Neuroengineering Materials Seminar

Kick-off meeting

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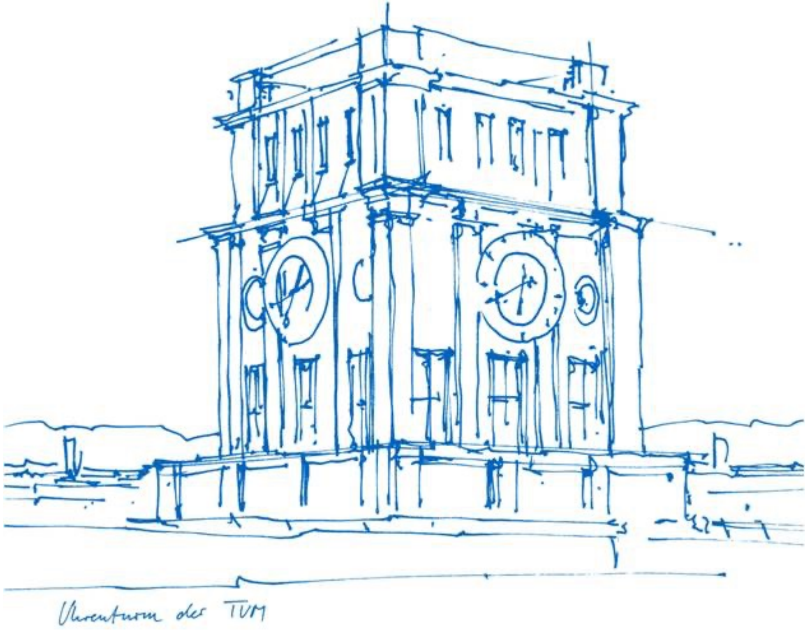
Department of Electrical and Computer Engineering

Assistant Professorship of Neuroengineering Materials



What neural implant technologies are out there?

Electrical Activity in the Nervous System

- Neurons communicate via the transmission of electric signals
- These consist of individual action potentials, which represent a fast change and recovery in the voltage of the neuronal membrane
- Neurons also communicate electric signals to non-neuronal cells to control their activity (e.g. motor neurons to muscles)

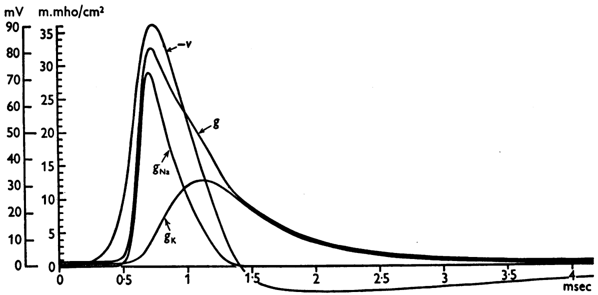
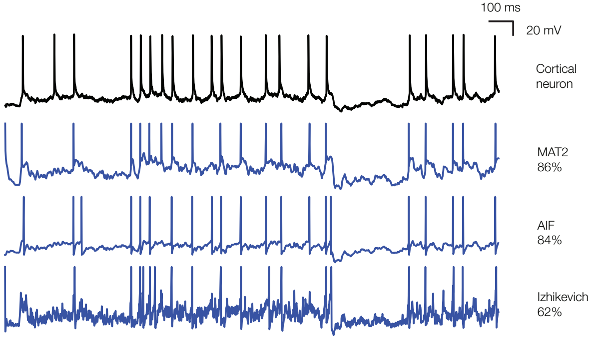
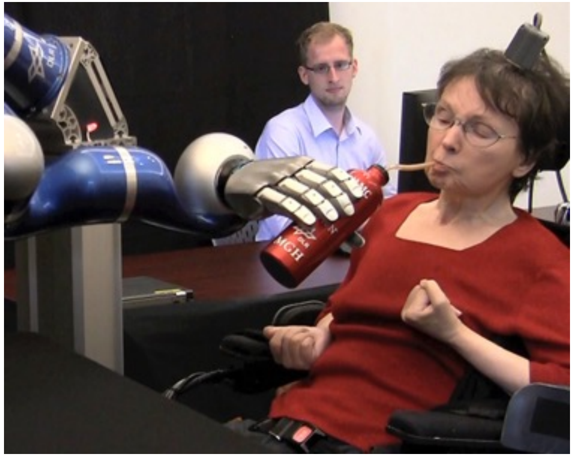


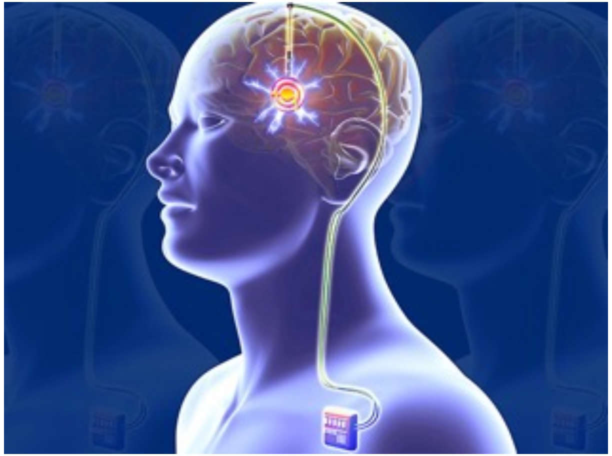
Fig. 17. Numerical solution of eqn. (31) showing components of membrane conductance (g) during propagated action potential ($-V$). Details of the analysis are as in Fig. 15.



Neural Implants

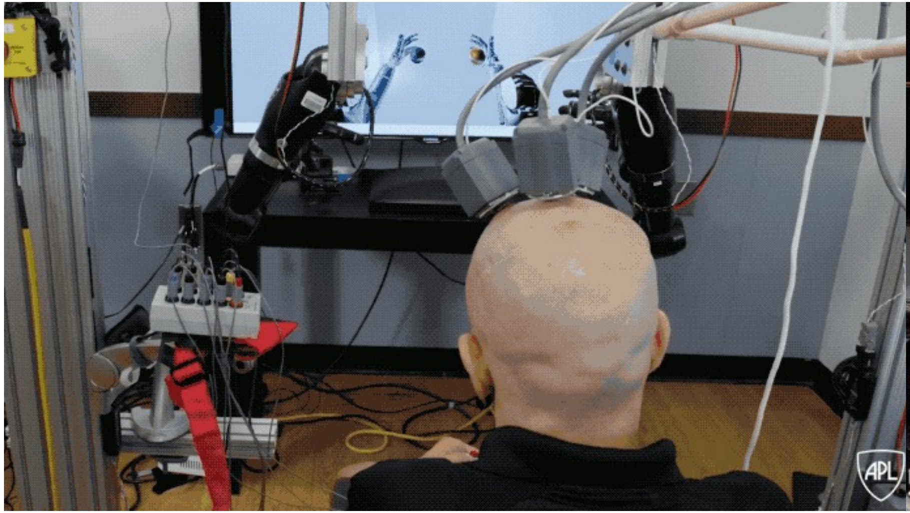
- Create an electrical interface with the nervous system
- Allow us to communicate with neurons through electrical signals
- We can ***measure or modulate*** neuronal activity using implants that transmit electrical signals

