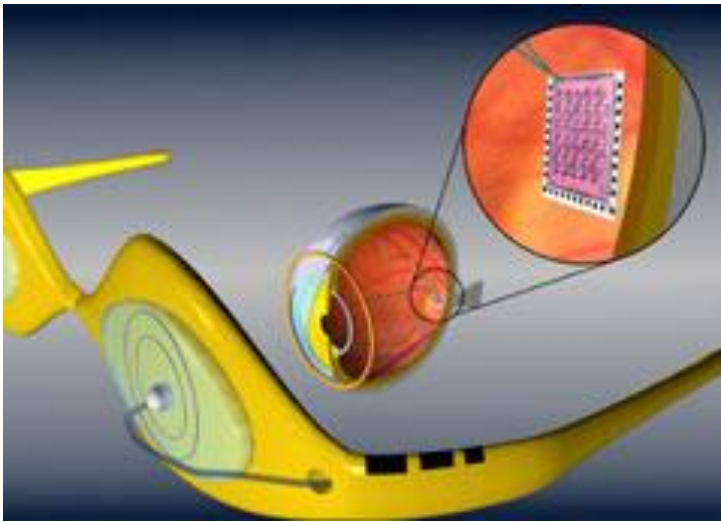
Spinal Cord Stimulation (Penta Electrode StJude-ANS)



Bhadra & Kilgore: High-frequency electrical conduction block of mammalian peripheral motor nerve.

Muscle and Nerve 2005

Retinal Prostheses

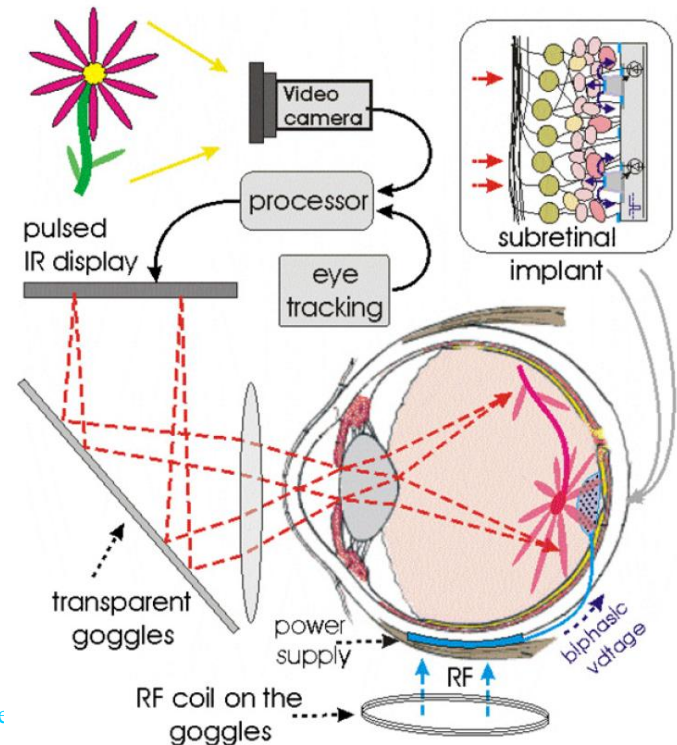


Second sight:

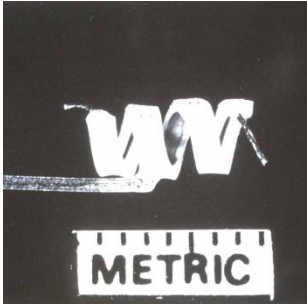
http://medgadget.com/archives/2007/01/second_sight_me.htm
<http://www.sciencedaily.com/releases/2009/10/091021012847.html>

Initial studies, started in 2002, with six patients and a sixteen electrode device have provided blind subjects with basic object recognition.

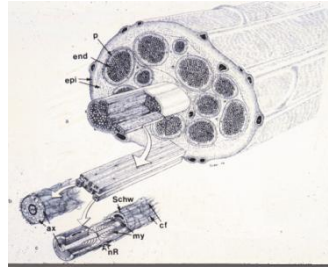
Optoelectronic retinal prosthesis: system design and performance J D Loudin, et al, *J. Neural Eng.* 4 No 1 (March 2007) S72-S84



