W1) Introduction
Fundamentals of neuroengineering

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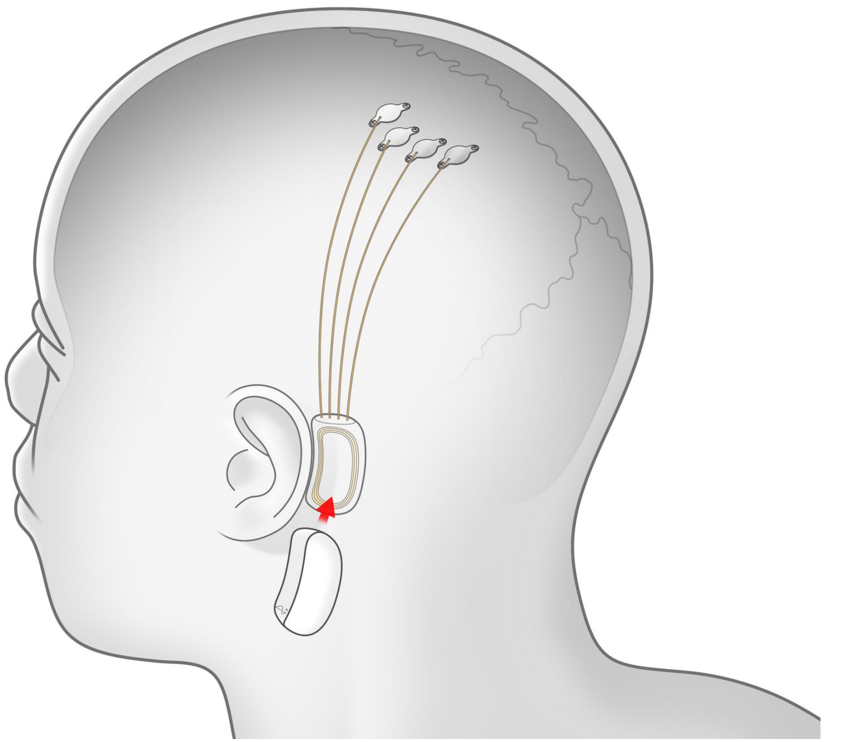

Neural Engineering

- Neural engineering (also known as neuroengineering) is a discipline within biomedical engineering that uses engineering techniques to understand, repair, replace, or enhance neural systems.
- Neural engineers are uniquely qualified to solve design problems at the interface of living neural tissue and non-living constructs (Hetling, 2008).

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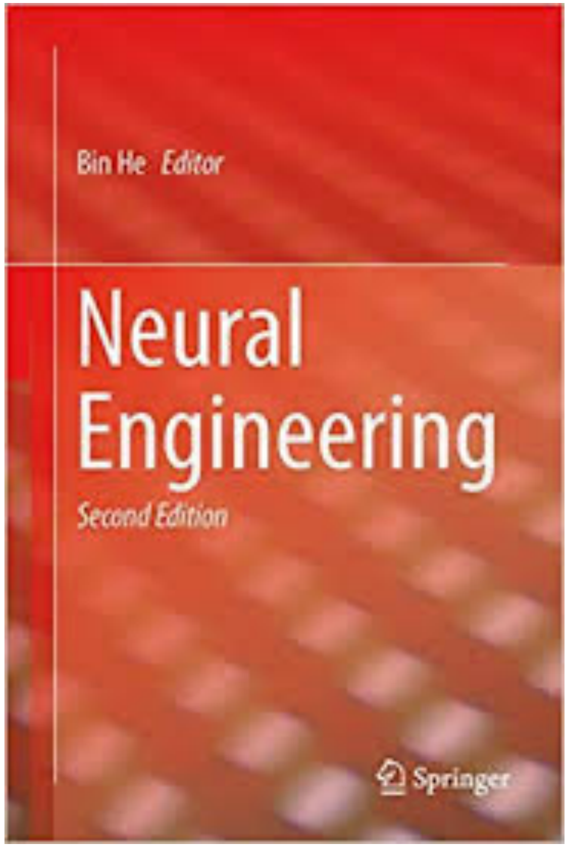
Neural Engineering

- The field of neural engineering draws on the fields of computational neuroscience, experimental neuroscience, clinical neurology, electrical engineering and signal processing of living neural tissue, and encompasses elements from robotics, cybernetics, computer engineering, neural tissue engineering, materials science, and nanotechnology.

- Prominent goals in the field include restoration and augmentation of human function via direct interactions between the nervous system and artificial devices.

- Much current research is focused on understanding the coding and processing of information in the sensory and motor systems, quantifying how this processing is altered in the pathological state, and how it can be manipulated through interactions with artificial devices including brain-computer interfaces and neuroprosthetics.

- Other research concentrates more on investigation by experimentation, including the use of neural implants connected with external technology.



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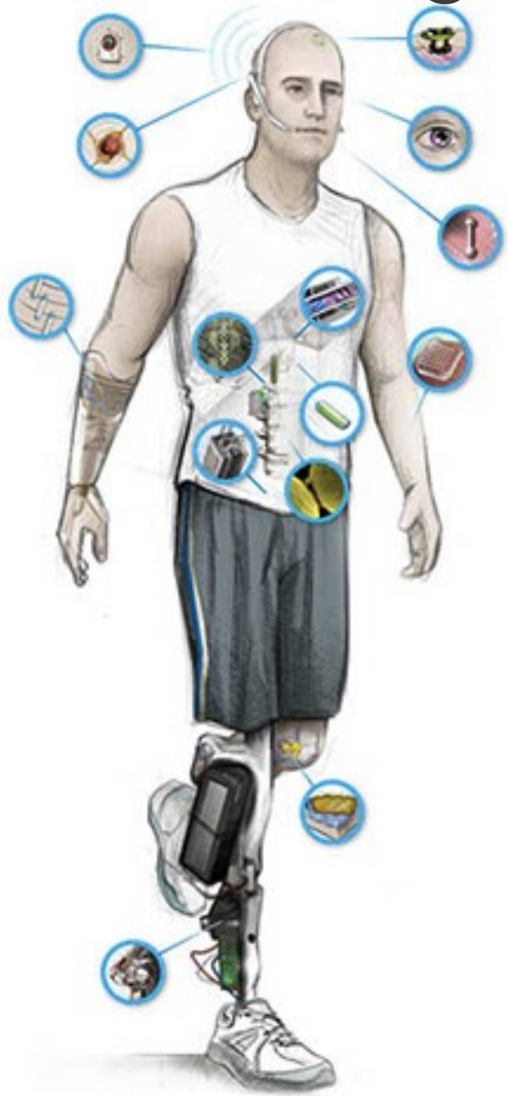
Neural Engineering



If you can play with the nervous system you have **UNLIMITED** possibilities

Tom Mortimer
Case Western

These technologies are already helping disabled people and more can be achieved in the near future

