

# Grand challenges in neural interface technologies

Daryl R. Kipke, PhD  
([dkipke@umich.edu](mailto:dkipke@umich.edu))

Neural Engineering Laboratory  
Biomedical Engineering  
University of Michigan



NIH/NIBIB Biotechnology Resource Center; P41-EB002030

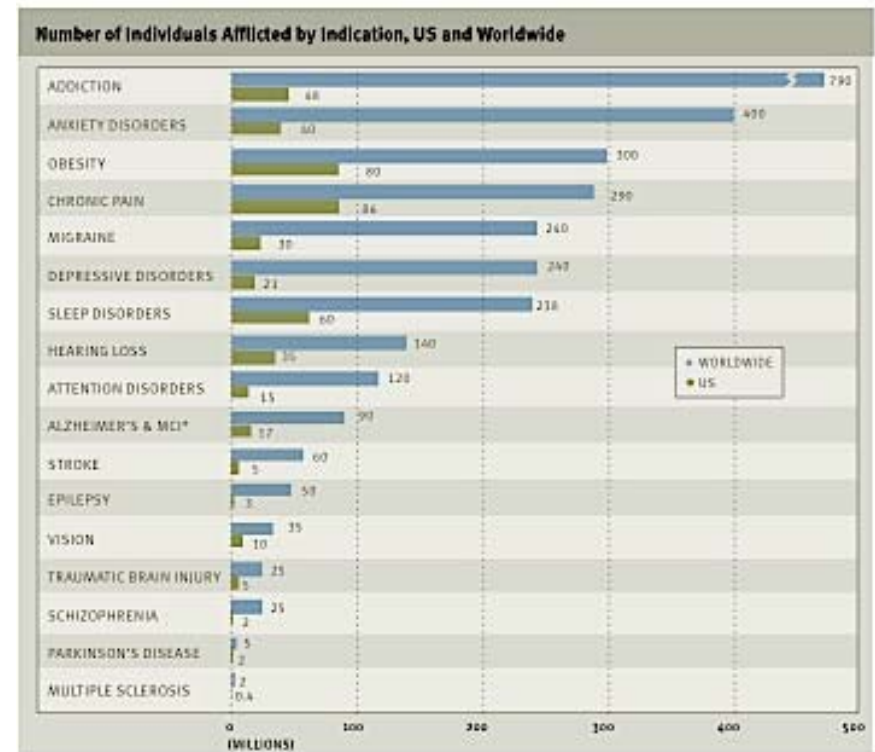
Disclosure:

D. Kipke has a financial and leadership interest in  
NeuroNexus Technologies, Inc.

# Neurotechnology: Problems & Opportunities

World-wide burden of brain-related illness exceeds \$2 trillion/year

- Neurotechnology is \$130+ billion industry
- Neurotechnology sectors
  - Neurodevice (\$6B, 22% growth)
    - Neuromodulation devices
    - Neurosurgical devices
    - Neuroprosthetic devices
    - Neurosoftware
  - Neurodiagnostics (\$16B, 6% growth)
  - Neuropharmaceuticals (\$109B)
  - Neuroscience Research (??)

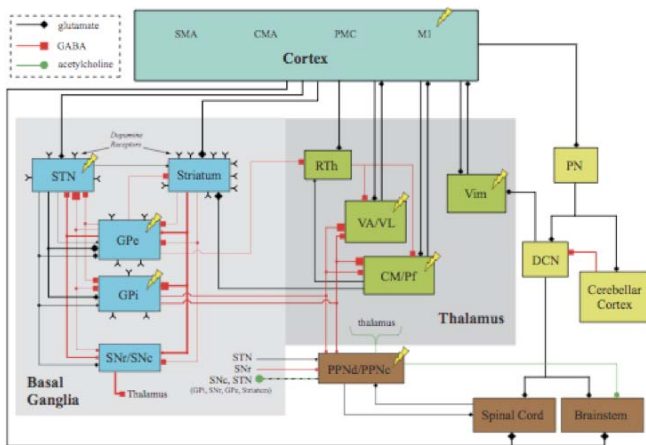


SOURCE: NEUROINSIGHTS, WORLD HEALTH ORGANIZATION, UNITED NATIONS, NATIONAL INSTITUTE OF HEALTH, PUBLISHED STUDIES  
\*ALZHEIMER'S DEMENTIA (1 MILLION IN THE US, 17 MILLION WORLDWIDE)