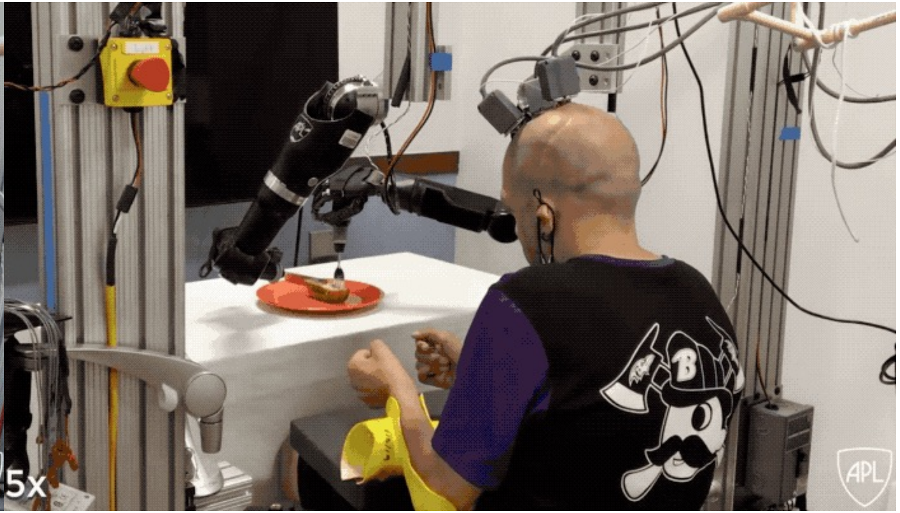




Medical Uses for Neural Implants

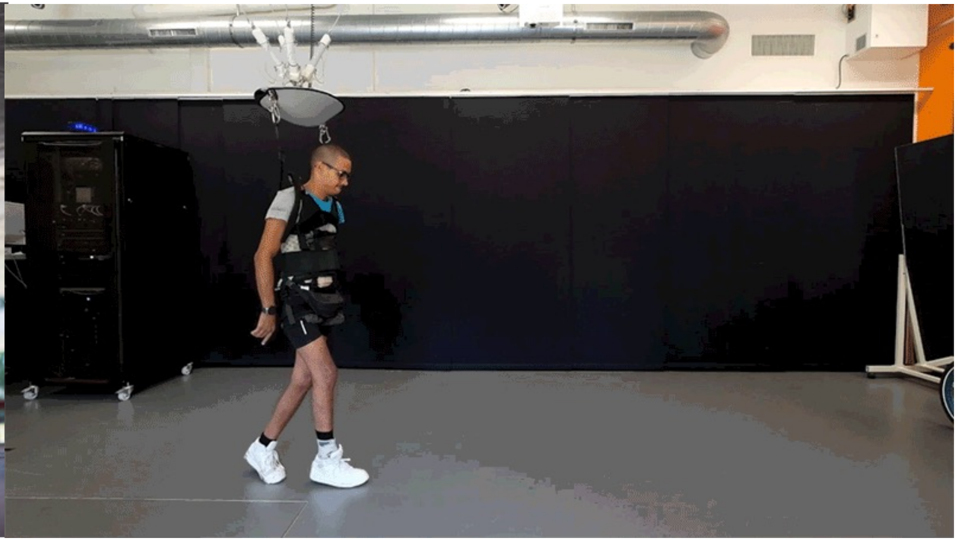
Somatosensory cortex recording for robotic limb control





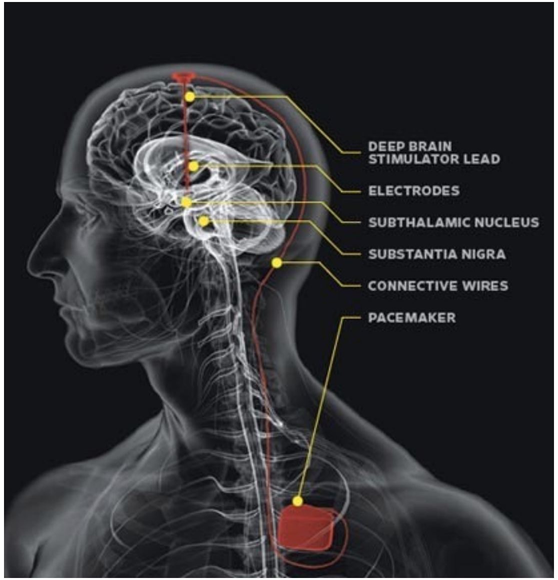
Medical Uses for Neural Implants

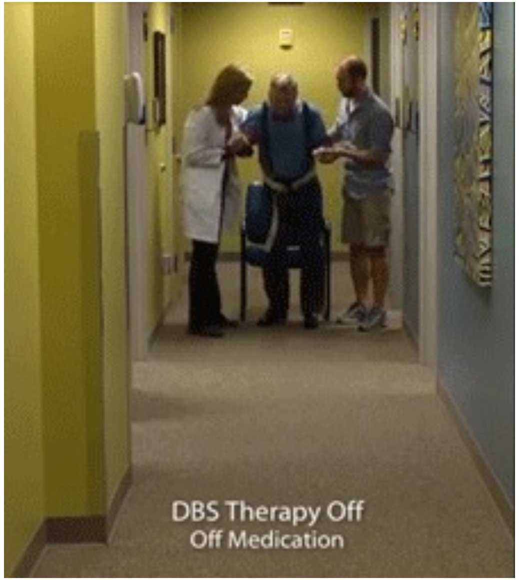
Spinal cord stimulation for SCI rehabilitation