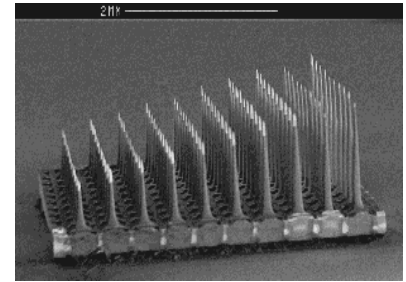
Neural Interface with the PNS



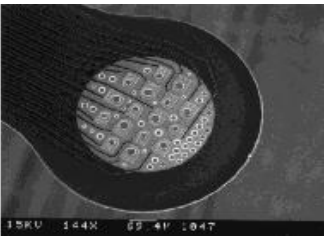
Huntington's Helix



Nerve Injury and Repair, Lundberg, 1988



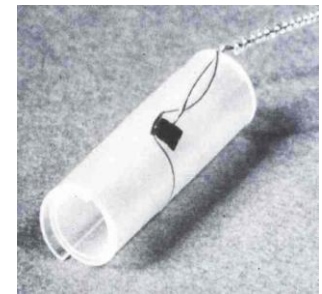
Utah Slanted Array



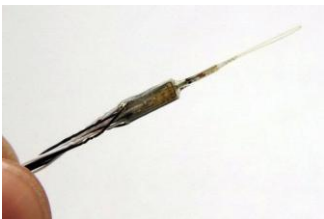
Michigan Sieve



Tyler and Gustafson



Spiral CWRU

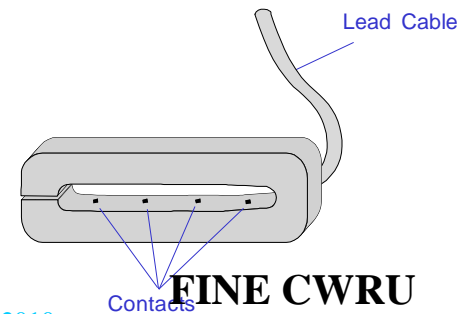


Utah LIFE



Park and Durand

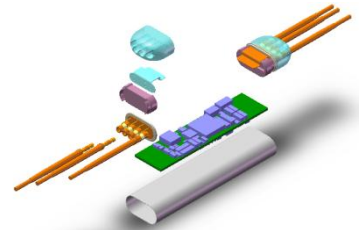
© Dominique Durand, NEC CWRU, 2010



FINE CWRU

Neural Prosthesis for Spinal Cord Injury

Hand grasp/release
 Elbow extension
 Cough
 Postural stability
 Turning over
 Bladder/bowel control