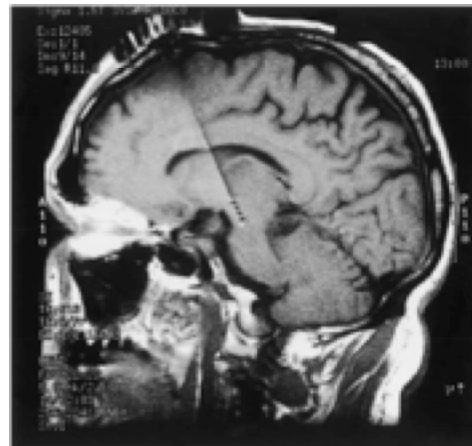
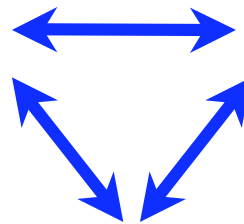
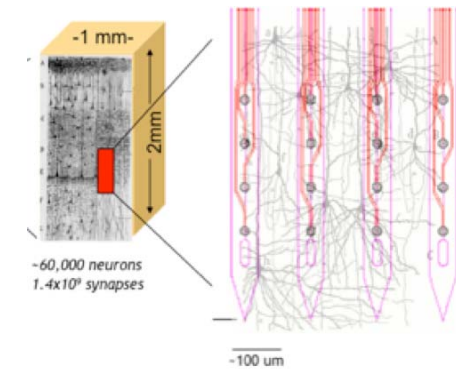
Neurotechnology Industry Report, 2008

# Interplay between neuroscience, technology & clinical drivers

**Science drivers:** Increased understanding of normal, diseased, and injury mechanisms in brain



**Technology drivers:** Increased neural interface selectivity, sensitivity, fidelity, bandwidth



**Clinical drivers:** Meeting specific and significant clinical needs

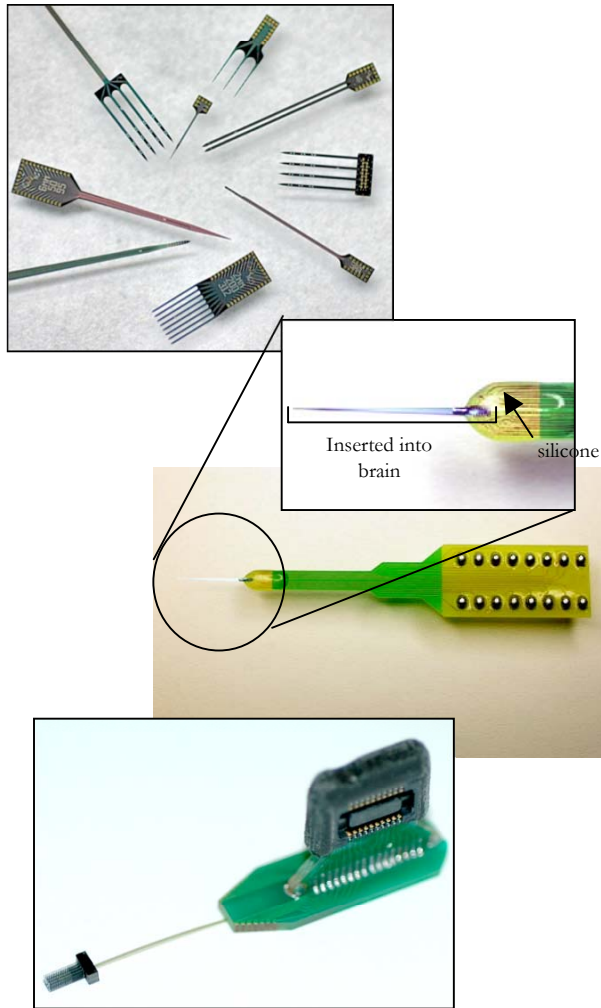
# What's new in neural interface technologies?

