Micro Electro Mechanical Systems for mechanical engineering applications

Lecture 15:
Device examples (3):
Cell chip, Neuro implant, Micro reactor, Drug delivery

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Cell chip

- Cell-based biosensor

- Neuro chip

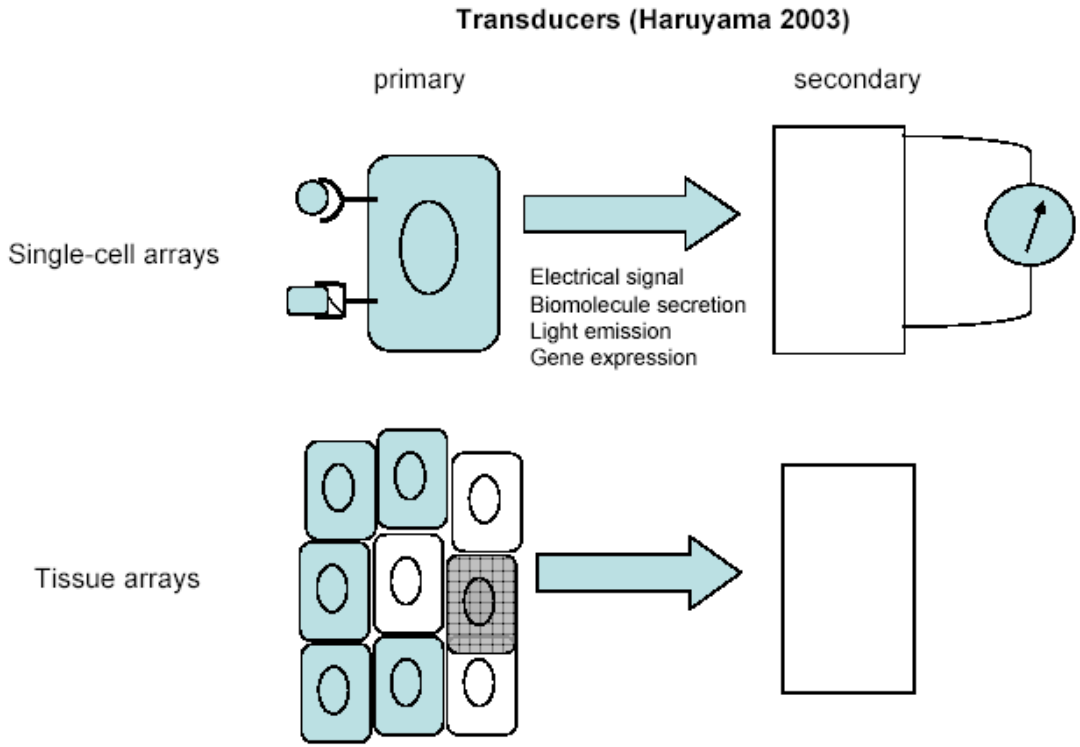
- Known ultrasensitivity of cells:
  - Olfactory neurons respond to single odorant molecules
  - Retinal neurons triggered by single photons
  - T cells triggered by single antigenic peptides

- Reading: J. J. Pancrazio et al., “Development and applications of cell-based biosensors,” Ann. Biomed. Eng. 27, 697-711 (1999).

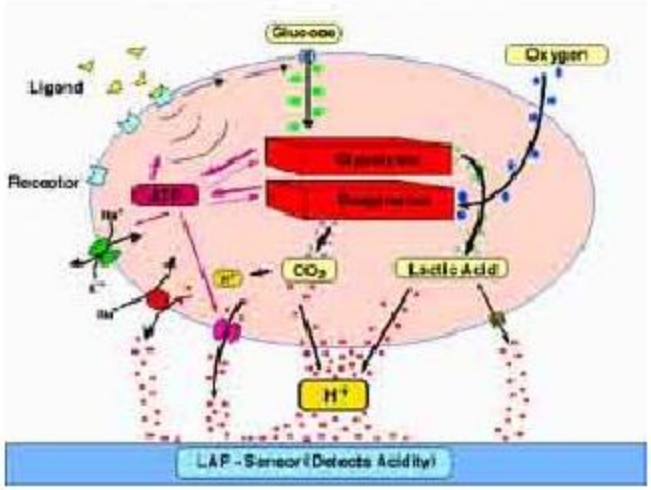
Design of cell chip

Design of CBBs:

- Cell-based biosensors are based on a primary transducer (the cell) and secondary transducer (device which converts cellular/biochemical response into a detectable signal)
  - Secondary transducer may be electrical or optical
  - Example pathways for signal transduction:
    - Toxin -> cell stress -> changes in gene expression
    - Analyte -> cell metabolism -> changes in extracellular acidification rates



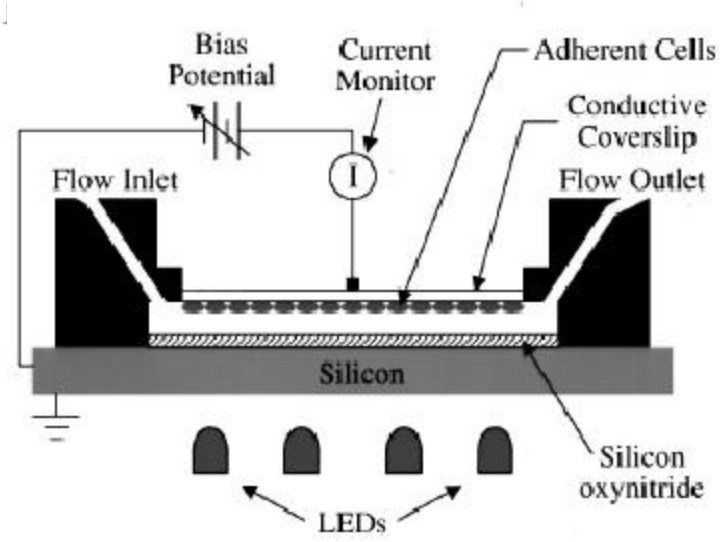
Chip example



Effects on proton release rate:

Receptor-ligand binding
Metabolic drugs/poisons
General cell stress

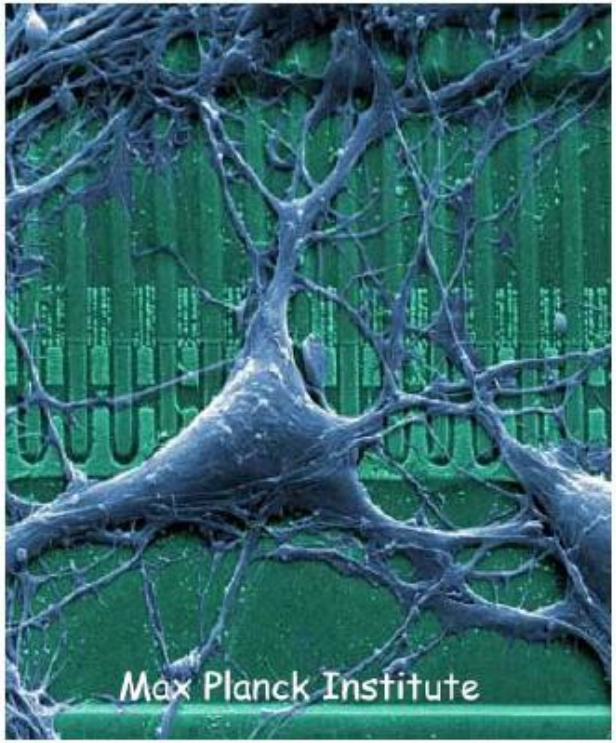
(McConnell et al. 1992)

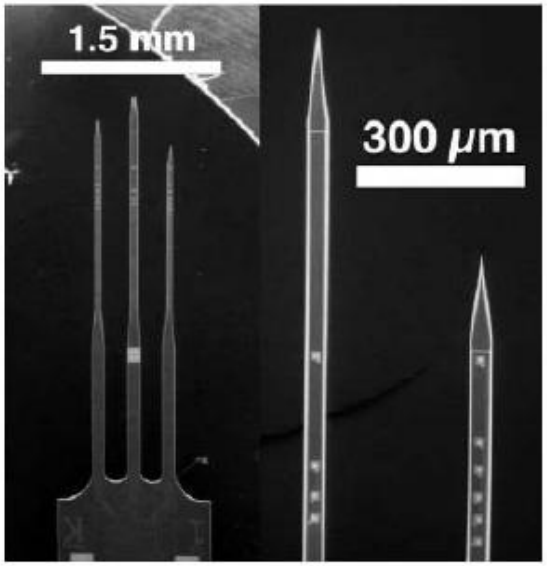


(Pancrazio et al. 1999)