The “stealth paradox”

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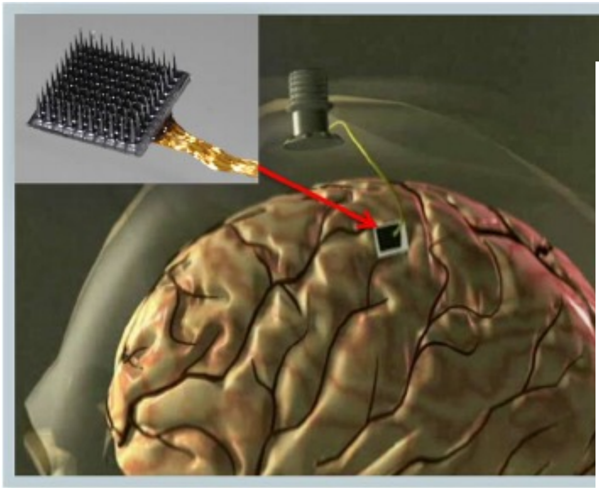
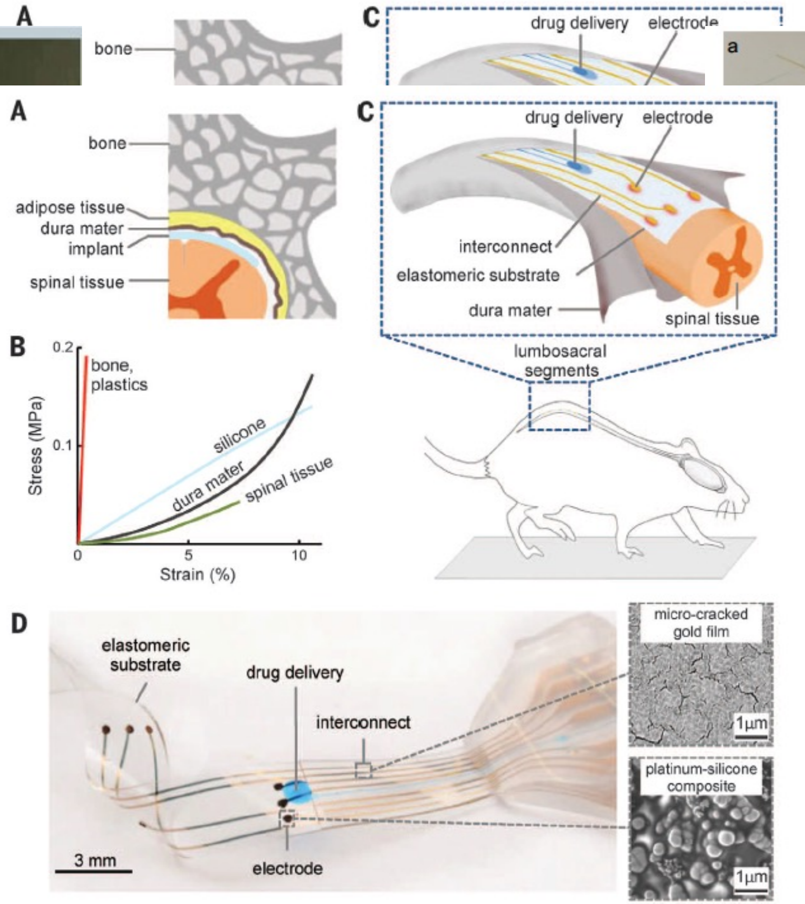
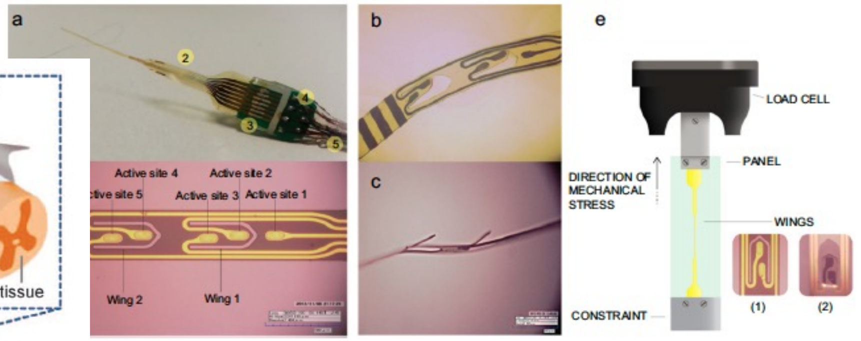
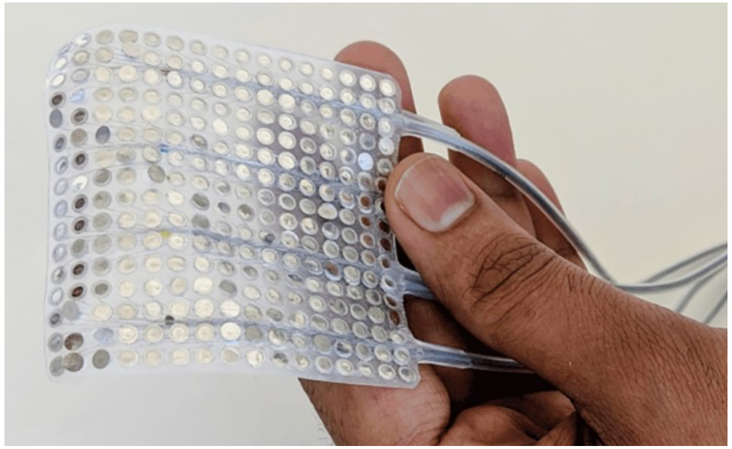
After the Second World War two stealth plains have been found…how to repair the not functioning one trying to understand how the working out can function