Walking



Shoulder Control

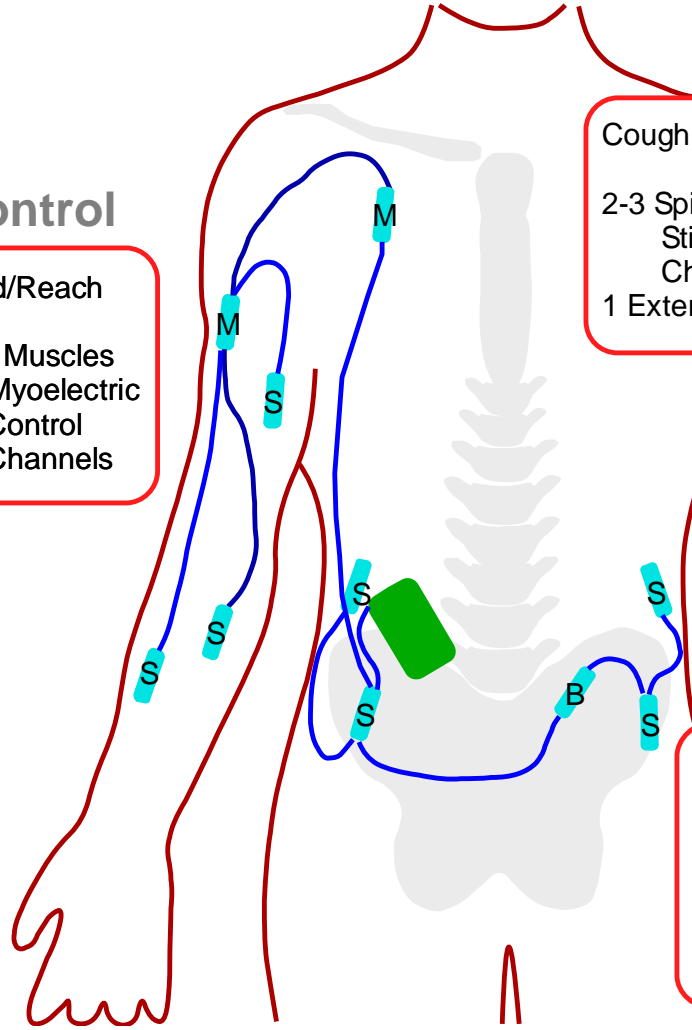


Hand/Reach
 8-12 Muscles
 2-4 Myoelectric Control Channels

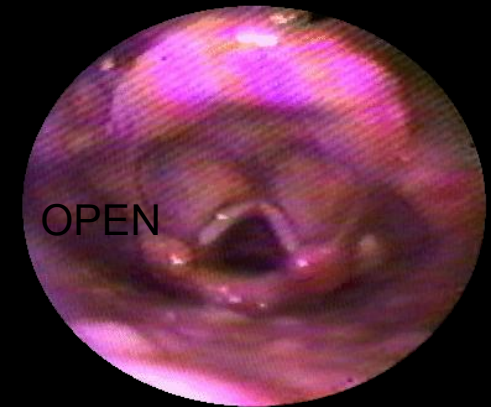
Cough
 2-3 Spinal Cord Stimulation Channels
 1 External Switch

Bladder/Bowel
 3 Spinal Root Stimulation Channels
 2 Nerve Block Channels
 1 External Switch

Trunk Support
 4-6 Muscles Per Side
 1-2 Myoelectric Control Channels
 1 External Switch



Stroke and Dynamic Control of the Larynx



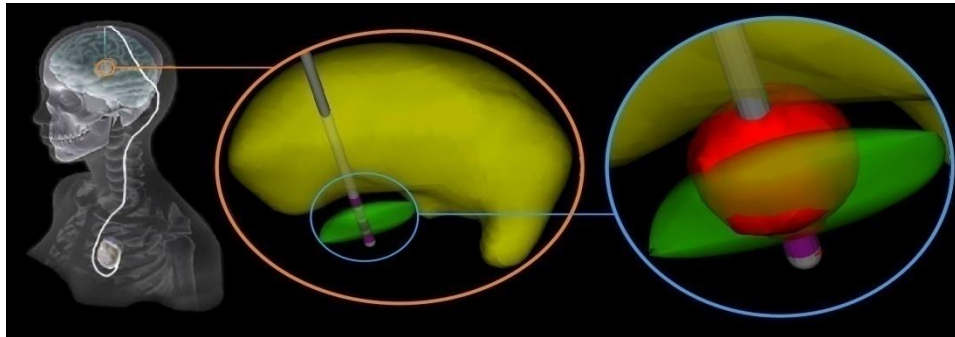
Applications :

- Prevention of aspiration
- Dynamic airway opening
- Restoration of voice
- Automation of swallow

Tyler, D CWRU

Detection and Control of Seizures

CENTRAL
Focus
Thalamus
Hypothalamus



Deep Brain Stimulation, C. McIntyre

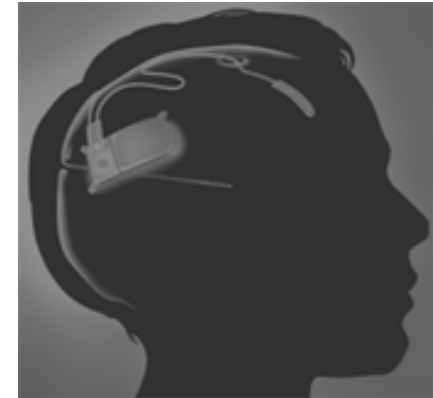
Many targets have been tried with limited success.

PERI-PHERAL
Vagus nerve
Trigeminal



Cyberonics, Vagus Nerve Stimulation

About 43% responders, with 50% decrease in seizure activity; About 20% with $\geq 75\%$ seizure reduction