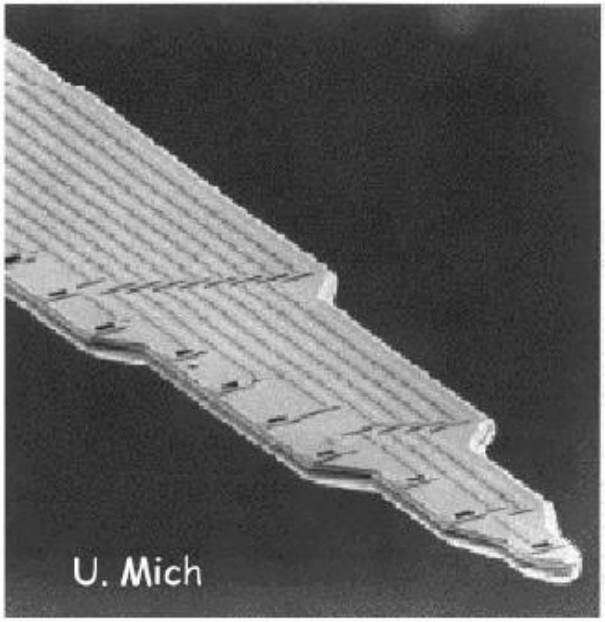
Neuro Implant

neuro-circuit interaction

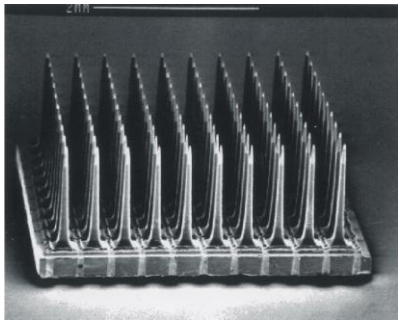


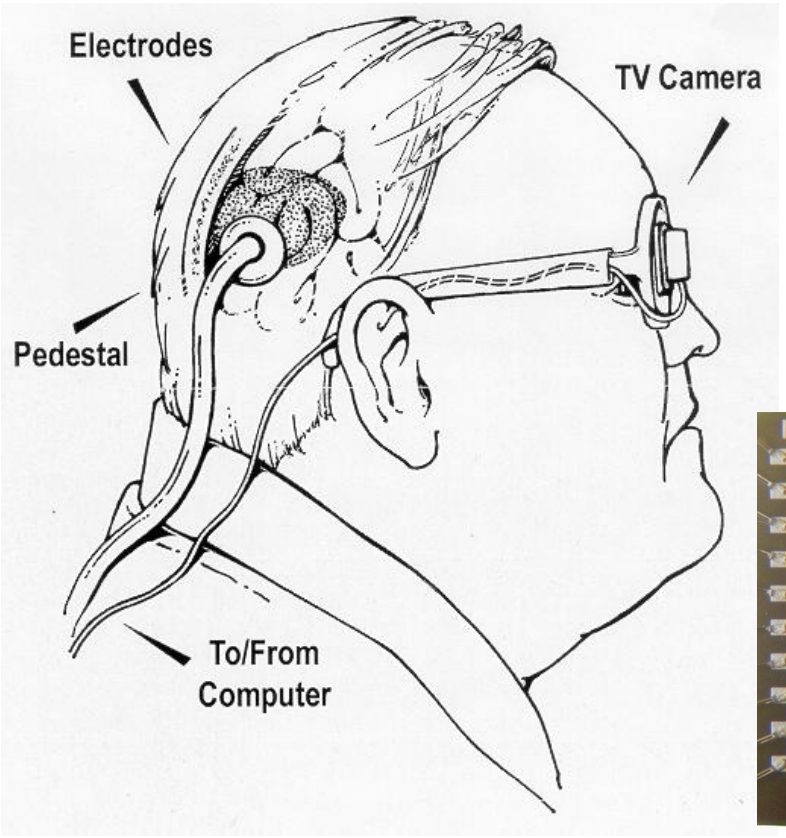


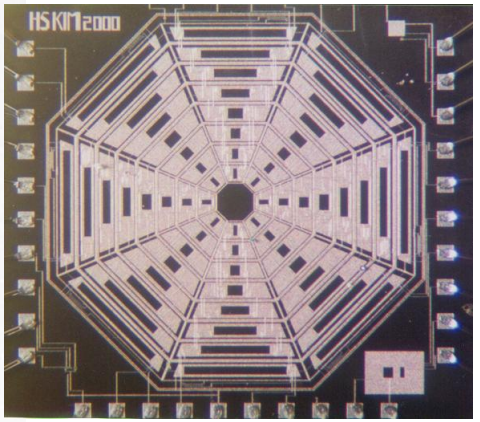
Stanford Neuro Probe



Microelectrode for brain/computer interface : prosthesis





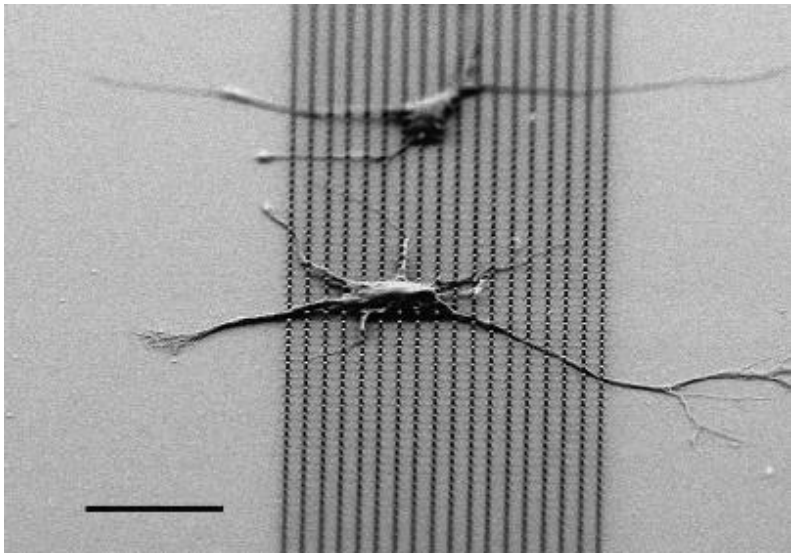


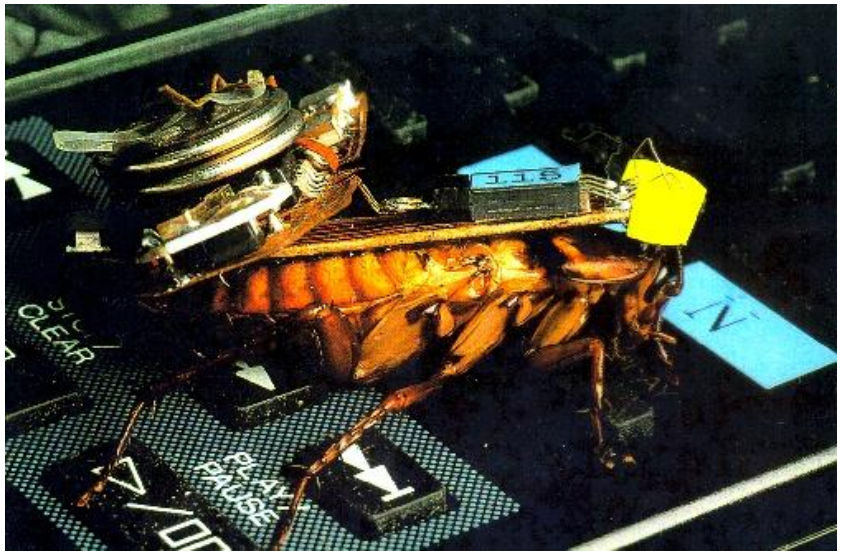
Integration of mechanics with living creatures