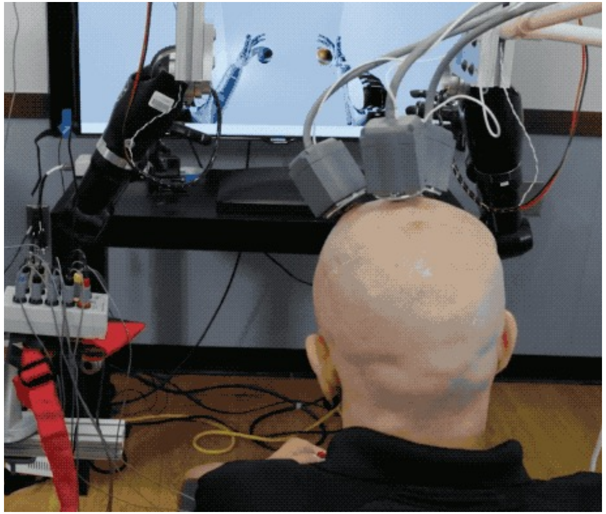
Medical Uses for Neural Implants

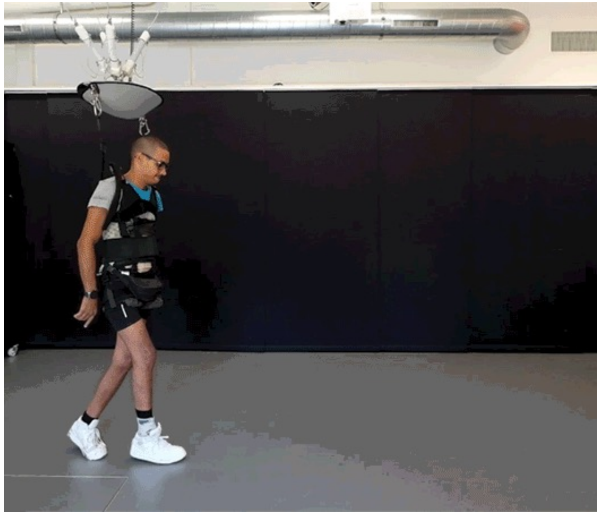
Deep Brain Stimulation for Parkinson's disease





Neural implants inside of the body

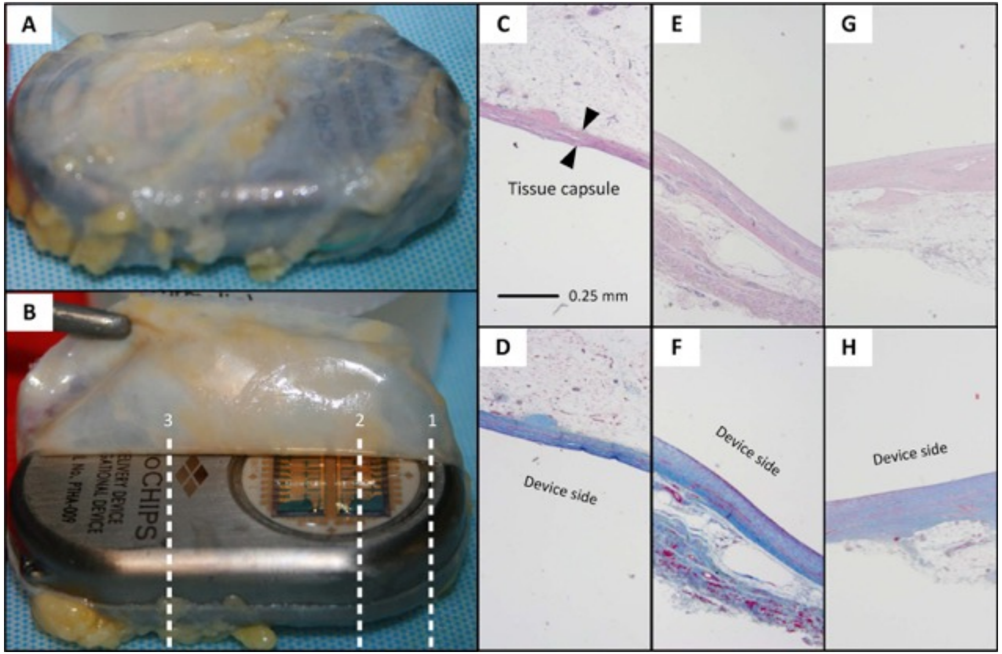




What happens to implanted devices inside the body?

Preimplantation

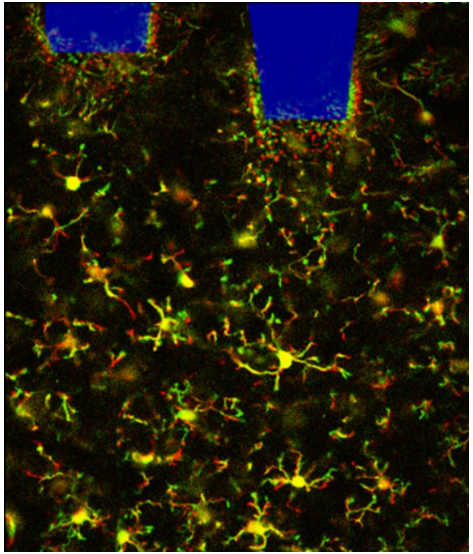
After 103 days



What happens to a neural implant inside of the body?