Central and peripheral interfaces

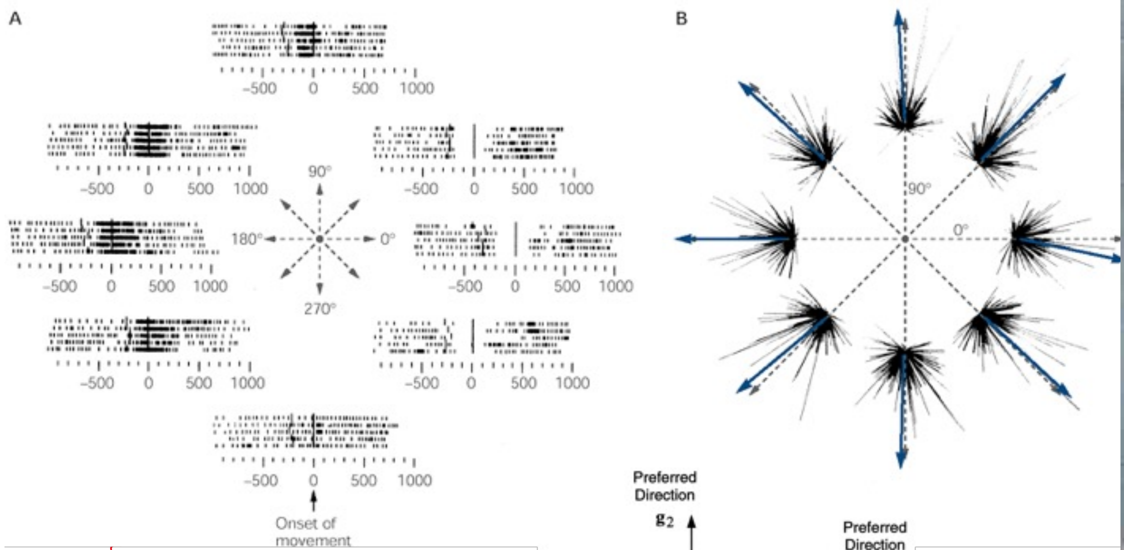


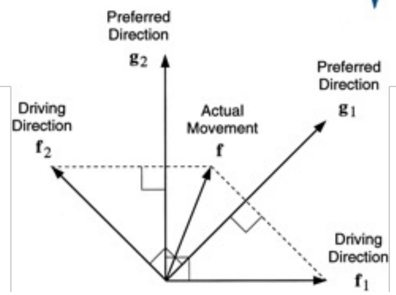


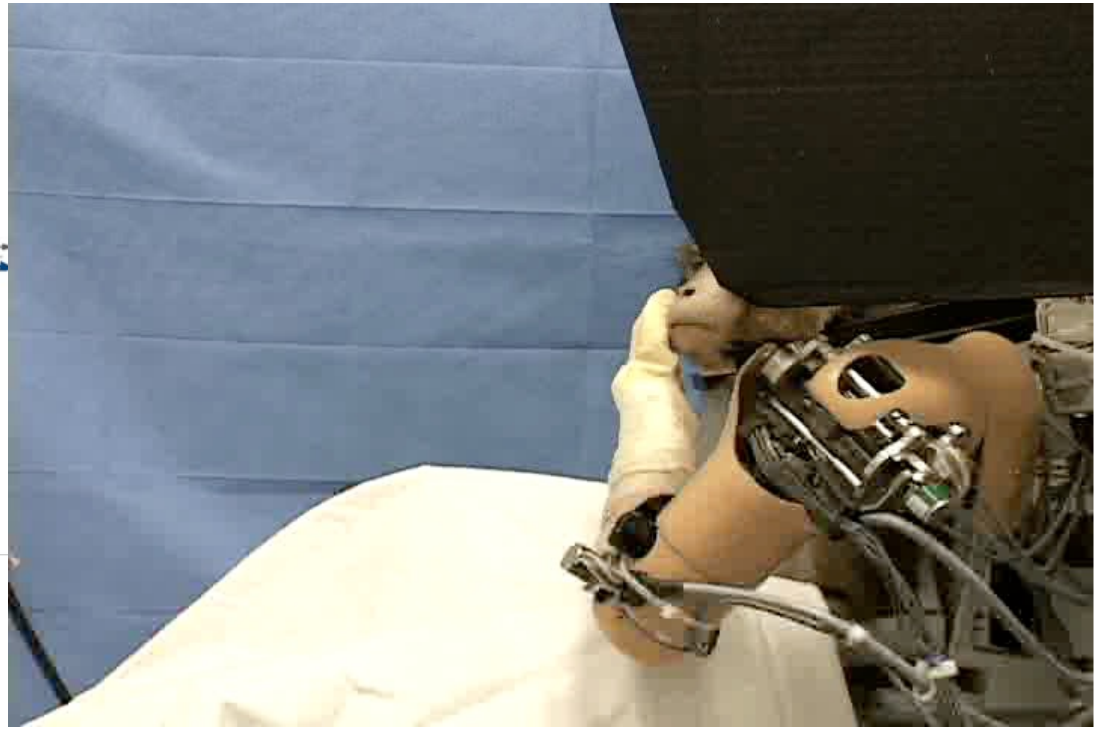




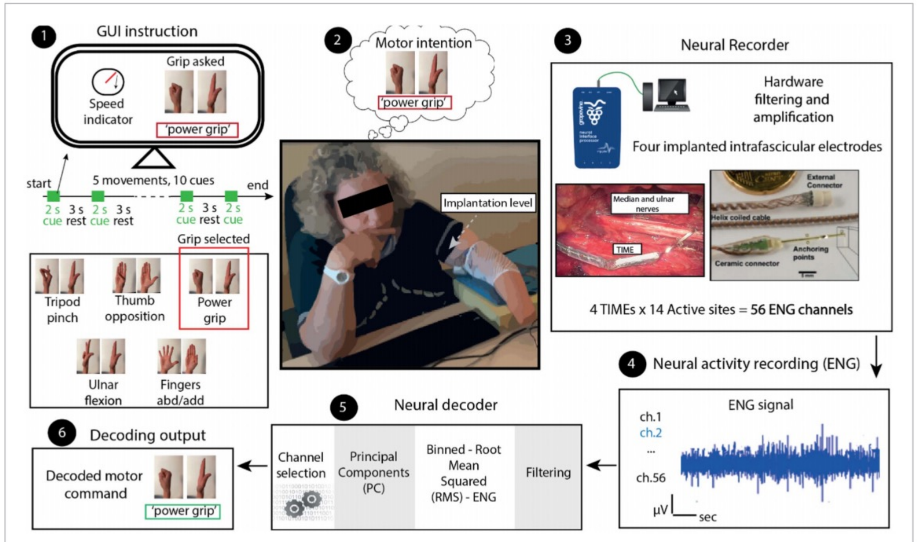