Biomimetics

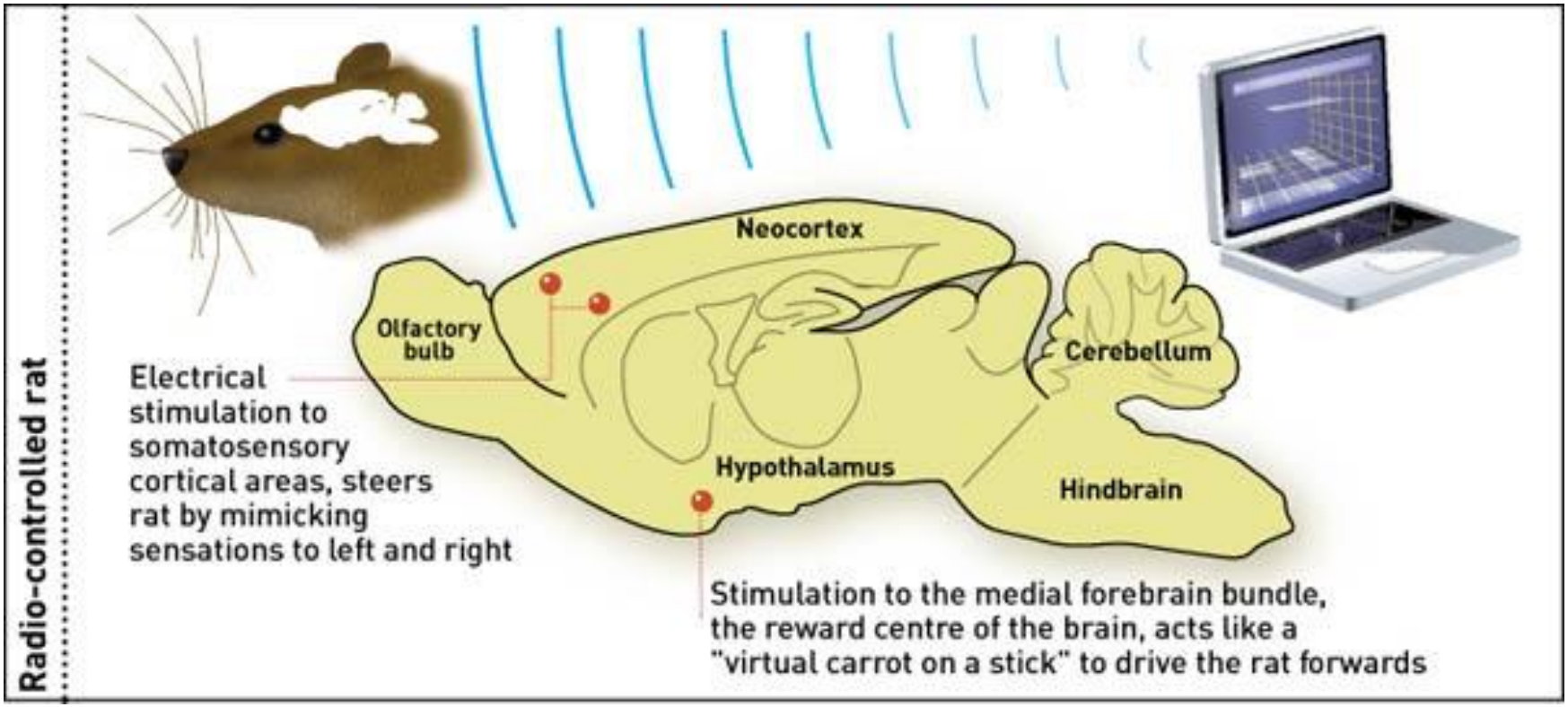
Biohybrids

Biosystems



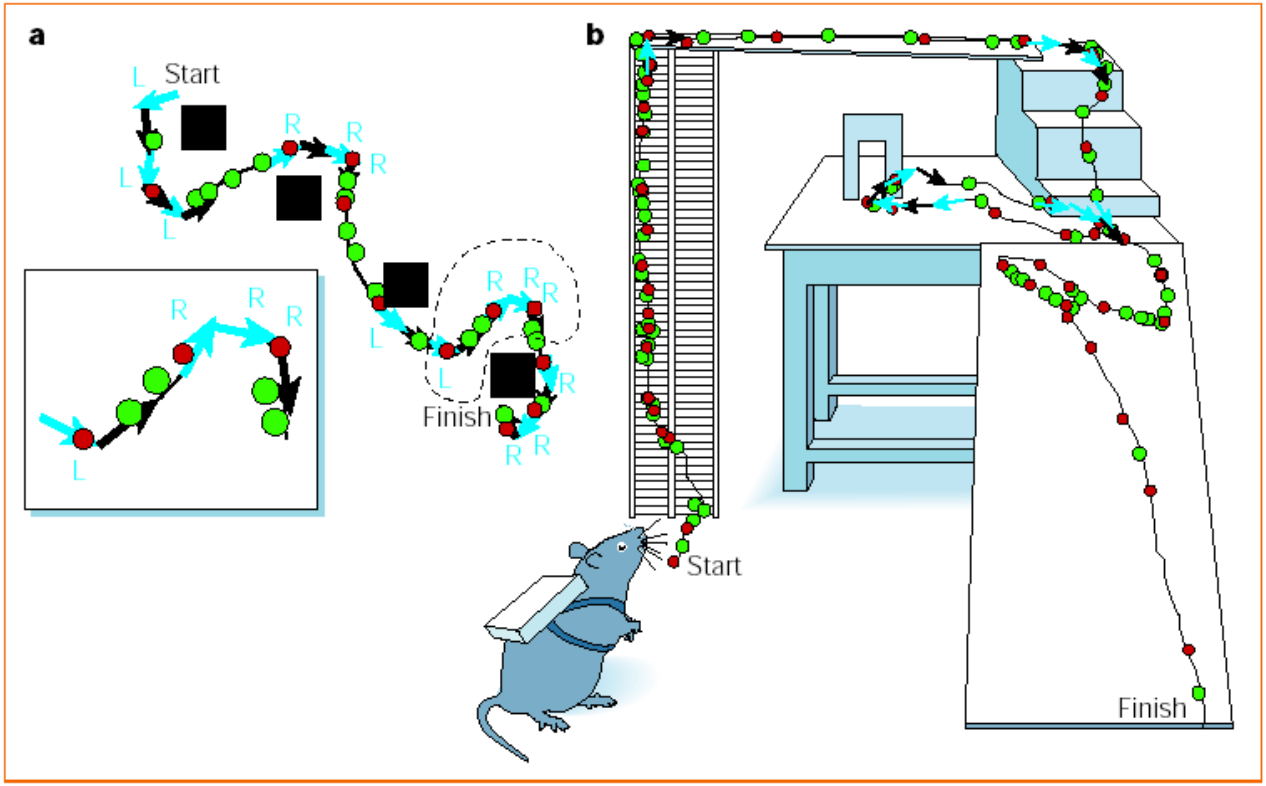


Robo-rat controlled by brain electrodes

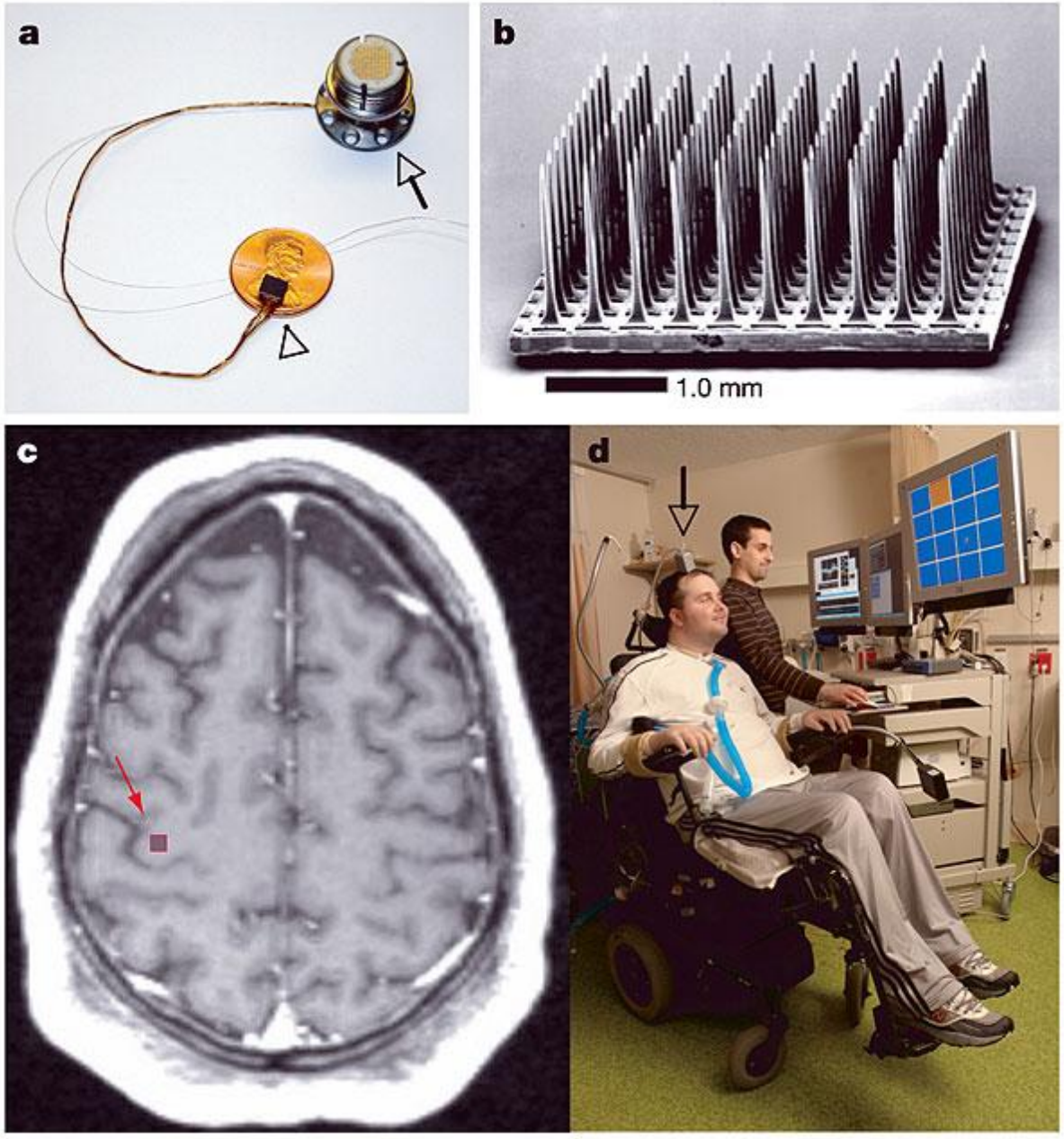


By courtesy of Prof. Jaeseung Jeong
KAIST, Department of BioSystems

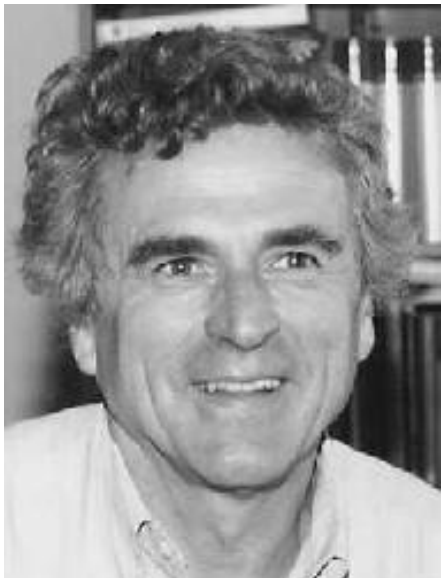
Rat navigation by remote control

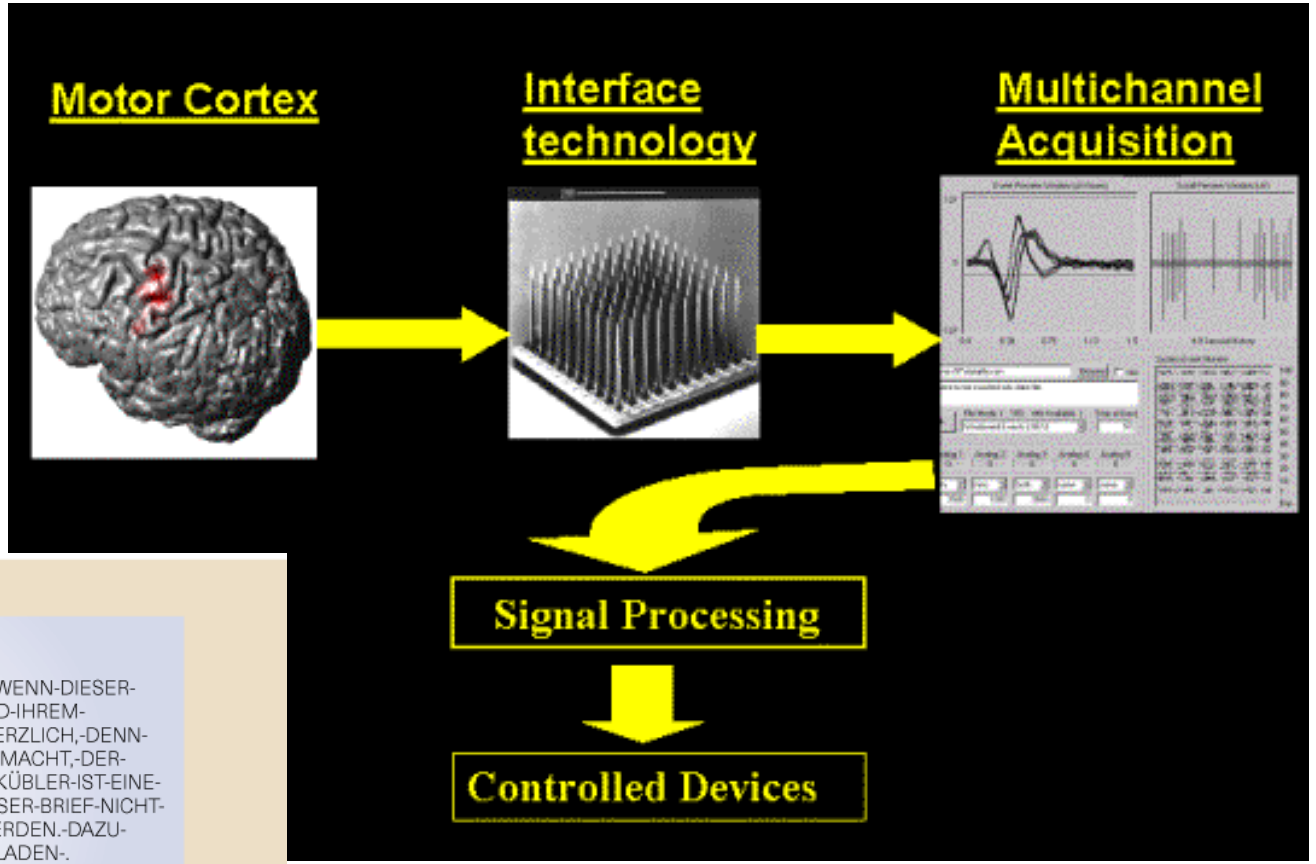


Is this the bionic man?


a
b
1.0 mm
c
d

Birbaumer N et al. A spelling device for the paralyzed. Nature (1999).





LIEBER-HERR-BIRBAUMER-

HOFFENTLICH-KOMMEN-SIE-MICH-BESUCHEN,-WENN-DIESER-BRIEF-SIE-ERREICHT-HAT-.ICH-DANKE-IHNEN-UND-IHREM-TEAM-UND-BESONDERS-FRAU-KÜBLER-SEHR-HERZLICH,-DENN-SIE-ALLE-HABEN-MICH-ZUM-ABC-SCHÜTZEN-GEMACHT,-DER-OFT-DIE-RICHTIGEN-BUCHSTABEN-TRIFFT.FRAU-KÜBLER-IST-EINE-MOTIVATIONSKÜNSTLERIN.OHNE-SIE-WÄRE-DIESER-BRIEF-NICHT-ZUSTANDE-GEKOMMEN.-ER-MUSS-GEFEIERT-WERDEN.-DAZU-MÖCHTE-ICH-SIE-UND-IHR-TEAM-HERZLICH-EINLADEN-.