Microglial Response

Blue = probe

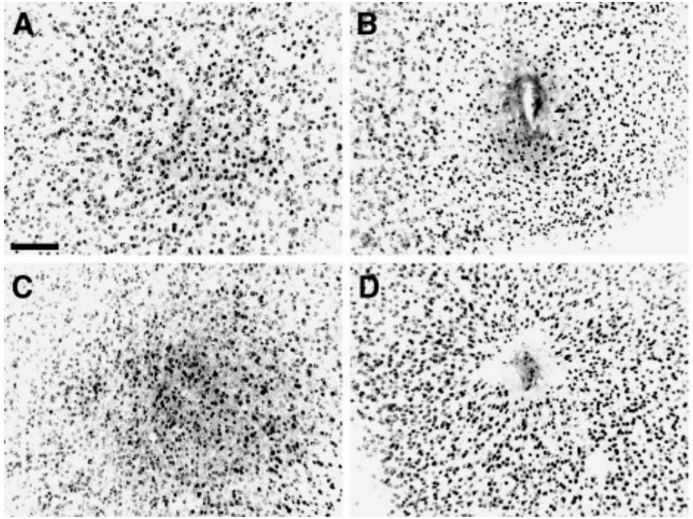


Neuronal Cell Loss

Stab Wound | Electrode

2 weeks

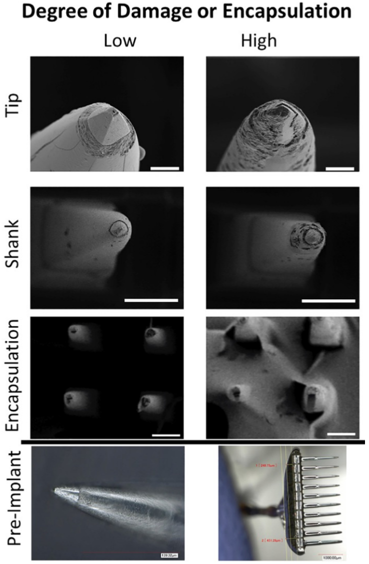
4 weeks

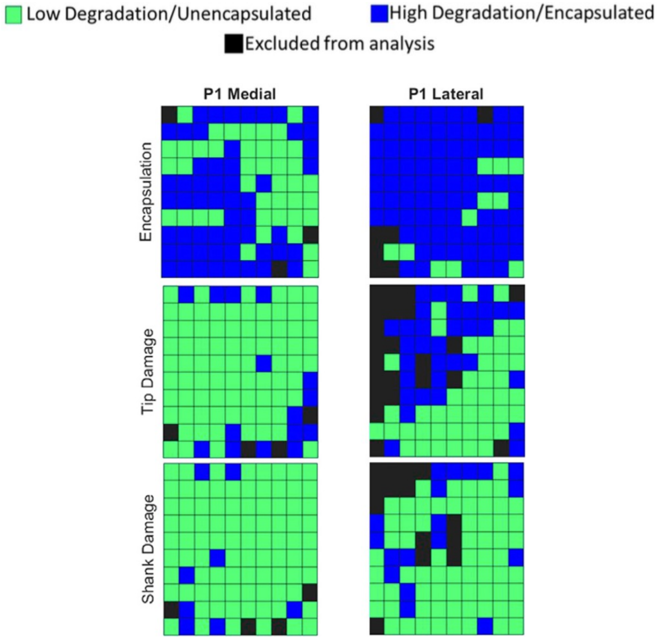


What happens to a neural implant inside of the body?

Encapsulation, degradation, and loss of function over time

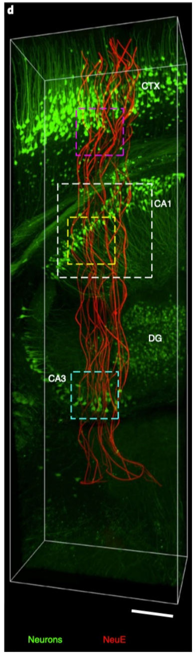
Utah Arrays in Patients



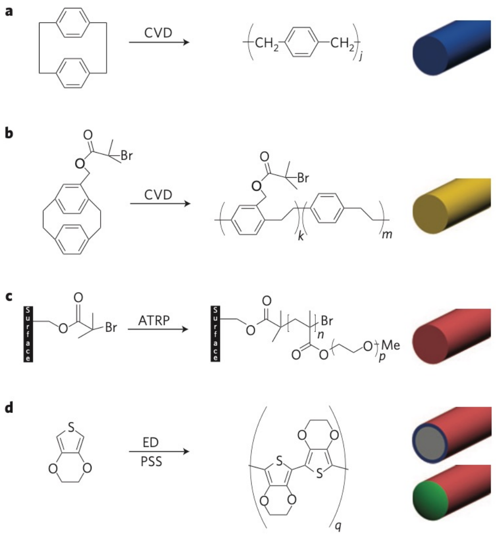


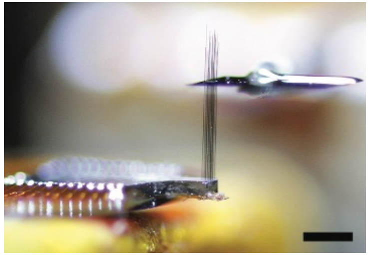
How can we use materials science to change this?

Soft electrodes



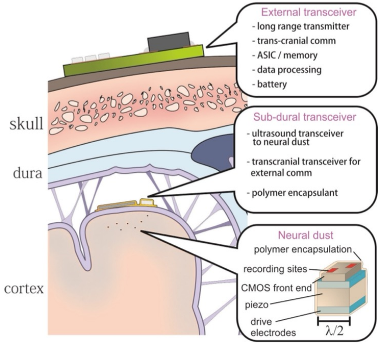
Changing surface chemistry





Small feature sizes/high aspect ratios

Going wireless



What we need to explore

- Why would these features (e.g. stiffness, size, shape, surface chemistry) change how the body responds to a device?

- How can we use materials science to control these properties?

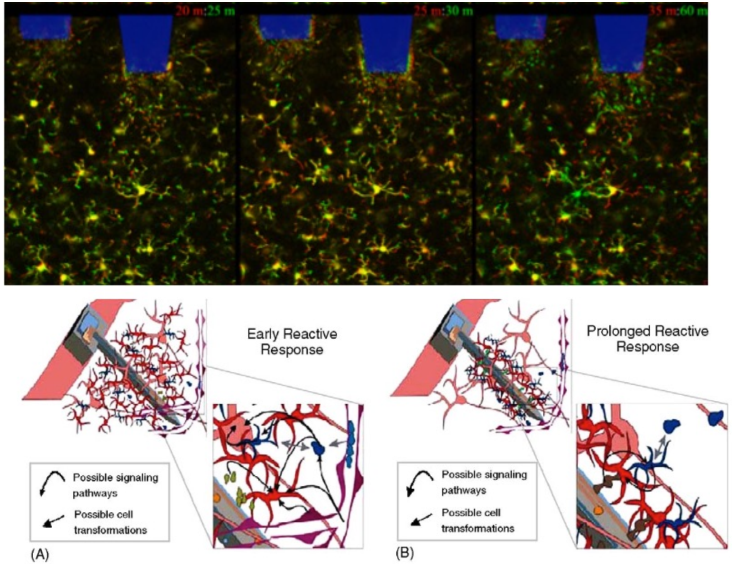
Neuroengineering Materials – Key Concepts

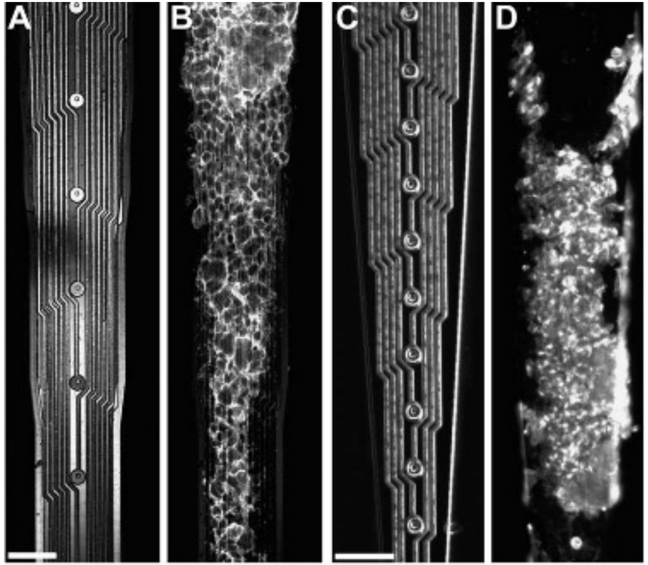
- Biological responses to neural implants