- Technology
  - Microfabricated microelectrode arrays (MEMS electrodes) are well established in neuroscience research
  - Starting to blur biotic and abiotic domains through advanced materials & technologies -- beyond MEMS, smaller, bioactive
- Science
  - Increasing understanding of mechanisms at all scales
  - Increasing understanding of reactive tissue responses to implantable probes
- Clinical Translation
  - Notable 'wins' in neurostimulation and neuroprosthetics
  - Progress in translating MEMS electrodes from research-grade to clinical-grade

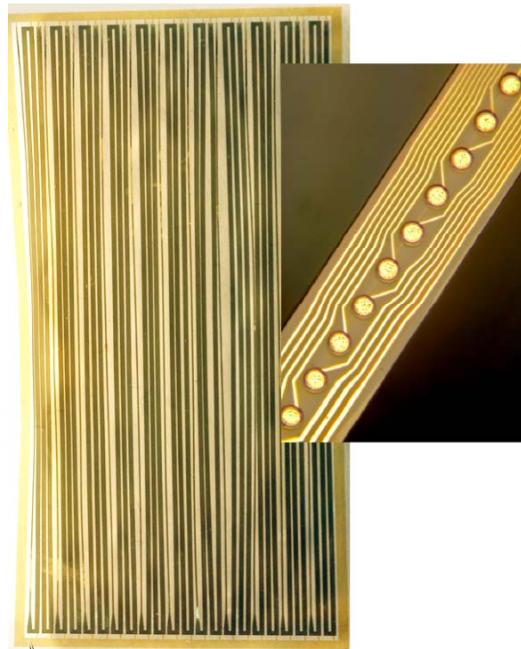
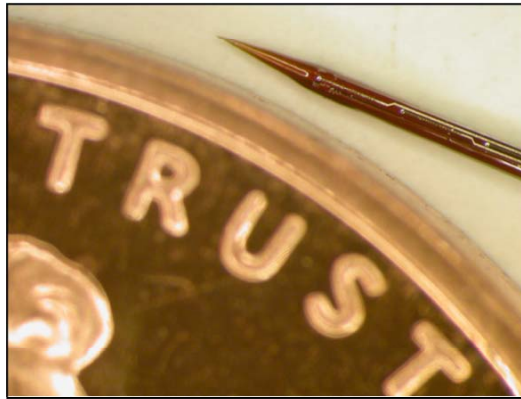
# MEMS neuroprobes established in