Motor Neuroprosthetics
Brain decoding

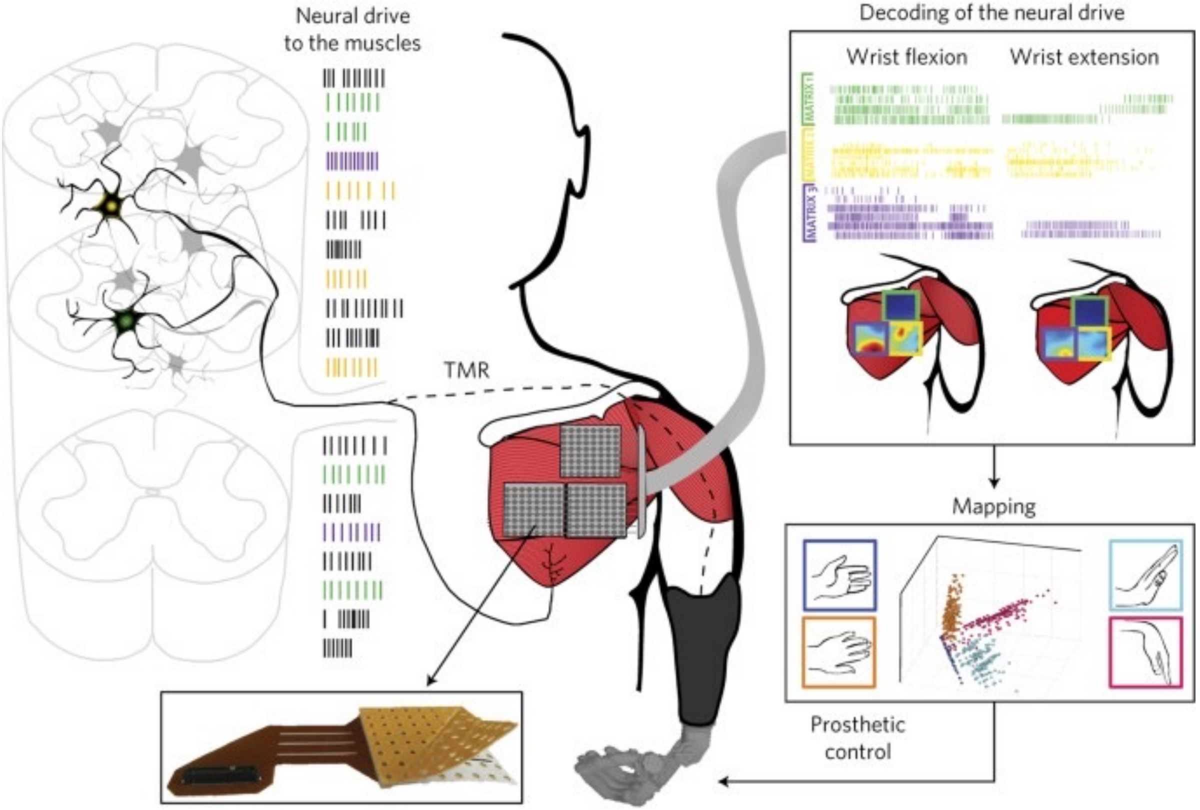






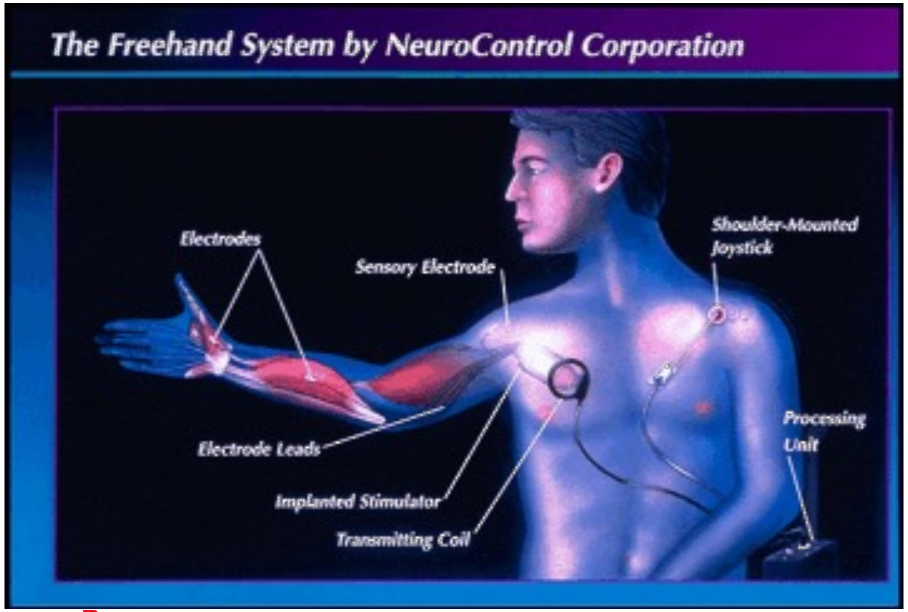
Motor Neuroprosthetics
Peripheral decoding