- Mitigating detrimental responses
  - Size and shape
  - Stiffness
  - Wireless devices

Biological responses to neural implants

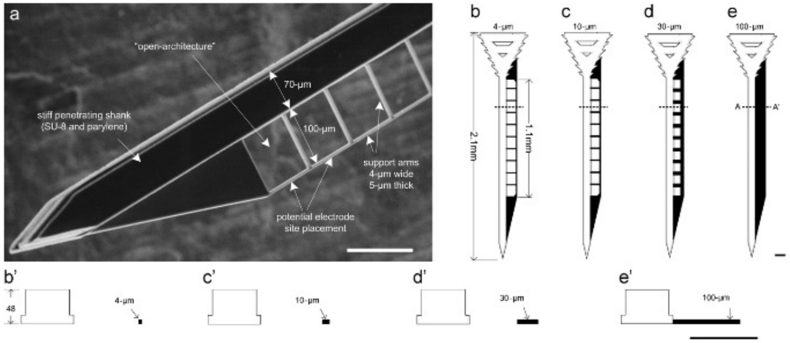
- Taking a look at some of the classic papers that helped us to understand the biological resopnse to implanted neural devices

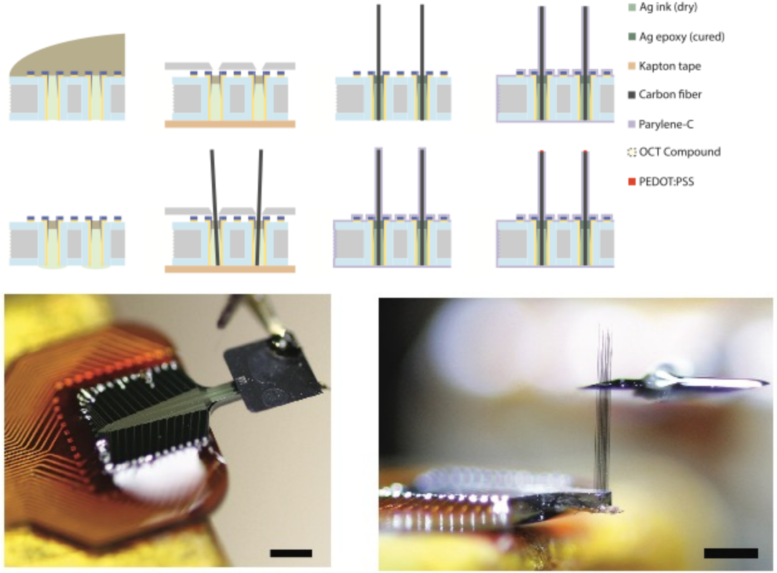




Mitigating detrimental responses: Size and shape

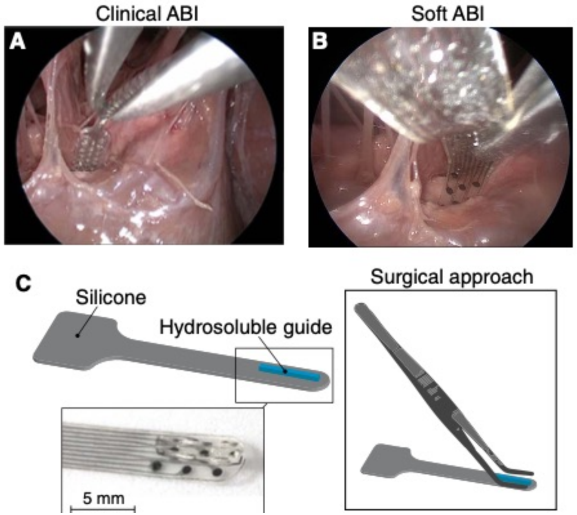
- Exploring implant designs with different sizes/aspect ratios/subcellular features, how they are made, and how these designs change the biological response

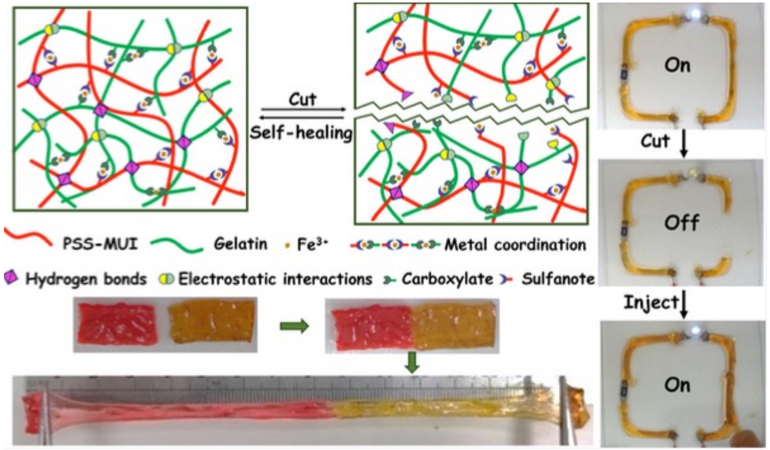




Mitigating detrimental responses: Stiffness

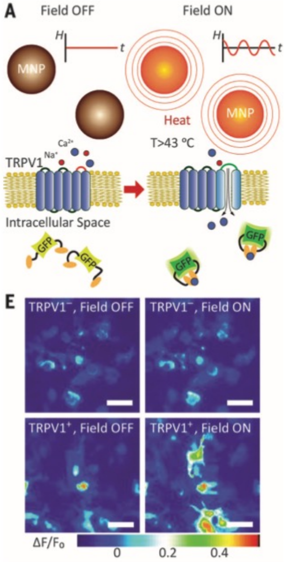
- Soft electrode design, manufacturing, and characterization, and how stiffness changes the biological response