## neuroscience

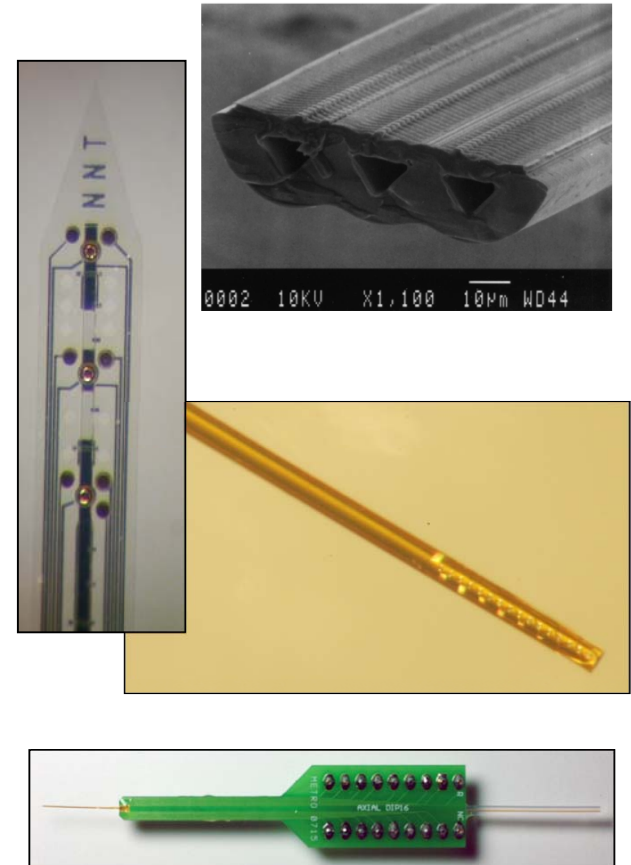
### Shallow Brain Probes



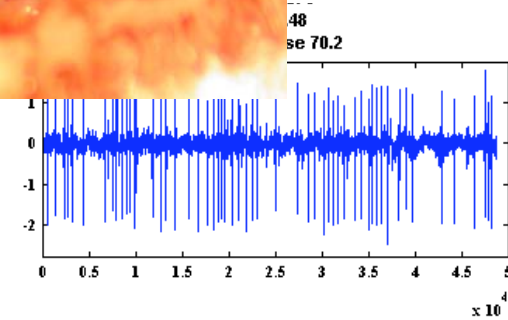
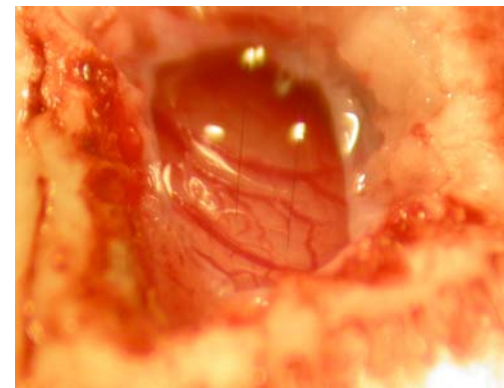
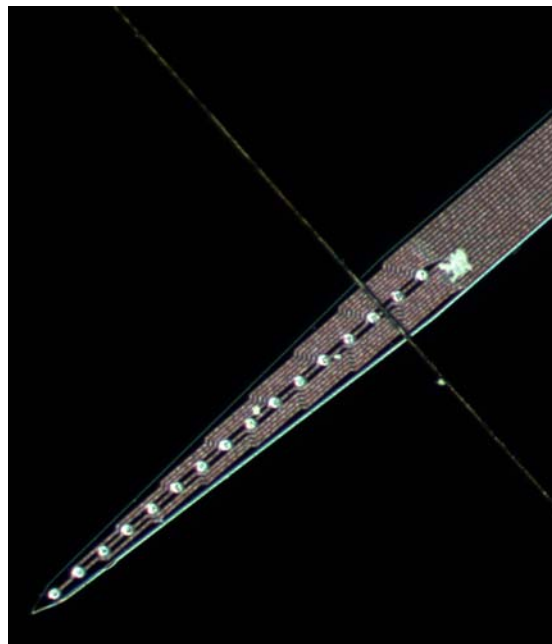
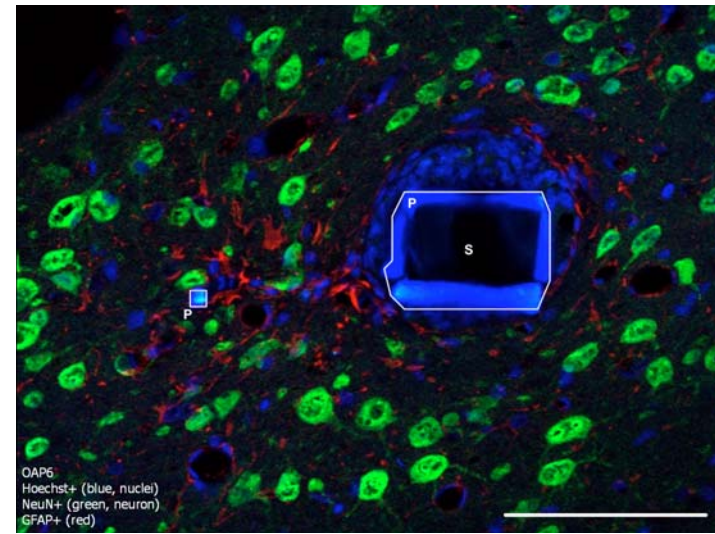
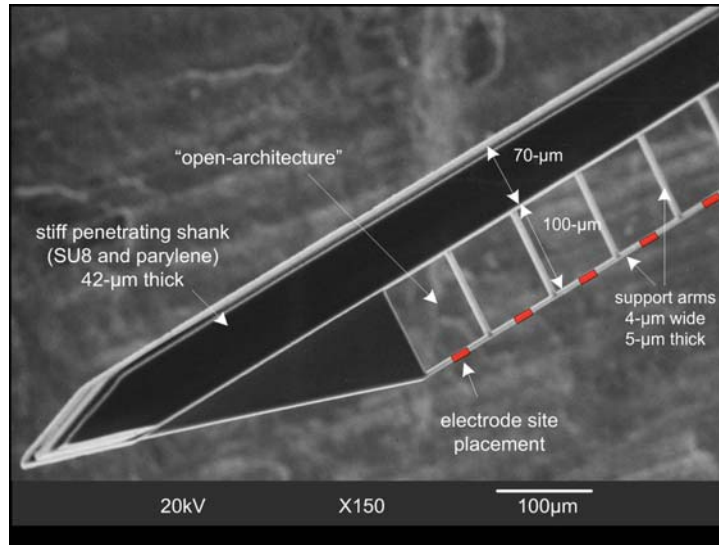
### Deep Brain Probes