EINE-GELEGENHEIT-FINDET-SICH-HOFFENTLICH-BALD.

MIT-BESTEN-GRÜSSEN-
IHR-HANS-PETER-SALZMANN

Kevin Warwick: the first cyborg?

Artificial limbs (to regain mobility)

- **Functional Electrical stimulation (FES)**

- It uses electrical impulses, either applied to nerves or directly to muscle (skin surface or implant).
- Only for the Therapy?
- Control over the bladder and bowel, regain the mobility
- Spinal cord microstimulation

Bionic man

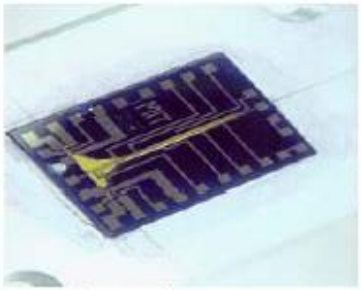
- **Bionic man: Jesse Sullivan**

- Dr. Todd Kuiken: Neural Engineering Center for Artificial Limb(NECAL) at the Rehabilitation Institute of Chicago (RIC)
- Muscle reinnervation which tags an amputee's own nerves and connects them to a healthy muscle
    - Sullivan : control through nerves grafted from his shoulder to his chest.
    - He moves his robotic arm just by thinking.

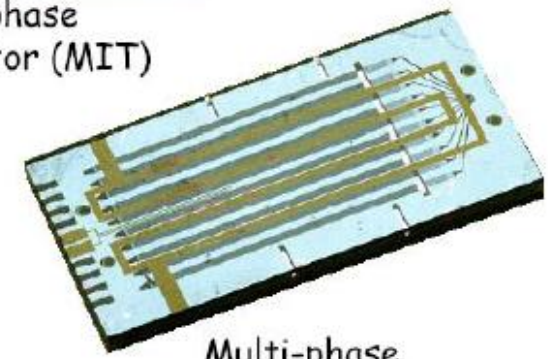
Exoskeletons

- **HAND EXERCISER**: An arm exoskeleton developed by a group at the University of Salford, in Manchester, England, helps users in rehabilitation exercises.
- **MASTER CONTROL**: Researchers at the Korea Institute of Science and Technology, in Seoul, created an exoskeleton master arm that can control a humanoid robot's arms
- **BIONIC BODY: HAL-5**, developed at the University of Tsukuba, Japan, is a powered robotic suit that can help elderly and disabled people walk and carry things.

Synthesis with Micro reactor

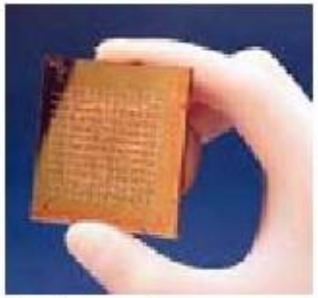


Gas phase reactor (MIT)



Multi-phase reactor (MIT)

Liquid phase reactor (MIT)