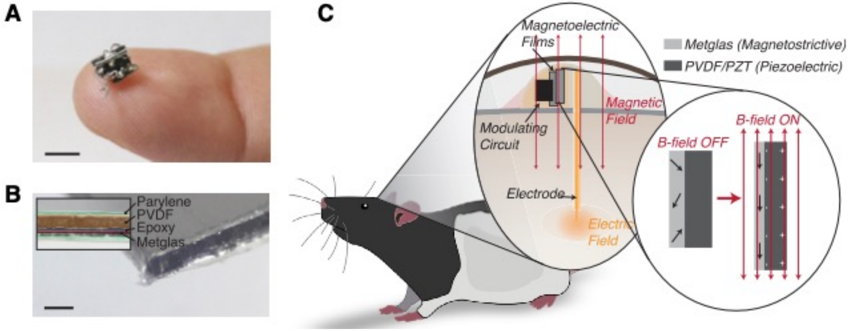


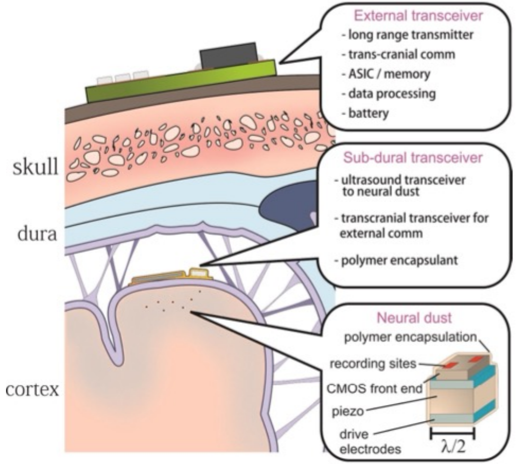


Mitigating detrimental responses: Wireless devices

- Exploring methods to wirelessly power neural devices, avoiding transcranial/transdural wiring, and injectable electrodes

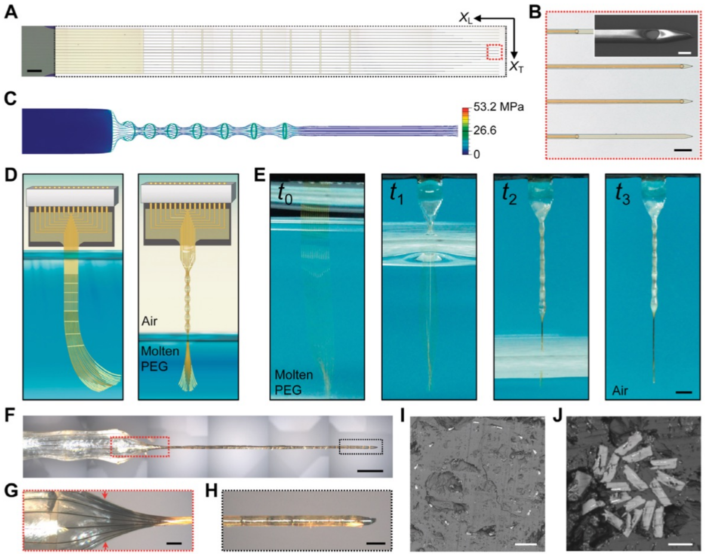






Journal article selection

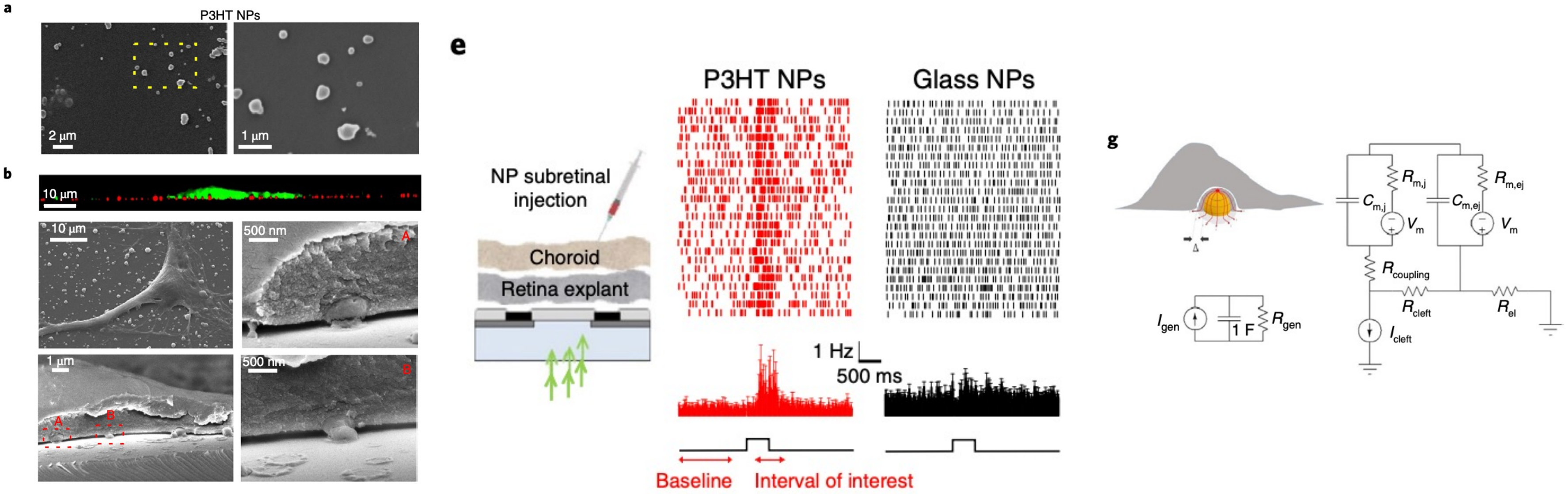
Elastocapillary self-assembled neurotassels for stable neural activity recordings



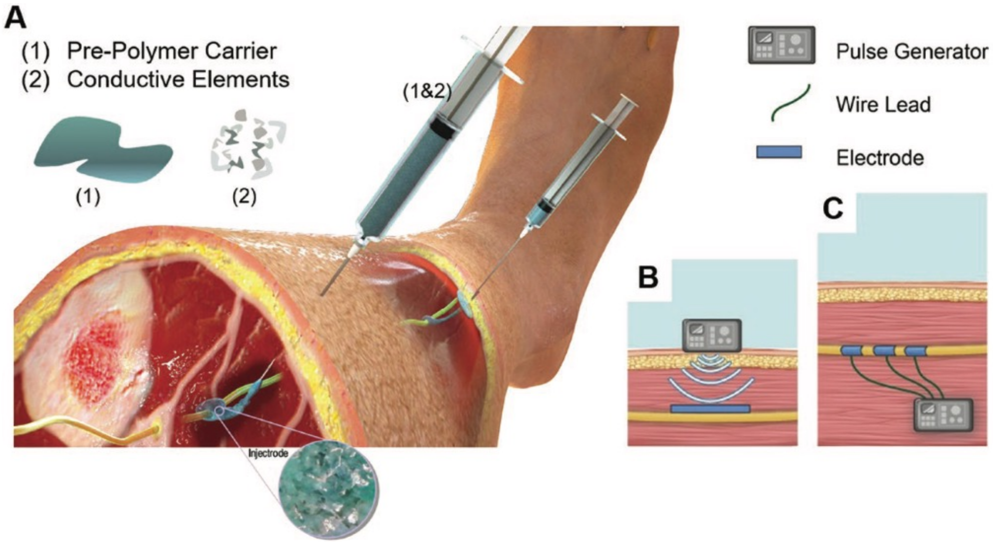
Depth implantation of Neurotassel in brain