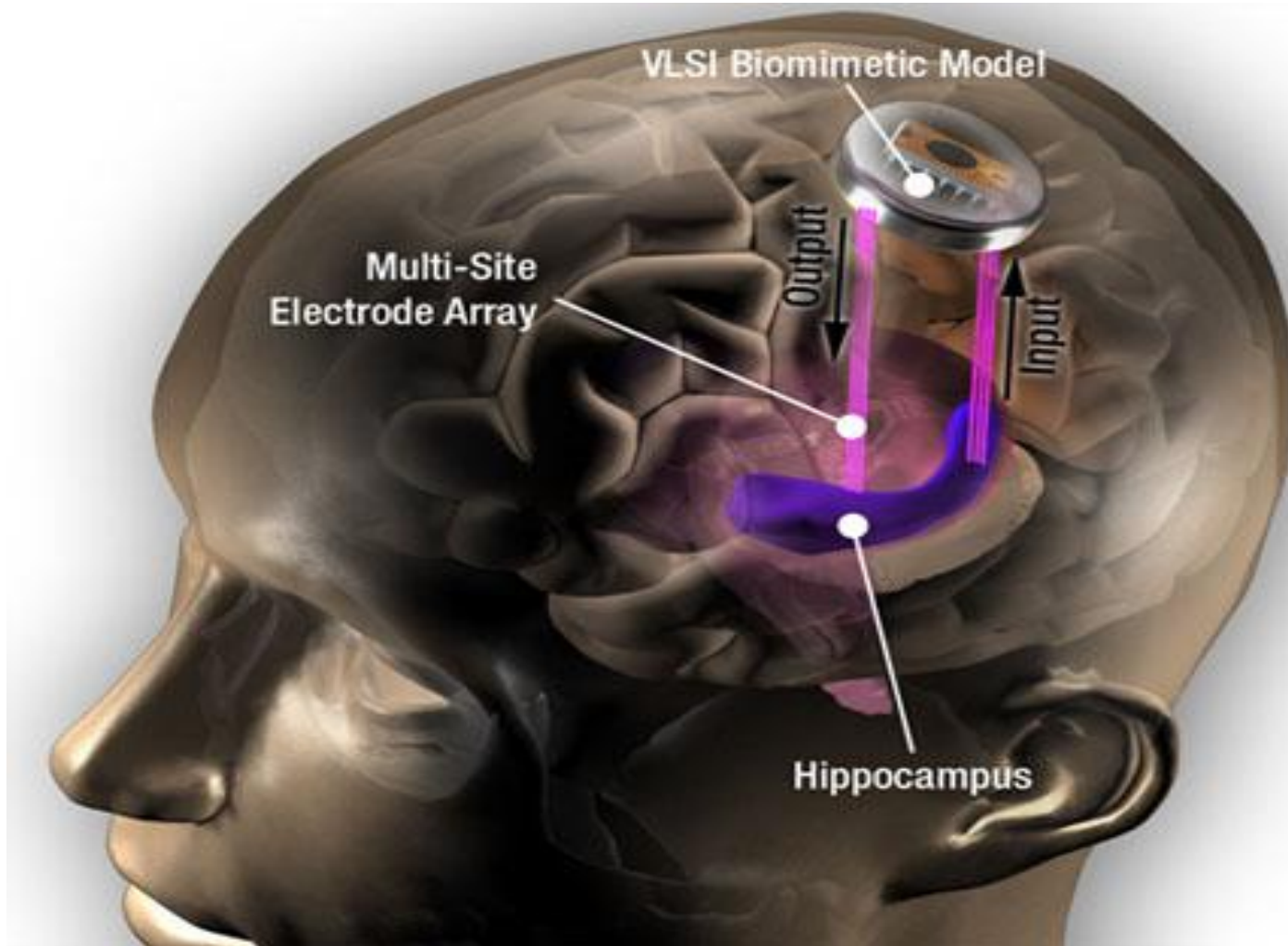


NeuroPace.com Close loop stimulation/detection system.