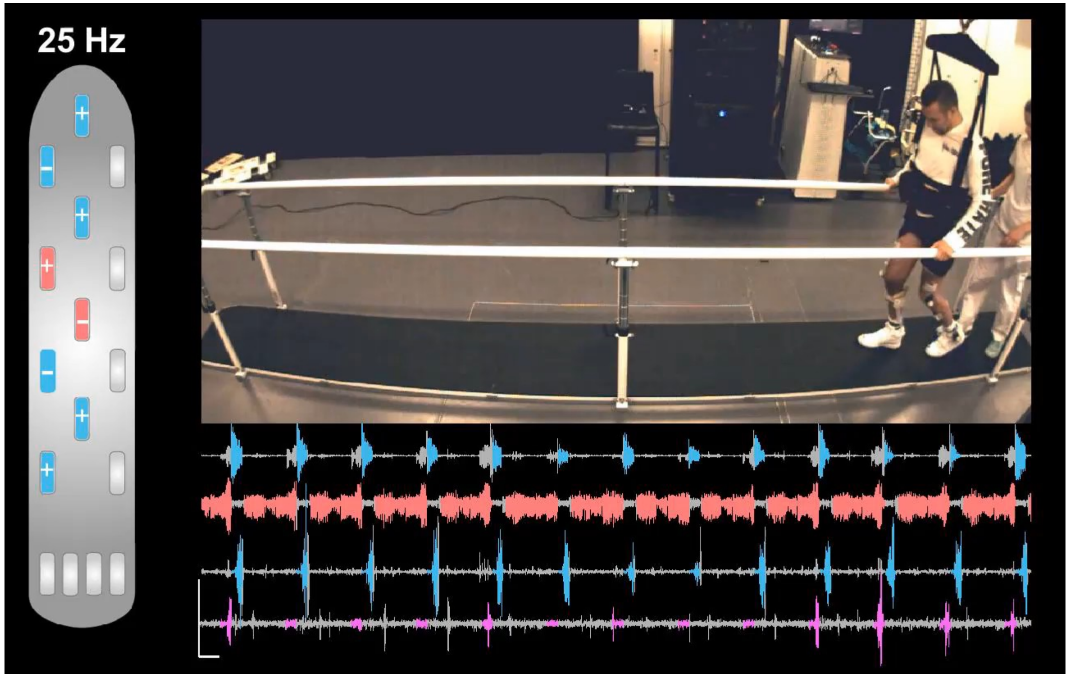


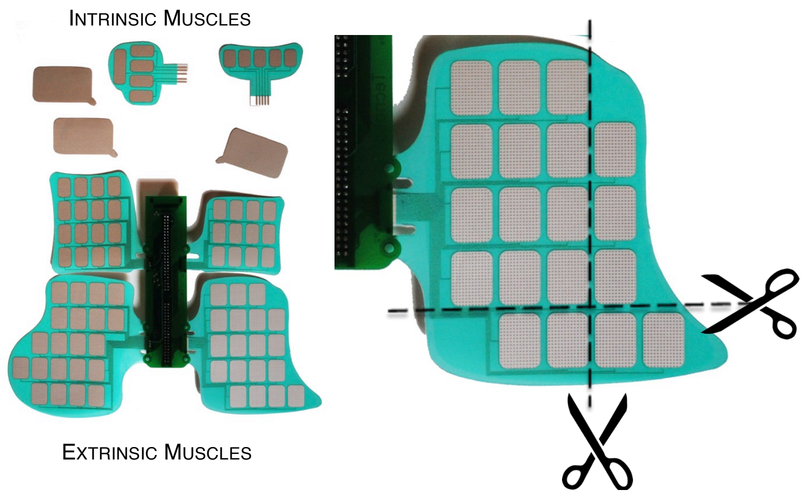


Fundamentals

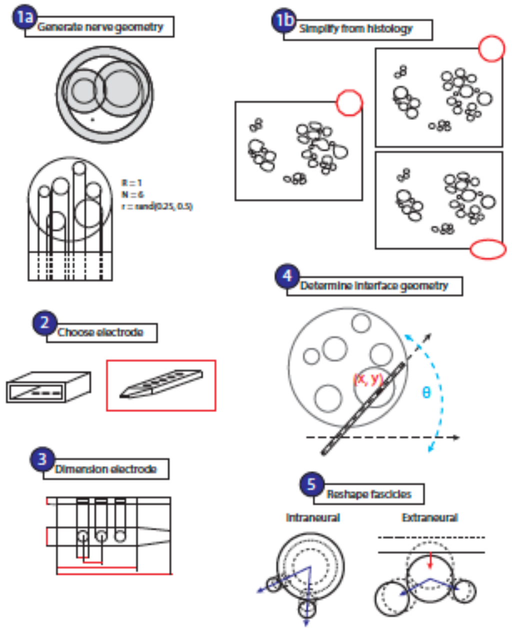
Electrical stimulation (actuation)