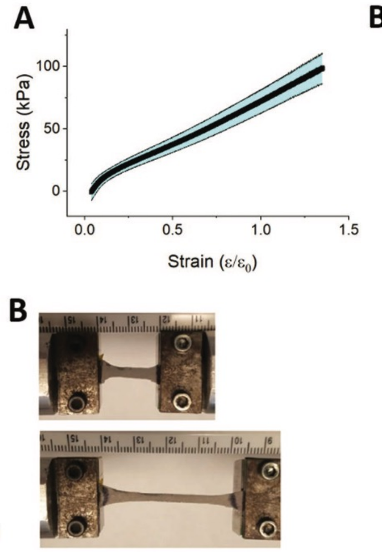
Dissolution of PEG of Neurotassel/PEG fiber in brain

Subretinally injected semiconducting polymer nanoparticles rescue vision in a rat model of retinal dystrophy

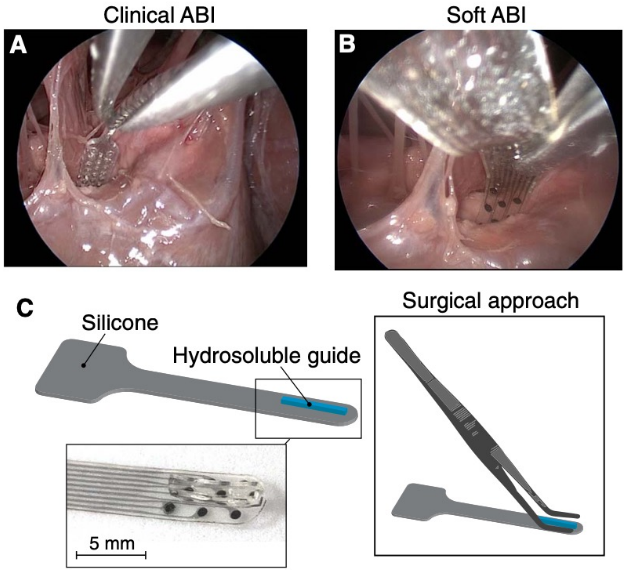


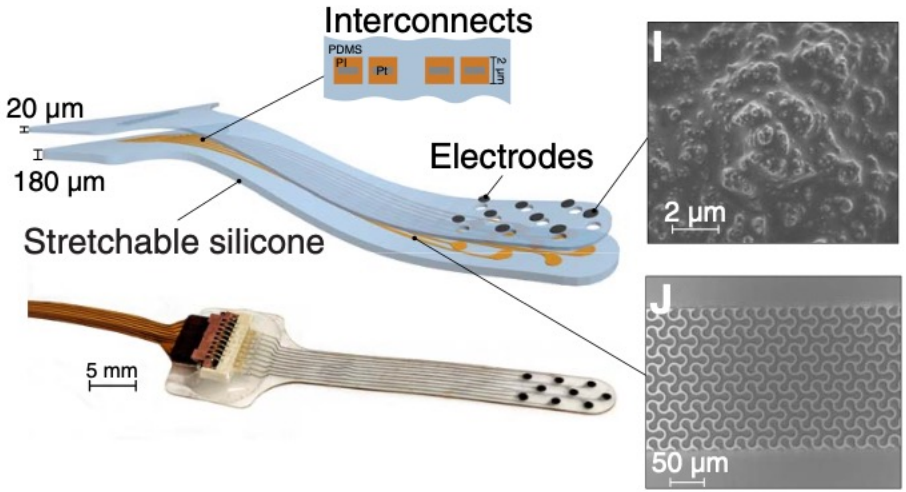
An Injectable Neural Stimulation Electrode Made from an In-Body Curing Polymer/Metal Composite



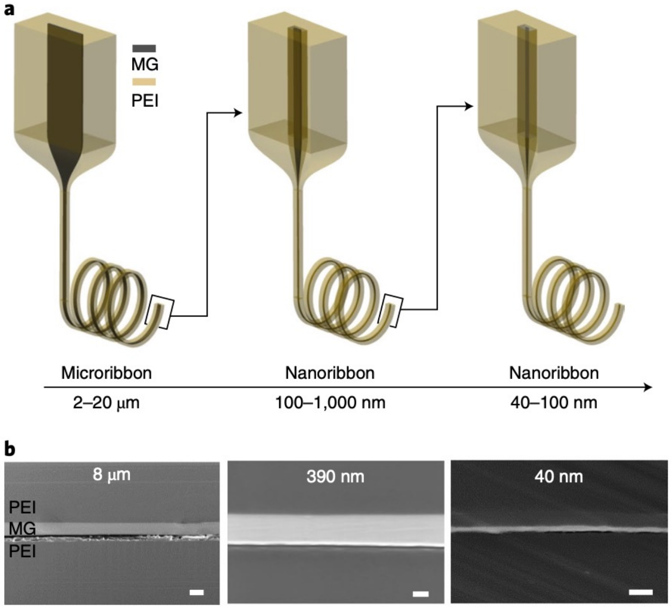


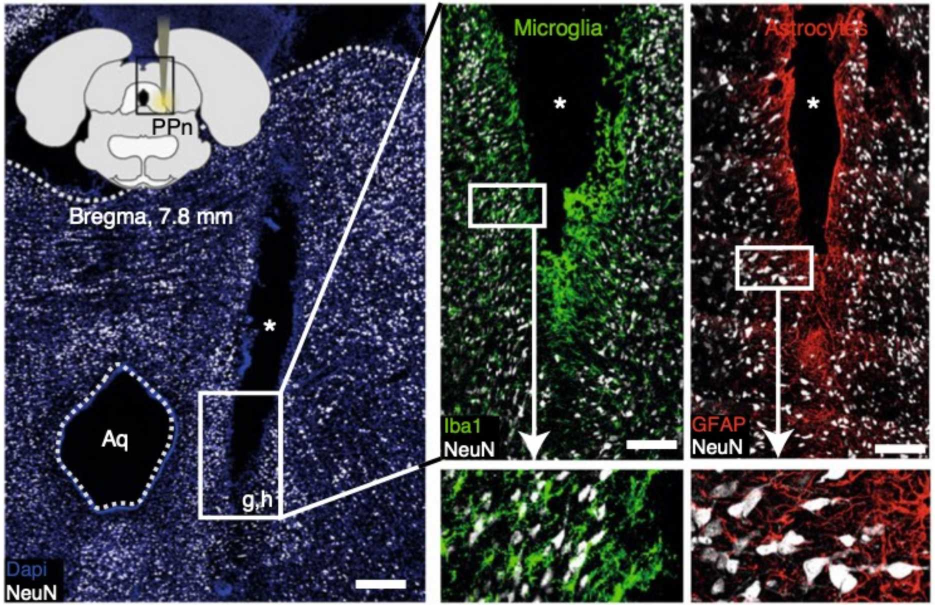
Microstructured thin-film electrode technology enables proof of concept of scalable, soft auditory brainstem implants