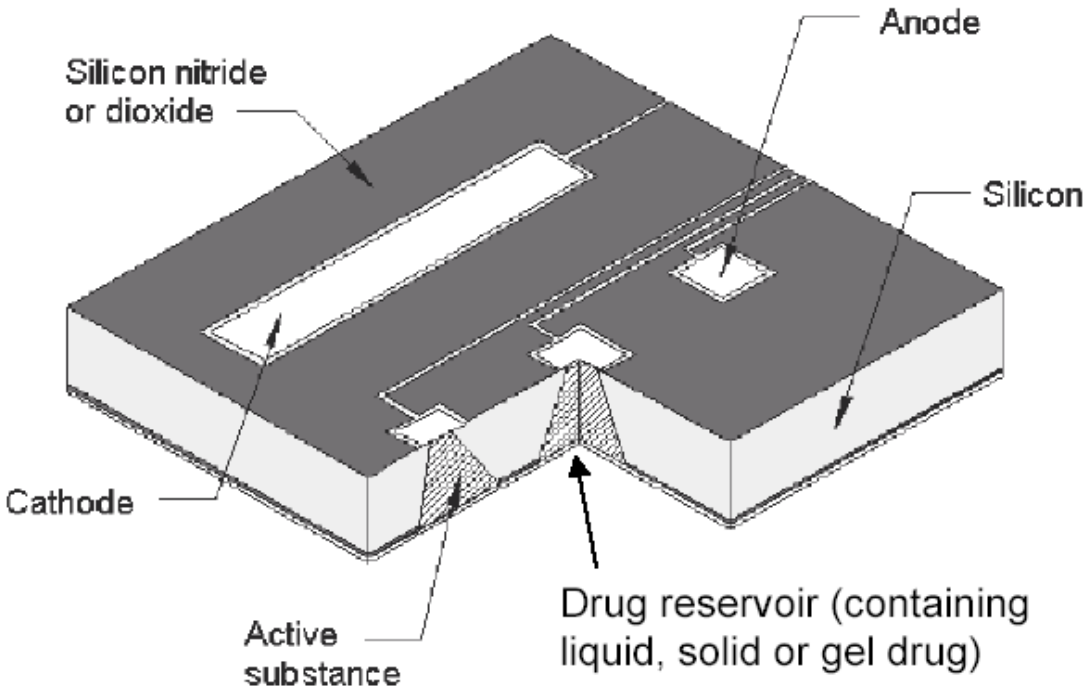


High throughput microreactor (Orchid BioSciences)

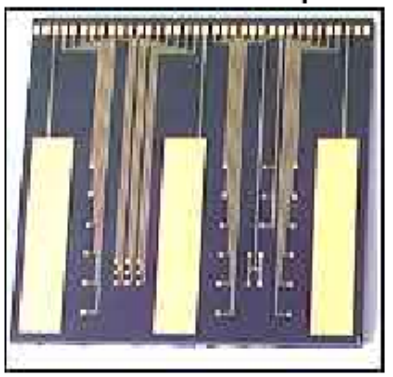
Micromixer (IMM)

- Microreactors for synthesis and chemical researches
- Temperature and pressure sensors, heaters, heat exchangers, valves, separators...