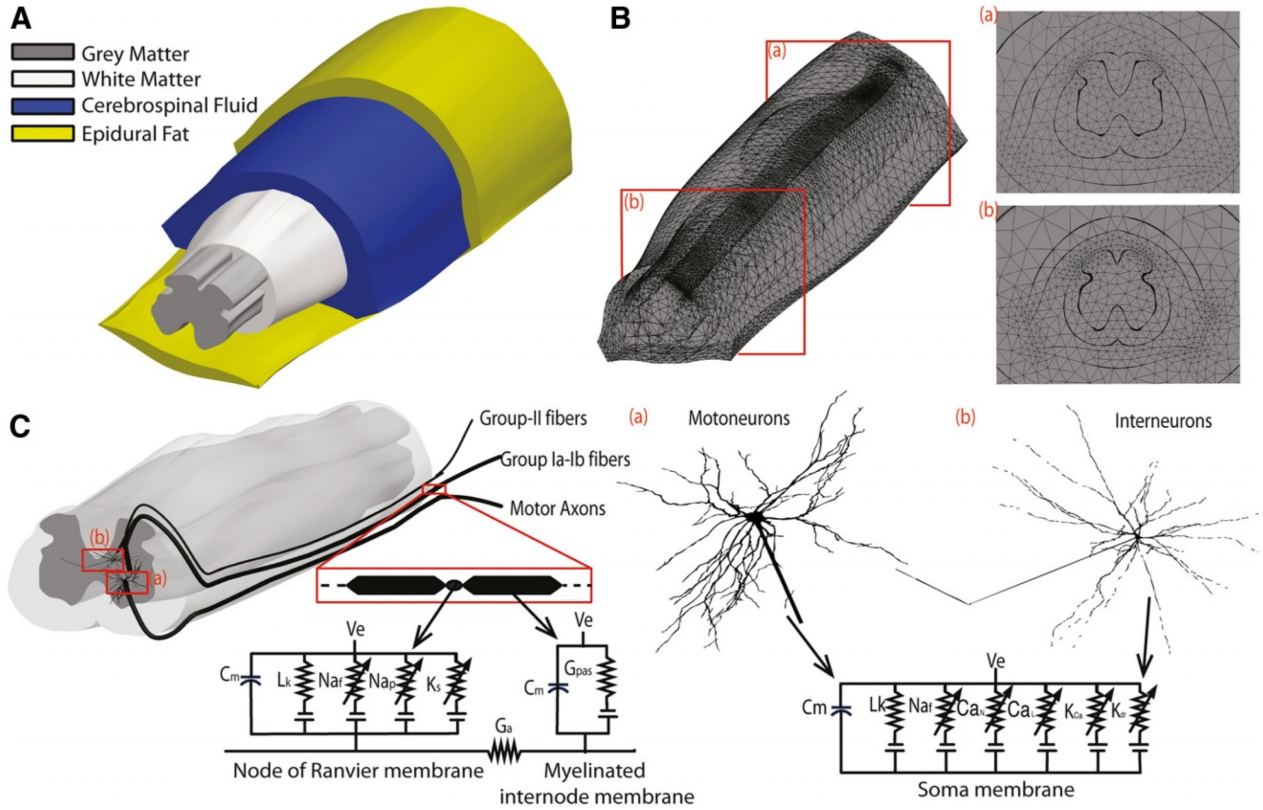




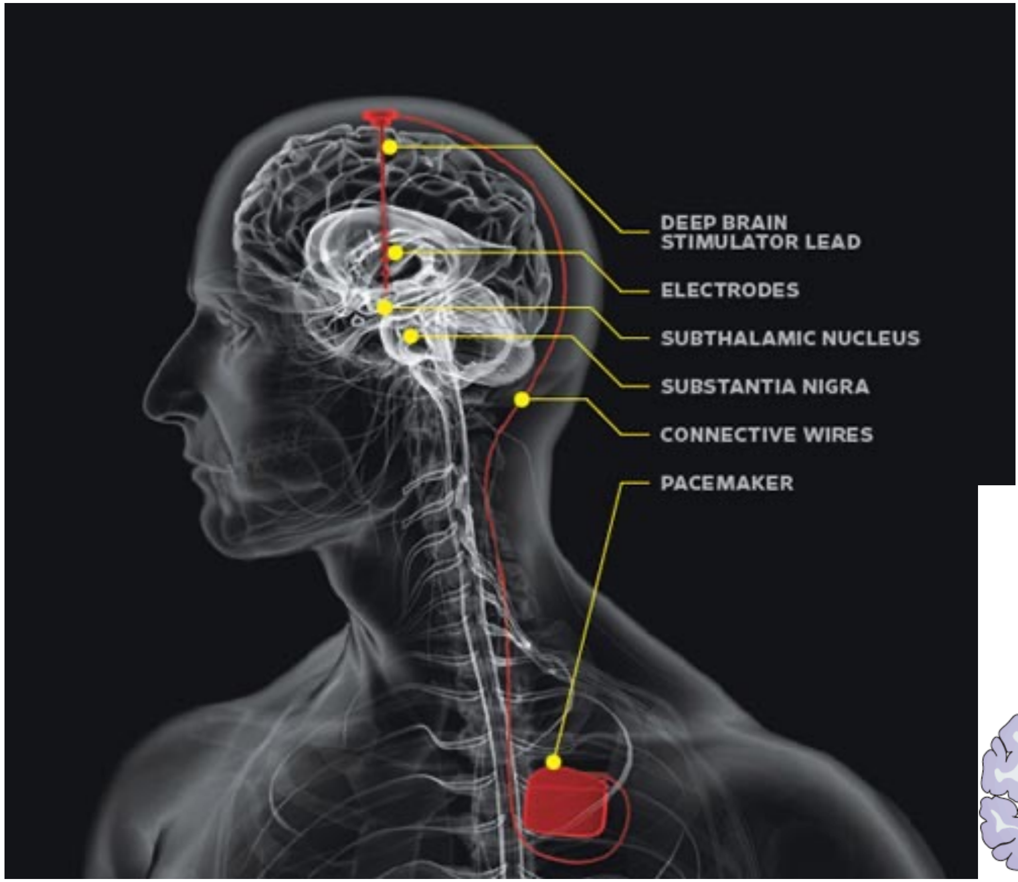


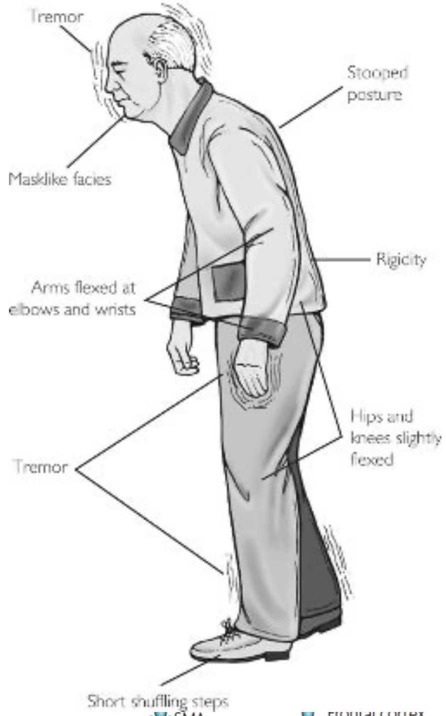
Computational models

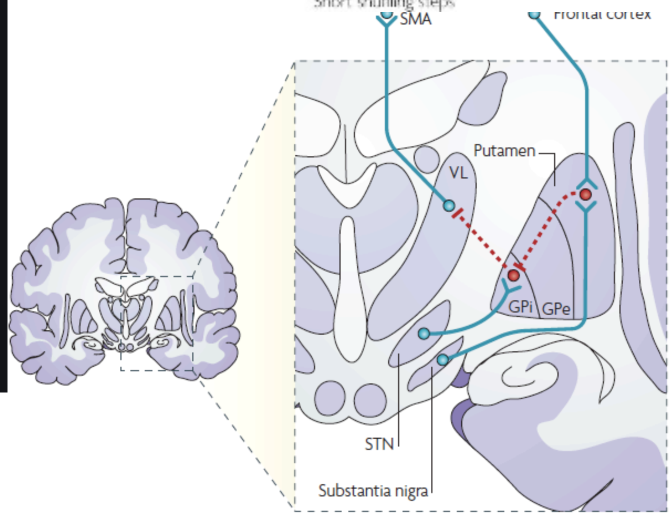




Deep Brain Stimulation

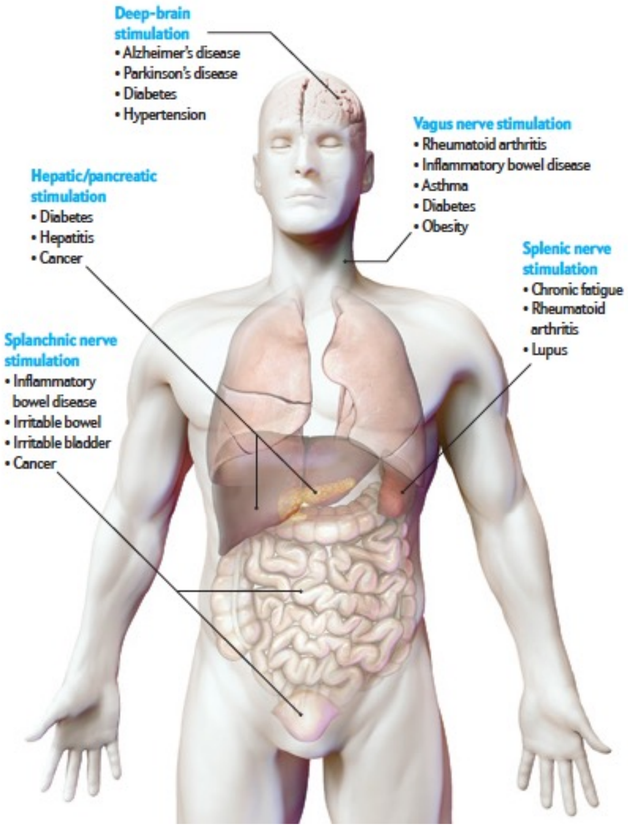






- GPi: internal globus pallidus
- GPe:external globus pallidus
- STN: subthalamic nucleus
- SMA: supplmentary motor area
- SNr: substantia nigra
- VL: ventrolateral nucleus of the thalamus