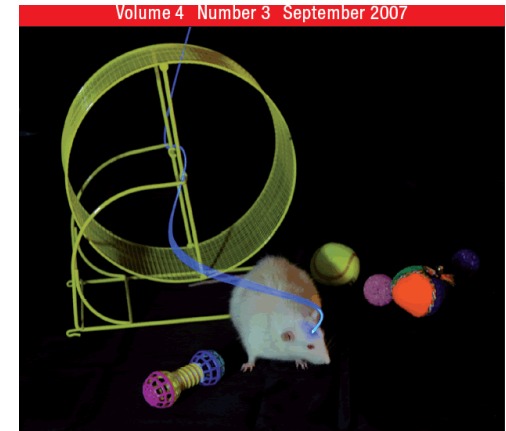
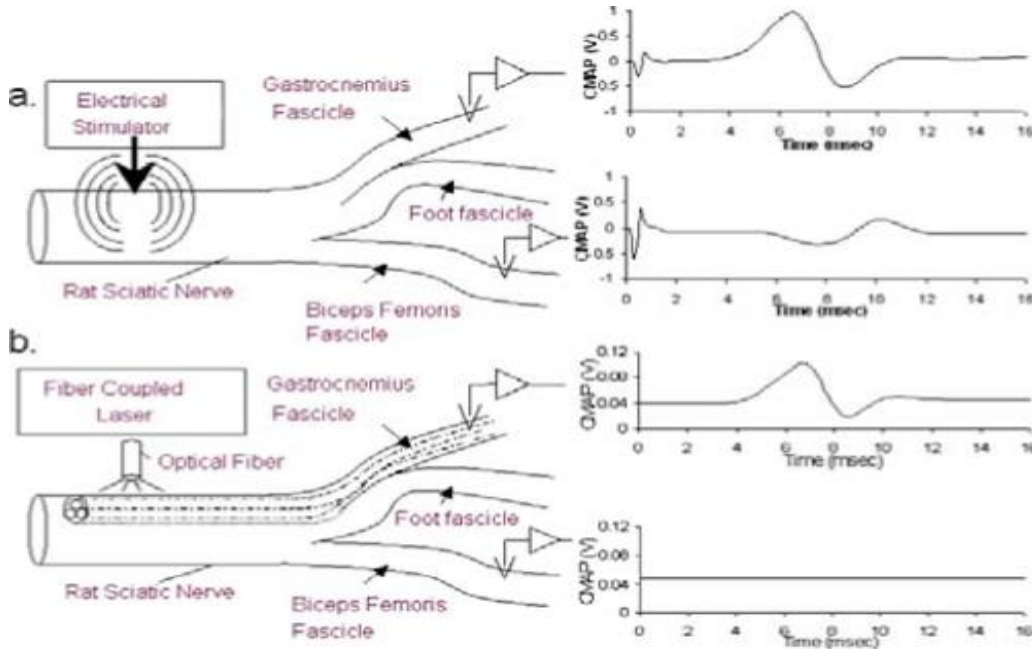
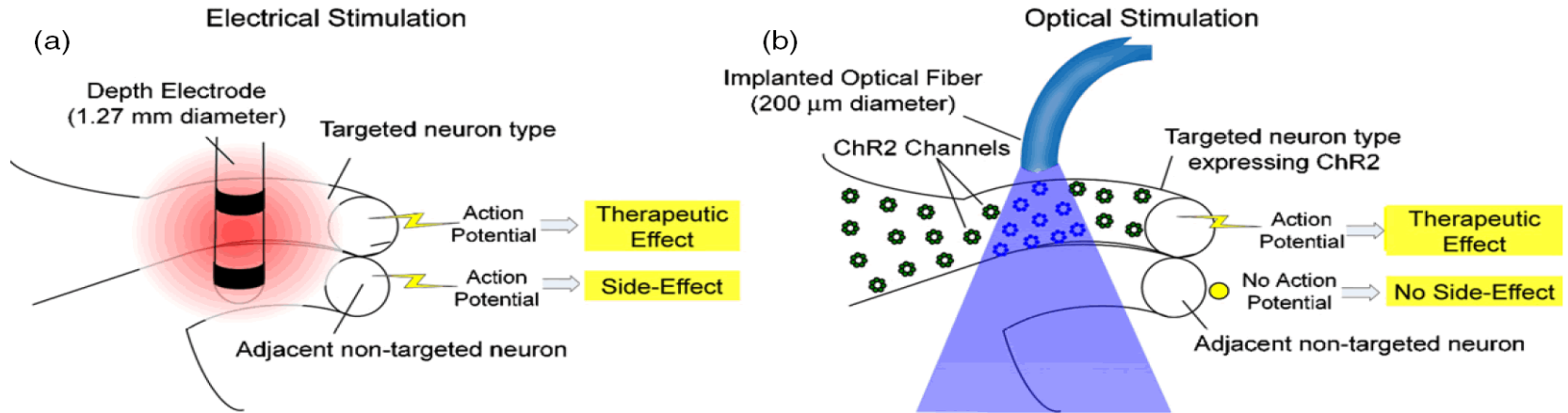
Target yet to be determined. Success unknown

Barkley et al. (2006 AES) RNS (trade) system produced 35% reduction of disabling seizures