### Drug Delivery Probes



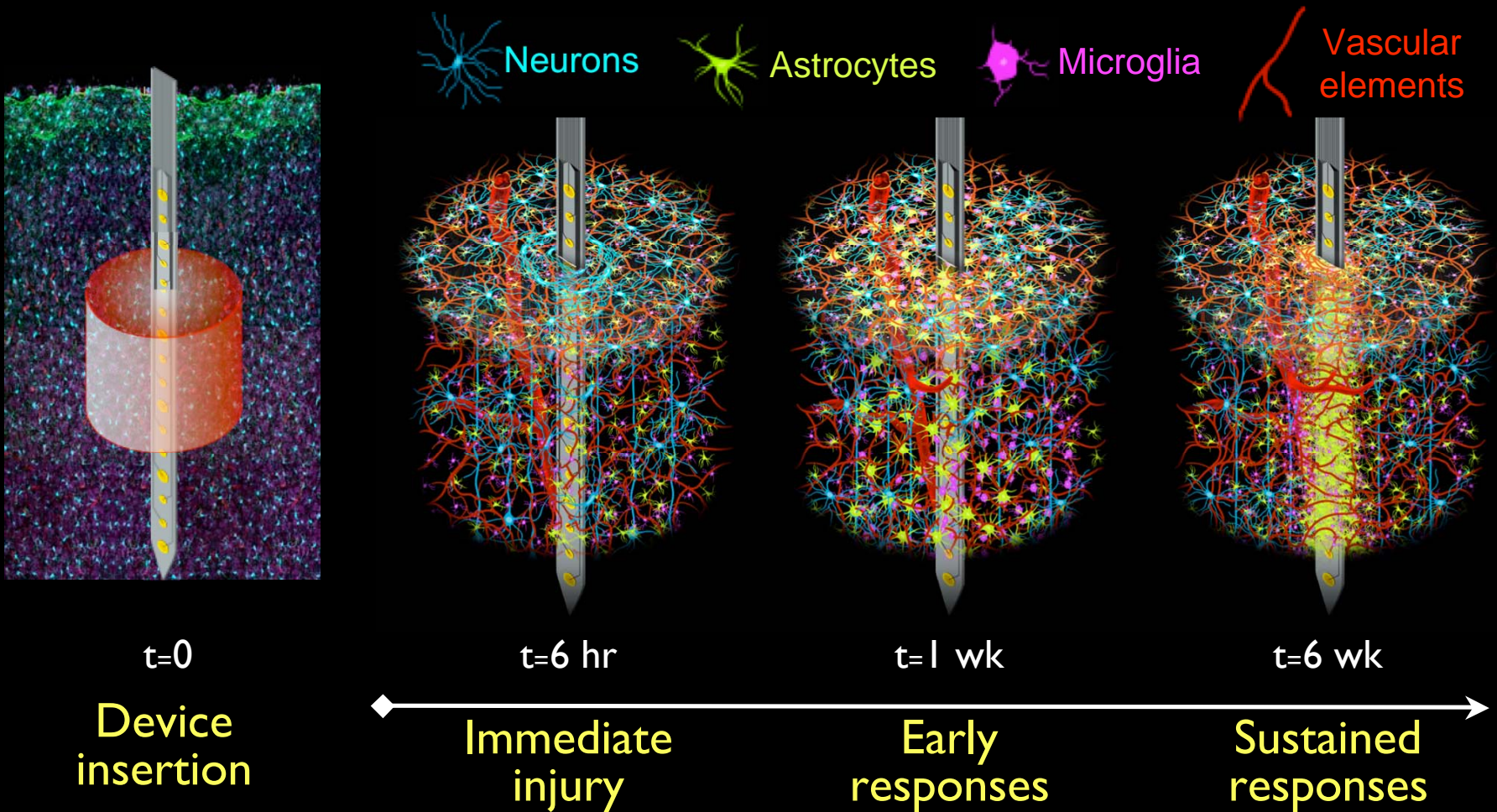
# Advanced Probe Designs and Technologies