Bioelectronic Medicine



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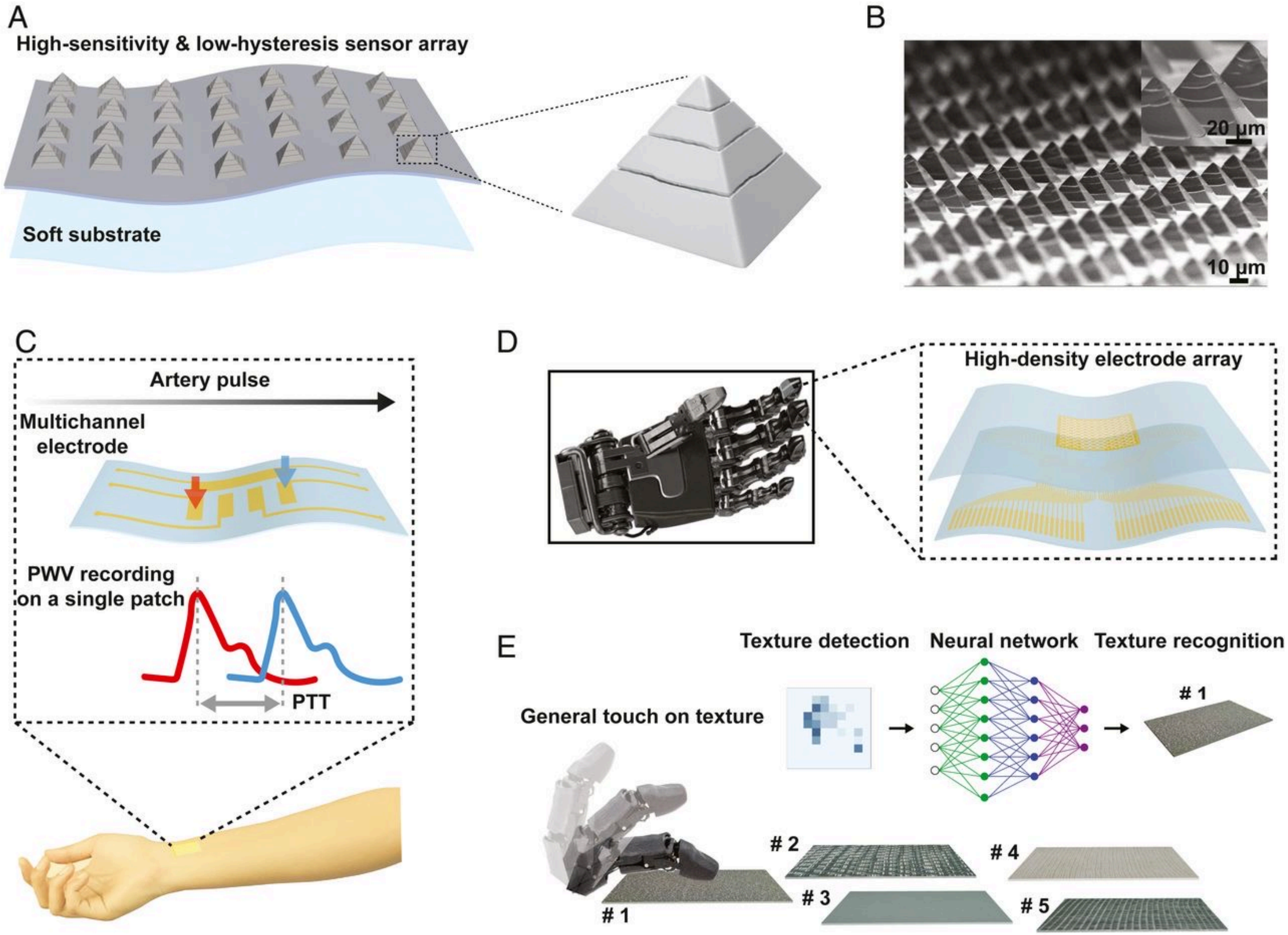
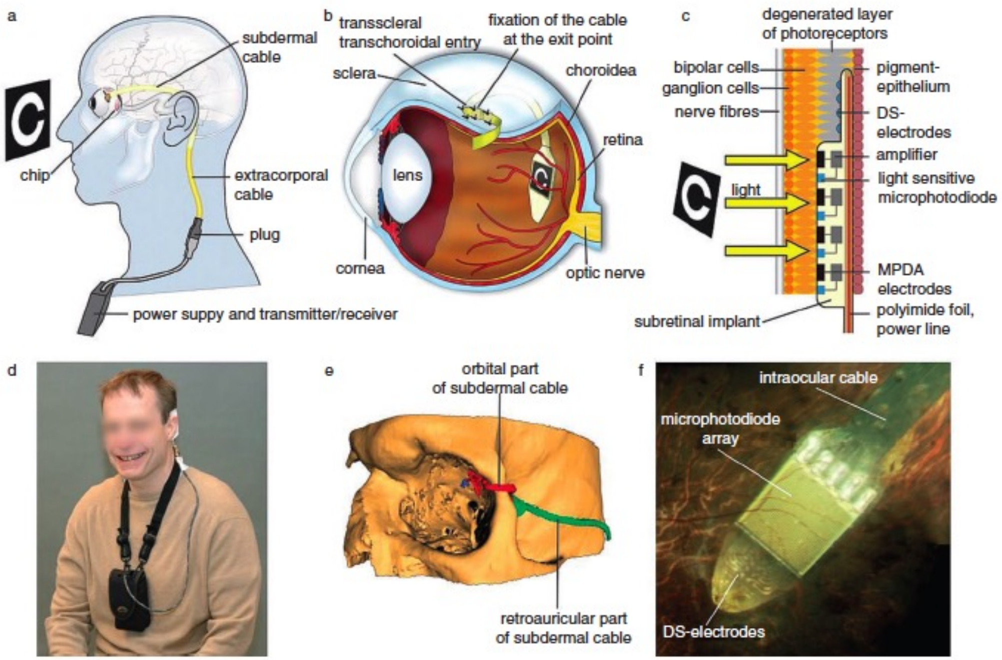
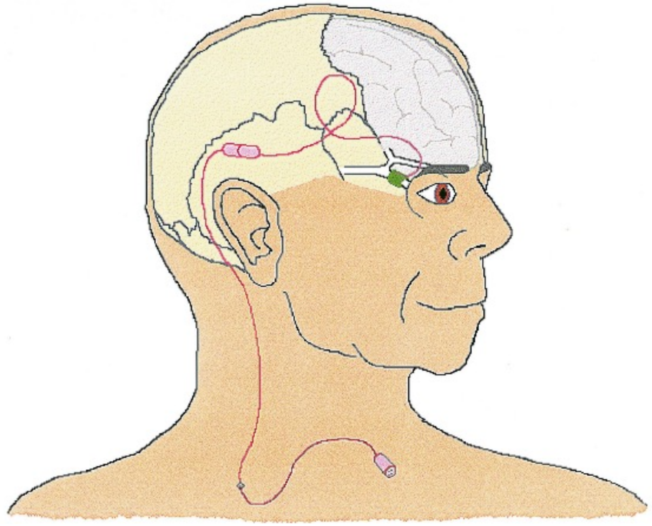
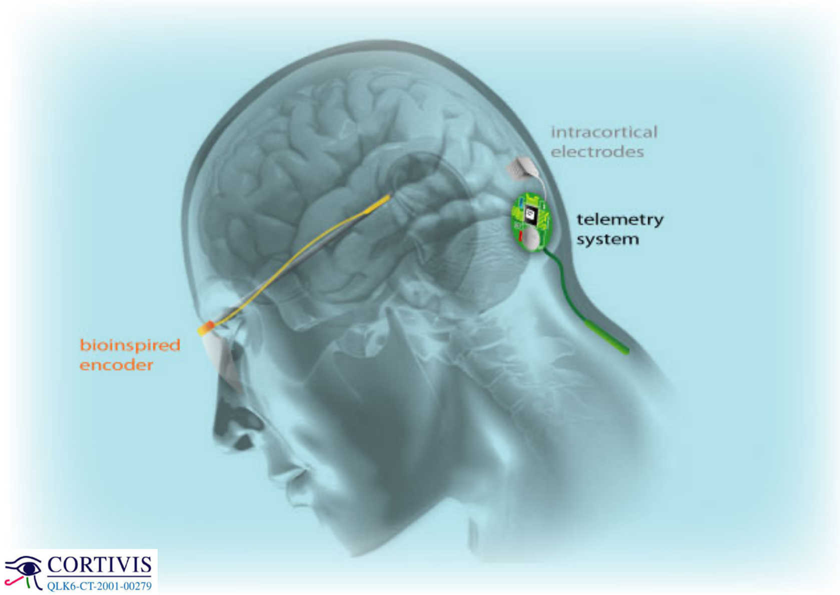
Wearable sensors