Cognitive Prostheses

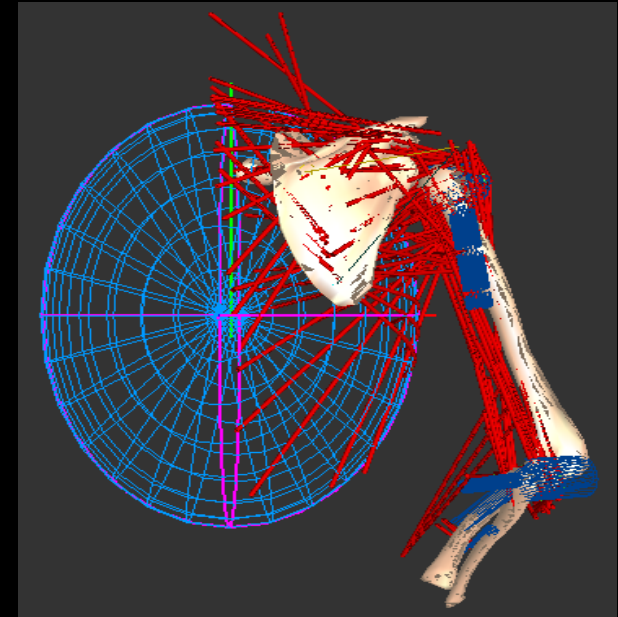
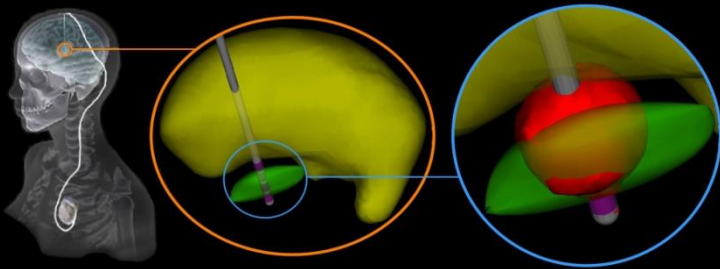


New Tools: Optical Neural Engineering

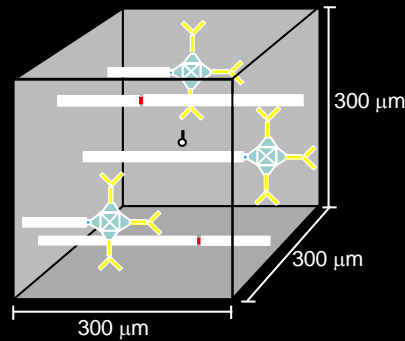
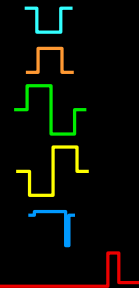
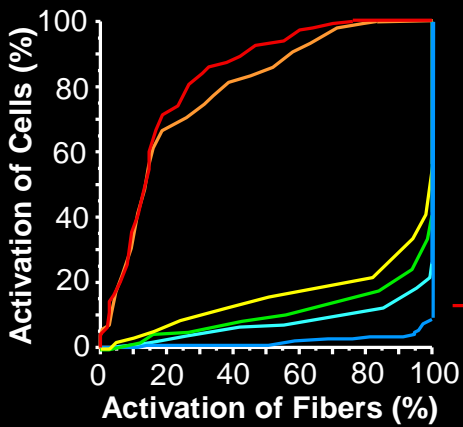