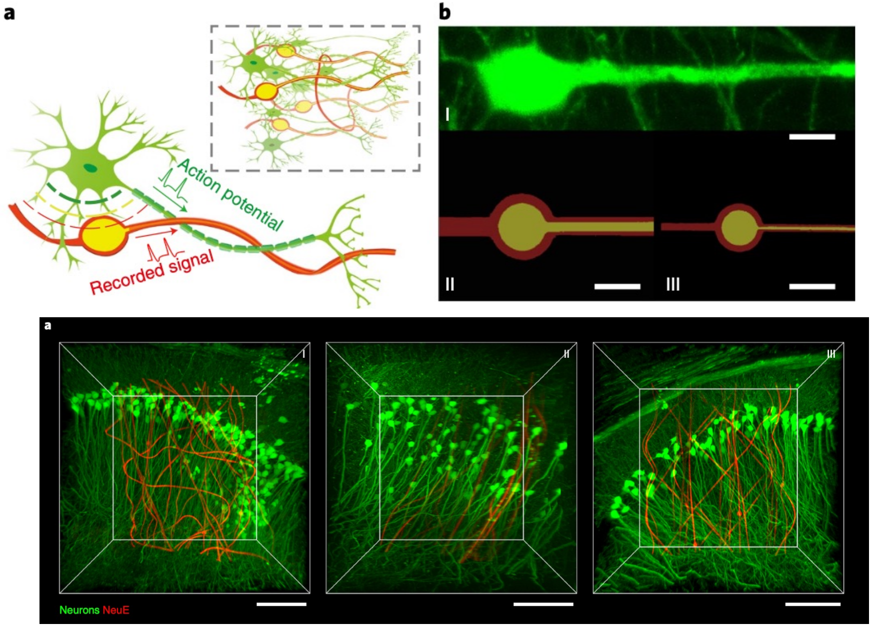


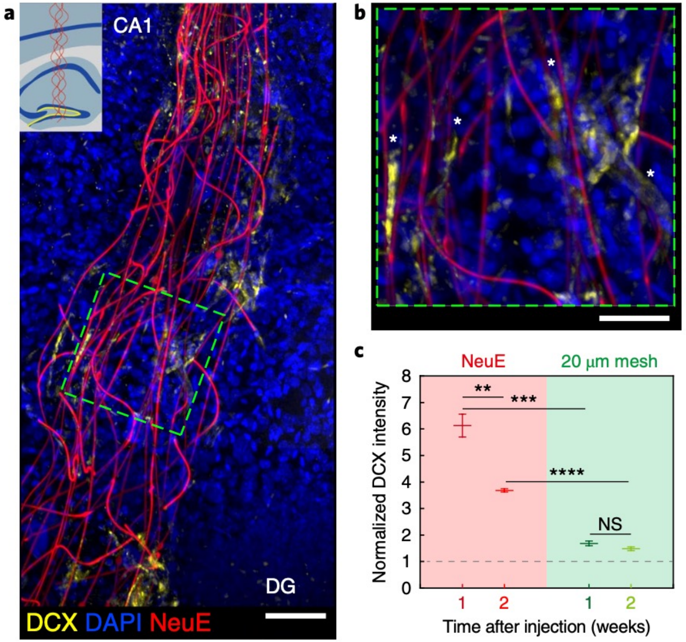
Structured nanoscale metallic glass fibres with extreme aspect ratios





Bioinspired neuron-like electronics





Course Information

Key Dates

- **Kick-off meeting**
  - October 20th, 11:30 – 13:00
- **Journal article selection opens**
  - October 27th, 11:30
  - Moodle
- **Student presentations**
  - February 2nd, 11:30 – 13:00 and February 9th, 9:45 – 11:15
- **Paper submission deadline**
  - February 23rd, via email to your supervisor
- **Meetings with supervisor**
  - 3X 1 hour, at the supervisor's discretion

Supervisors

- Prachi Kumari – p.kumari@tum.de
- Aleksandra Milojkovic – aleksandra.milojkovic@tum.de
- Hannah Wunderlich – hannah.wunderlich@tum.de

Seminar grading

- **50% presentation** - content, slide organization/clarity, presentation quality, thoroughness with regard to the sections/questions

- **50% paper** - content, thoroughness with regard to the sections/questions, clarity

Presentation – 50%

- ***Format***: 25 min long; please see the list in the “Paper” section to guide your presentation content

- ***Due***: July 19th, 11:30 – 14:45, during the student presentation session

- ***Submission***: Bring the prepared talk on your laptop to the session (email your supervisor the week prior if you cannot use your own)

Paper – 50%

- ***Format***: 2500 – 3000 words (not including references or figure captions)
- ***Due***: by the end of the day (midnight) on February 23rd, 2023
- ***Submission***: via email to your supervisor, with k.kozielski@tum.de in cc

Sections to include in your paper and presentation

- *Introduction* –
  - Provide context for what the paper is about.
  - Cite and discuss prior work that led up to this technology.

- *Methods* –
  - What were the key methods used, and how do they work?
  - Choose one fundamental method in the paper, and describe it in depth.

- *Results* –
  - What are the key results of the paper?
  - What is your evaluation of these results (e.g. controls, statistics, completeness of experimental set)?

Sections to include in your paper and presentation

- *Contribution to the field* –

  - What key step forward did the technology presented provide, or what key problem did it solve?
  - What are the pros/cons of this technology vs. technologies with similar goals and/or approaches?

- *Conclusions* –

  - Summarize important points of the above sections

- *Figures* –

  - Three total. One must be a cartoon/diagram made by the student that describes the overall aim/purpose/results of the paper (biorender.com offers free licenses to students for figure creation)

- *References*

Questions?