# What's new in neural interface technologies?

- **Technology**
  - Microfabricated microelectrode arrays (MEMS electrodes) are well established in neuroscience research
  - Starting to blur biotic and abiotic domains through advanced materials & technologies -- beyond MEMS, smaller, bioactive
- **Science**
  - Increasing understanding of mechanisms at all scales
  - Increasing understanding of reactive tissue responses to implantable probes
- **Clinical Translation**
  - Notable 'wins' in neurostimulation and neuroprosthetics
  - Progress in translating MEMS electrodes from research-grade to clinical-grade

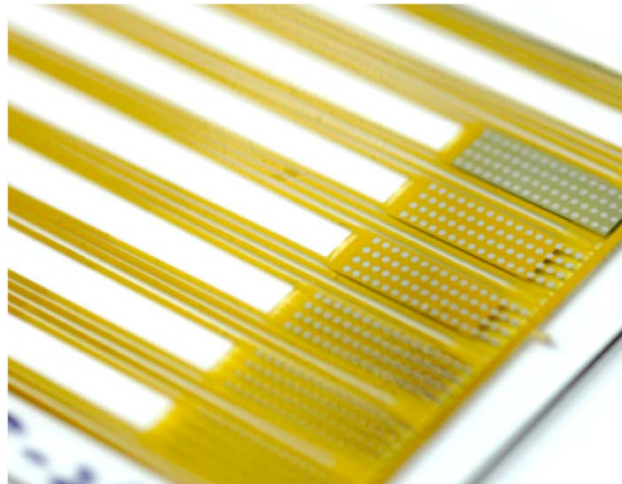
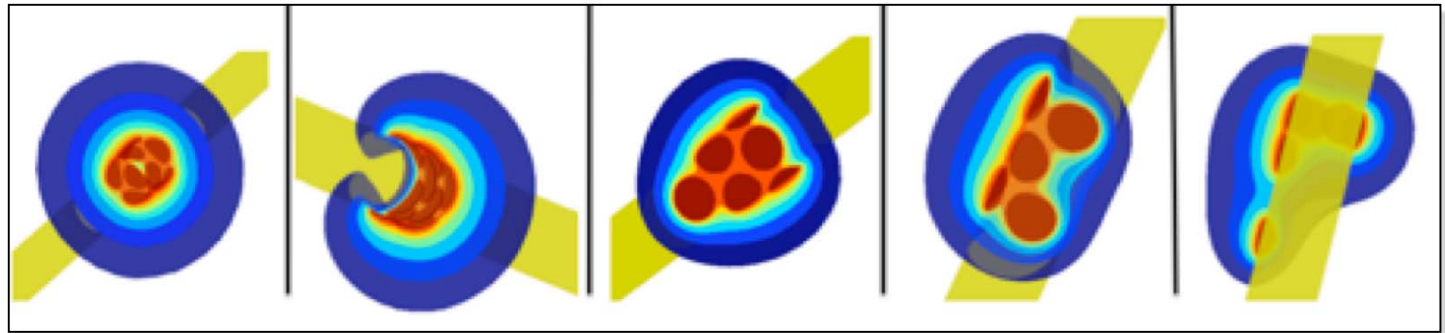
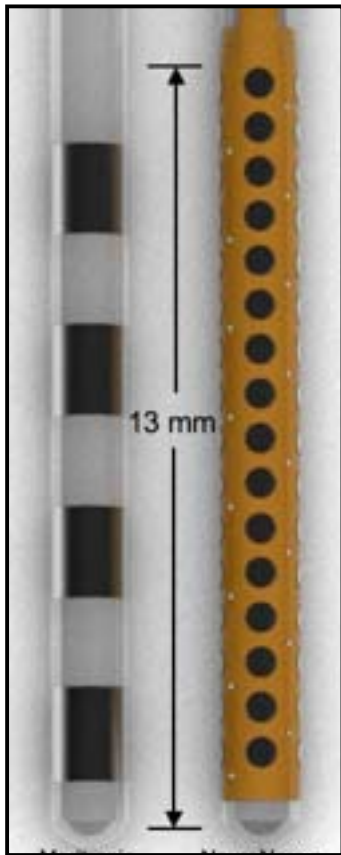
# Microscale reactive tissue responses to neuroprobe