jne.iop.org
Avaranis et al, 2007, Journal of Neural Engineering, 143-165

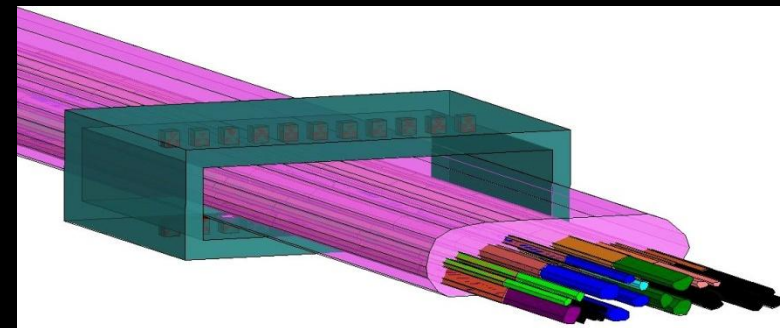
Neural Modelling



Kirsch's Lab

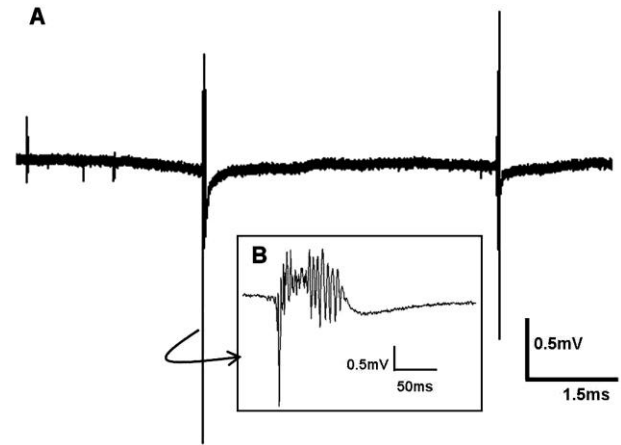
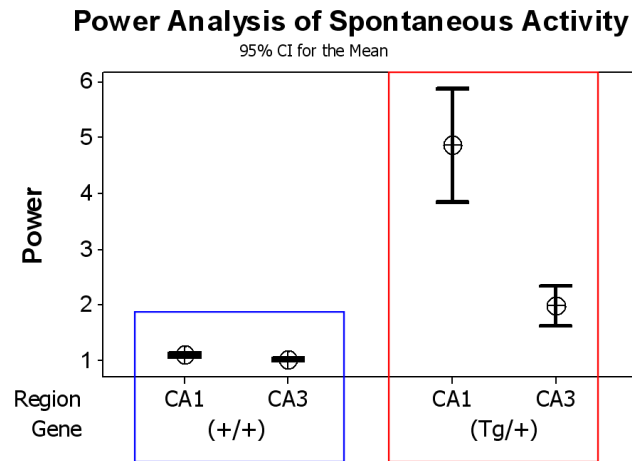
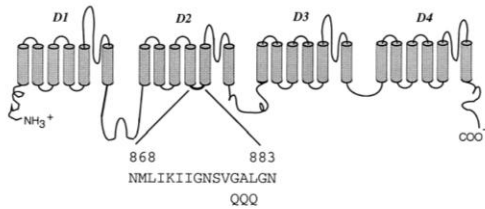
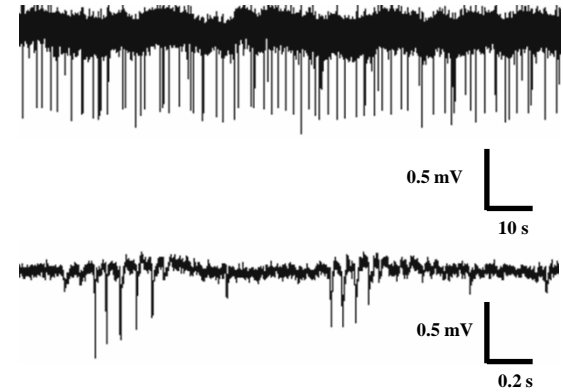
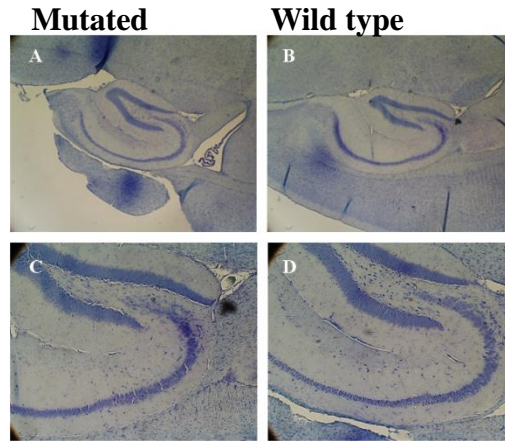