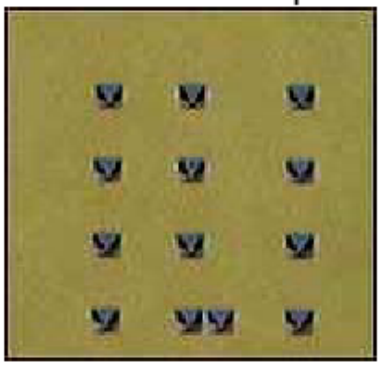
Drug Delivery Microchip



Front of chip



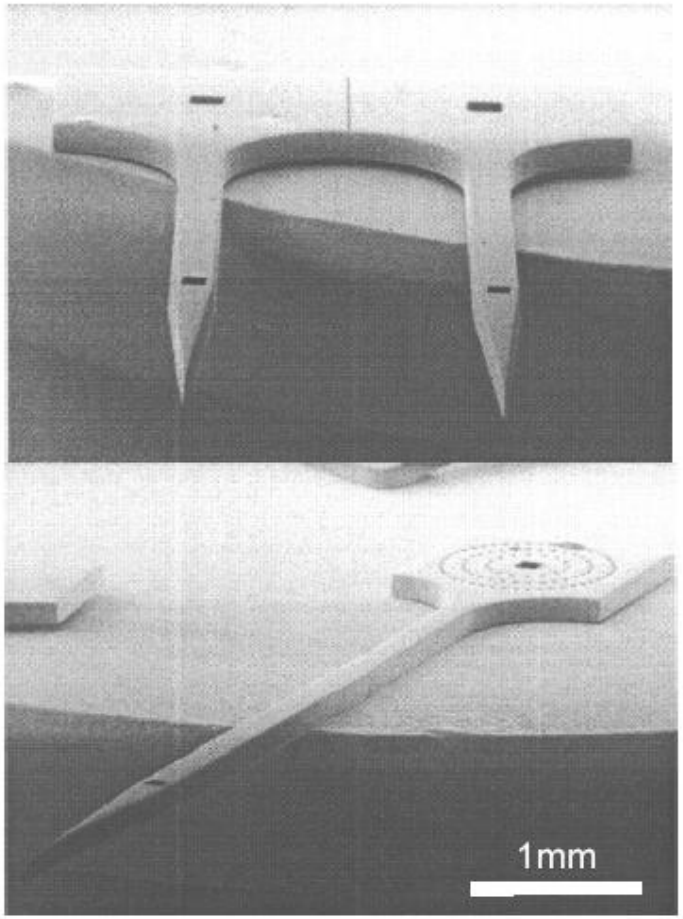
Back of chip

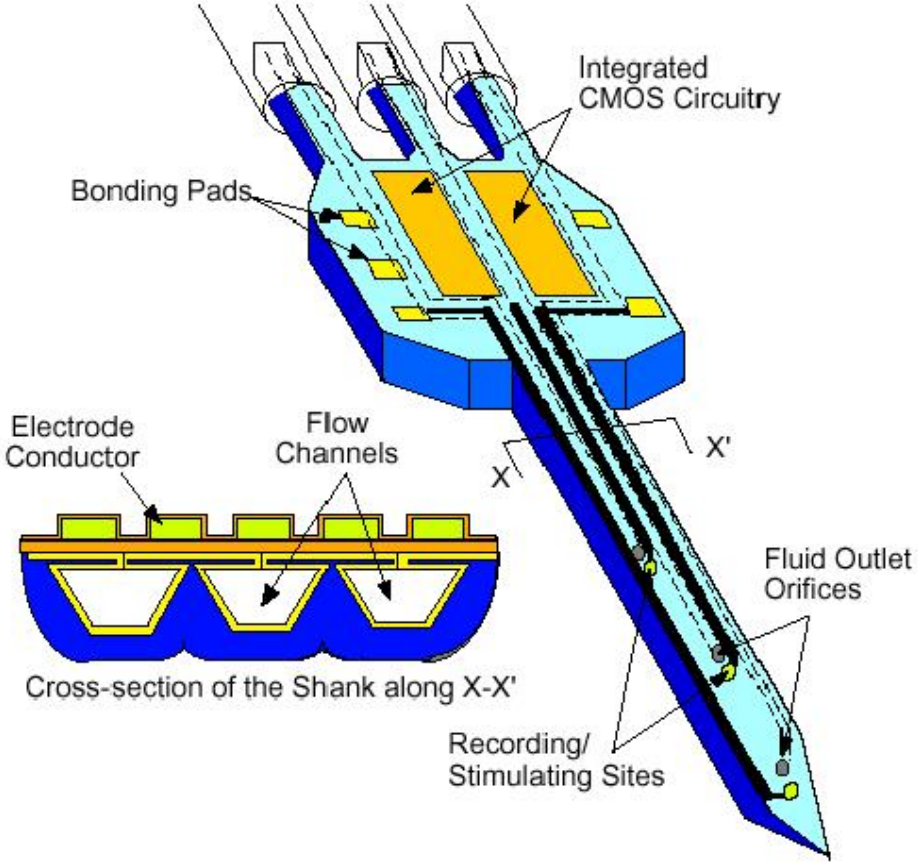


- Anode is a gold membrane that is dissolved when 1V is applied, releasing drug. Chip can be controlled remotely.
- Up to 1000 reservoirs on a dime-size chip.
- Chips can be implanted, swallowed, or integrated into an intravenous delivery system.

J. Santini and R. Langer, MIT

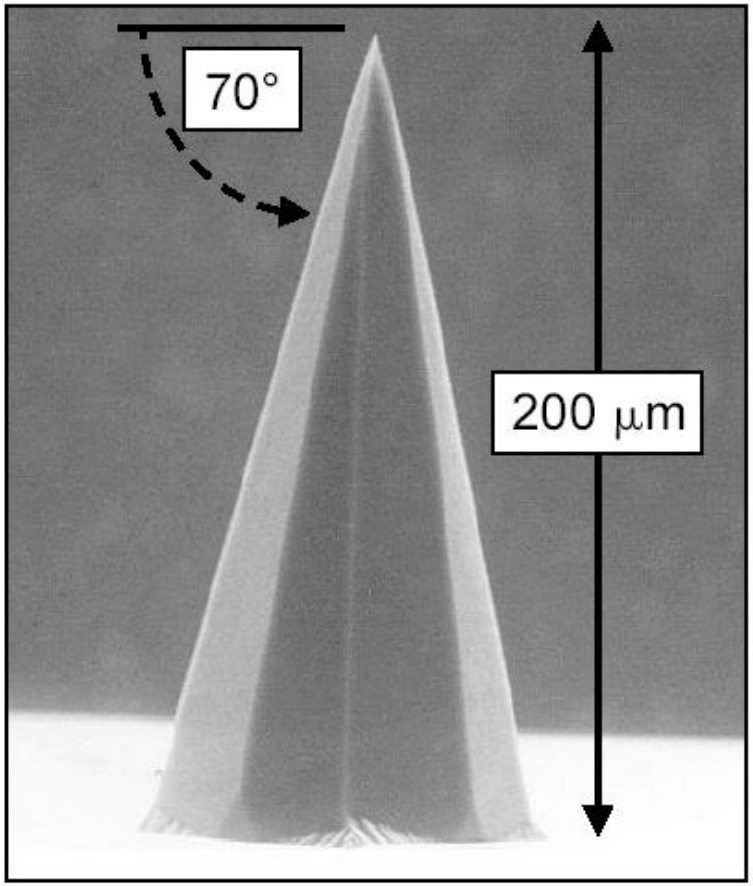
Drug Delivery Platforms

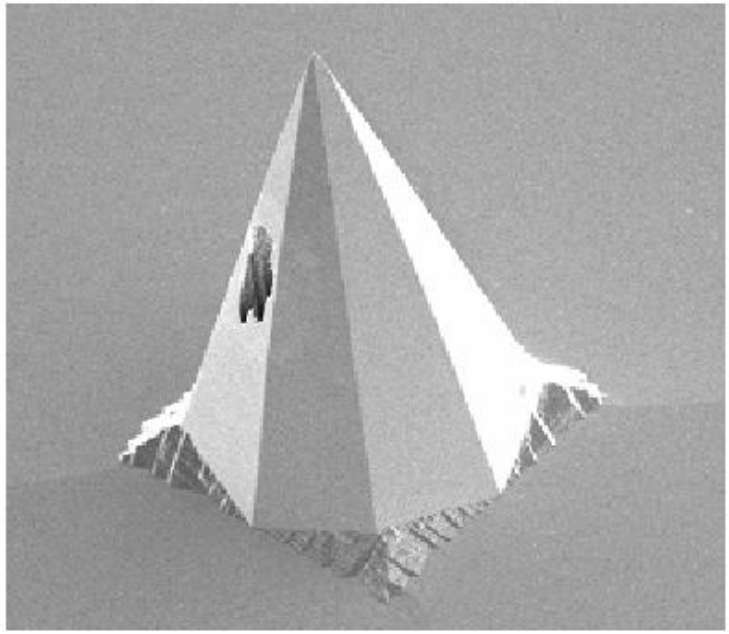




Photos courtesy of N. Talbot and A. Pisano, UC Berkeley
Diagram courtesy of K. Wise, U. Michigan.

Drug Delivery Microneedles





- Single crystal silicon
- Bulk micromachined
- Higher order planes exposed
- Laser drilled hole

Fabricated at Standard MEMS, Inc.