# What's new in neural interface technologies?

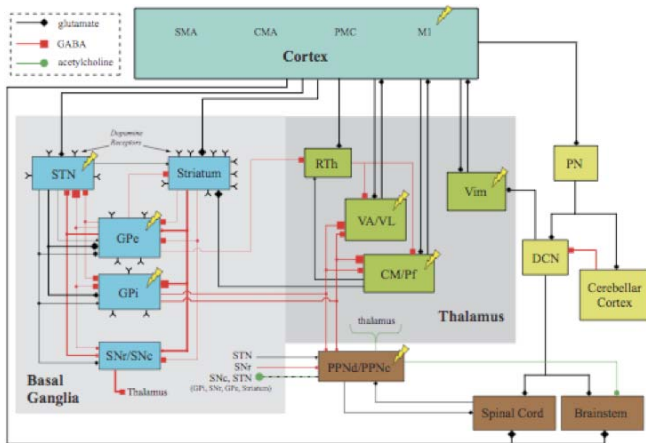
- **Technology**
  - Microfabricated microelectrode arrays (MEMS electrodes) are well established in neuroscience research
  - Starting to blur biotic and abiotic domains through advanced materials & technologies -- beyond MEMS, smaller, bioactive
- **Science**
  - Increasing understanding of mechanisms at all scales
  - Increasing understanding of reactive tissue responses to implantable probes
- **Clinical Translation**
  - Notable 'wins' in neurostimulation and neuroprosthetics
  - Progress in translating MEMS electrodes from research-grade to clinical-grade

# Developing next-generation Deep Brain Stimulation (DBS) electrode array

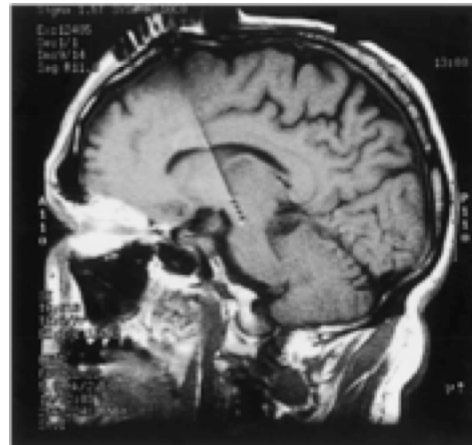
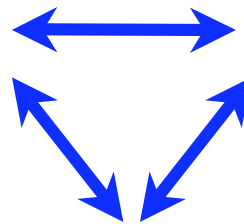
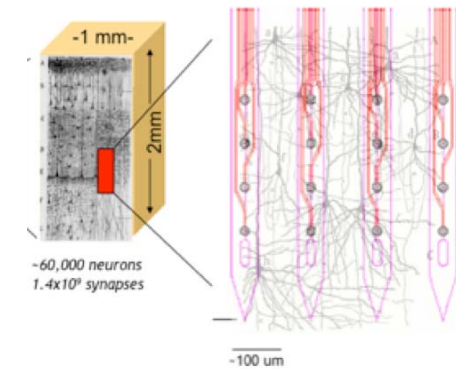


# Interplay between neuroscience, technology & clinical drivers

**Science drivers:** Increased understanding of normal, diseased, and injury mechanisms in brain



**Technology drivers:** Increased neural interface selectivity, sensitivity, fidelity, bandwidth



**Clinical drivers:** Meeting specific and significant clinical needs

# Grand Challenges: Neural interface technologies

1. Applied: Develop long-term, high-fidelity neural interfaces for recording, stimulation, drug delivery
2. Basic: Progress from creating neural interfaces to brain interfaces – *beyond function: neurons, glia, neurovasculature*
3. Translation: Identify a clear path for translation of advanced neural interface technologies for use in clinical devices
4. Education: Educate, motivate, enable the next generation of engineer scientists & clinicians