McIntyre Lab



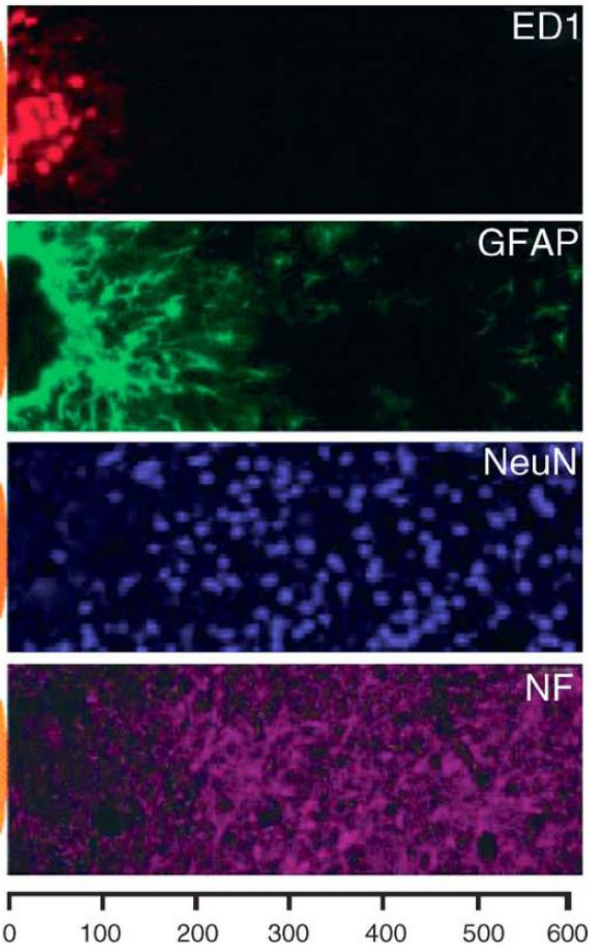
Tyler' Lab

Functional Genomics



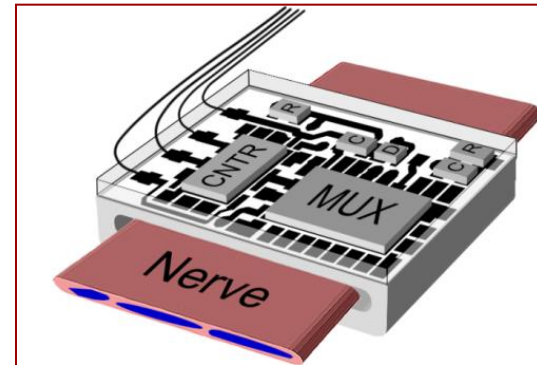
Obstacles

Tissue Response

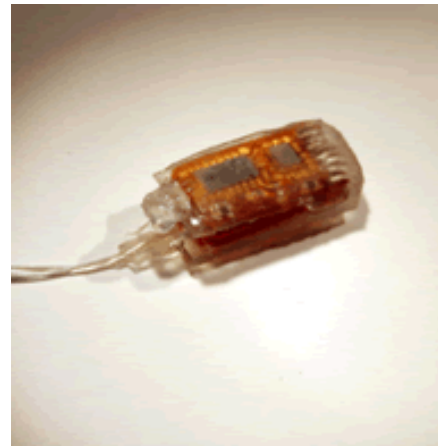


V. S. Polikov et al, Response of brain tissue to chronically implanted neural electrodes *Journal of Neuroscience Methods* 148 (2005) 1–18

Multiplexing



Hermeticity



Lertmanorat and Durand

Future Directions and Challenges

In Industry:

Market for neurotechnology products will reach \$8.8 billion in 2012. The largest segment of the market for neurotechnology is currently neuromodulation, followed by neural prostheses, and neurosensing. http://www.researchandmarkets.com/research/83cfae/the_market_for_neu

In Academia:

Research:

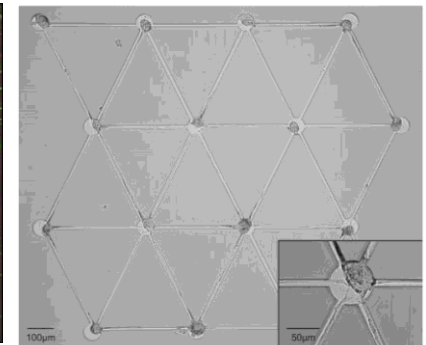
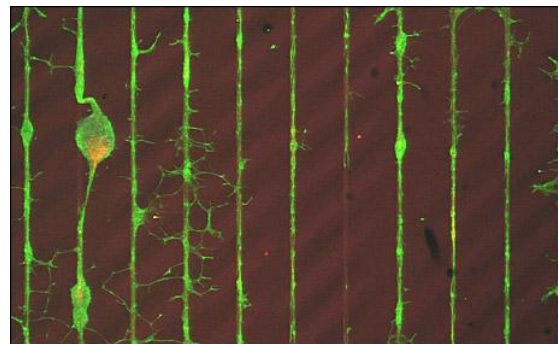
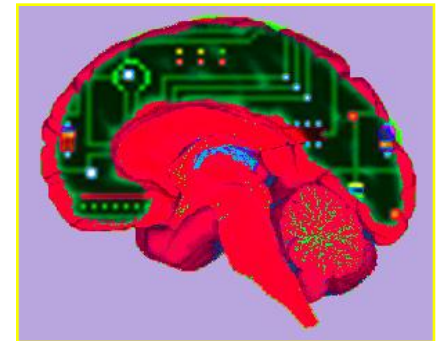
- Surface modification to hide prosthetic device from tissue
- Implantation of sealed flexible hybrid biological and silicon circuits
- Multiple channel implant to restore function in CNS_PNS
- Determination of the mechanisms of neuromodulation

Methodology:

- Integration of neuromolecular biology, nano-technology and neuroprosthetics
- Design ROBUST prosthetics
- Develop non-invasive methodology

Clinical:

- Translate simple but effective high impact neuroprostheses



M Merz, P. Fromherz, Silicon Chip Interfaced with a geometrically defined set of snail neurons, Adv Func Mat. 2005
Alan Murray, head of Edinburgh University http://news.bbc.co.uk/2/hi/uk_news/scotland/edinburgh_and_east/7867724.stm