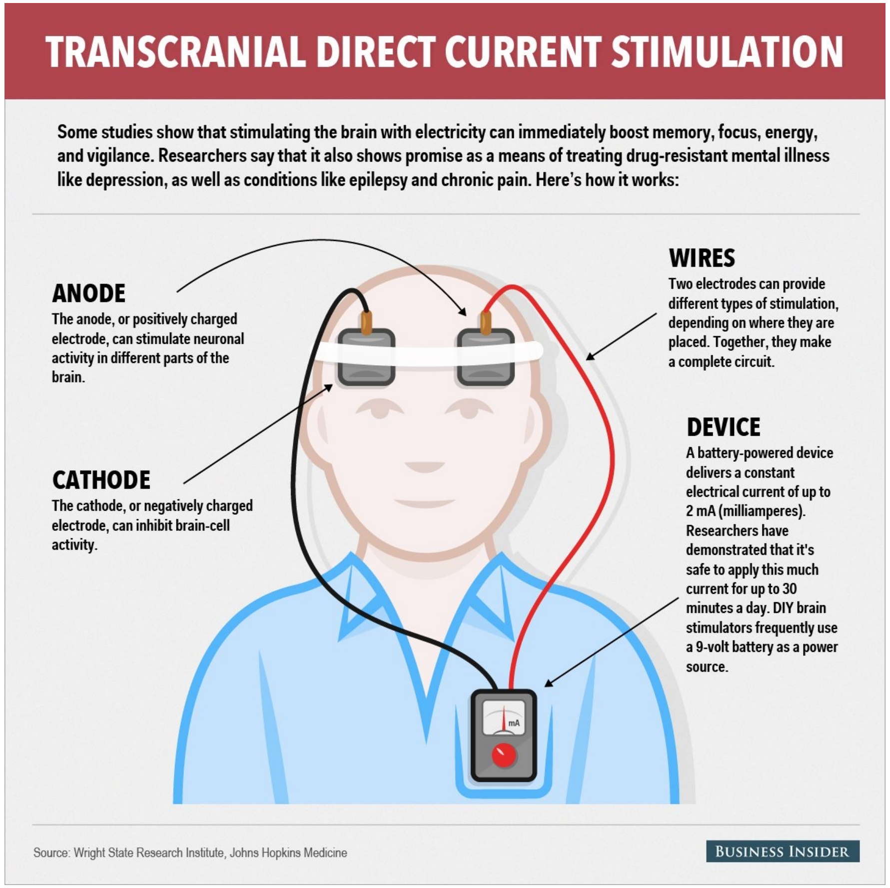
Visual Prostheses

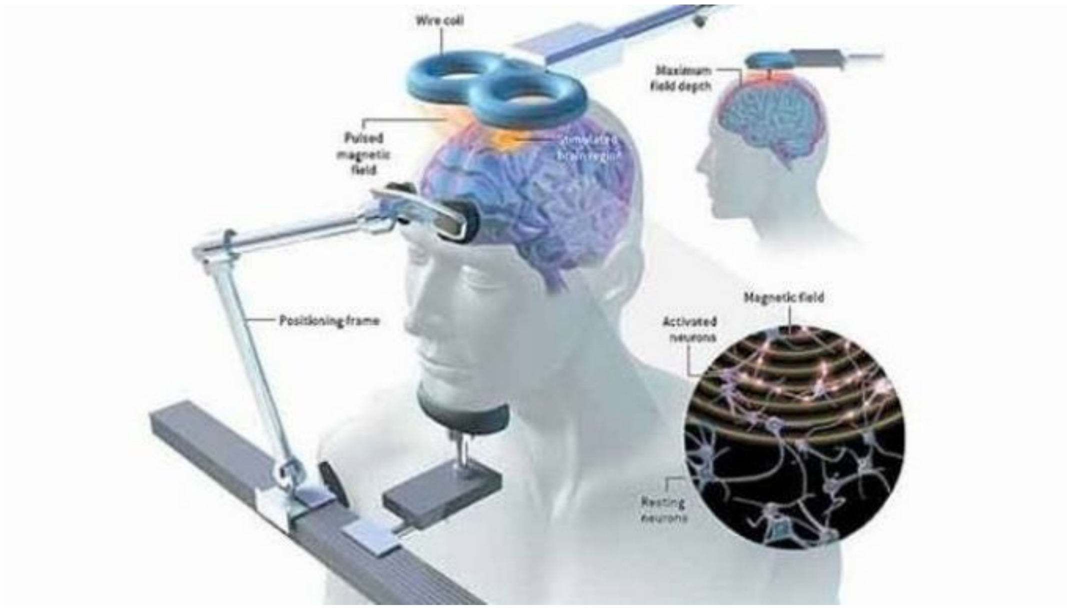




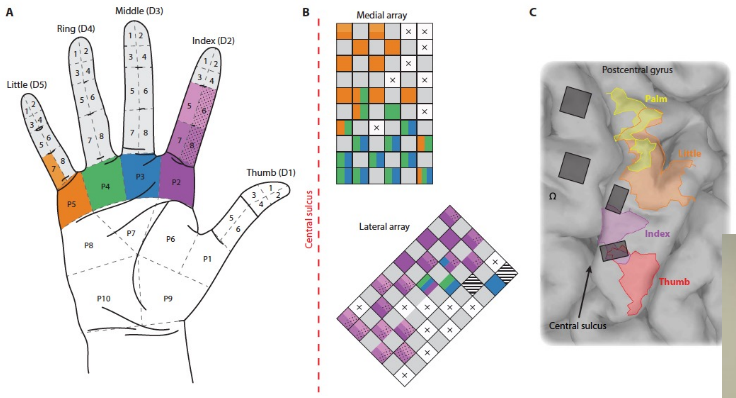


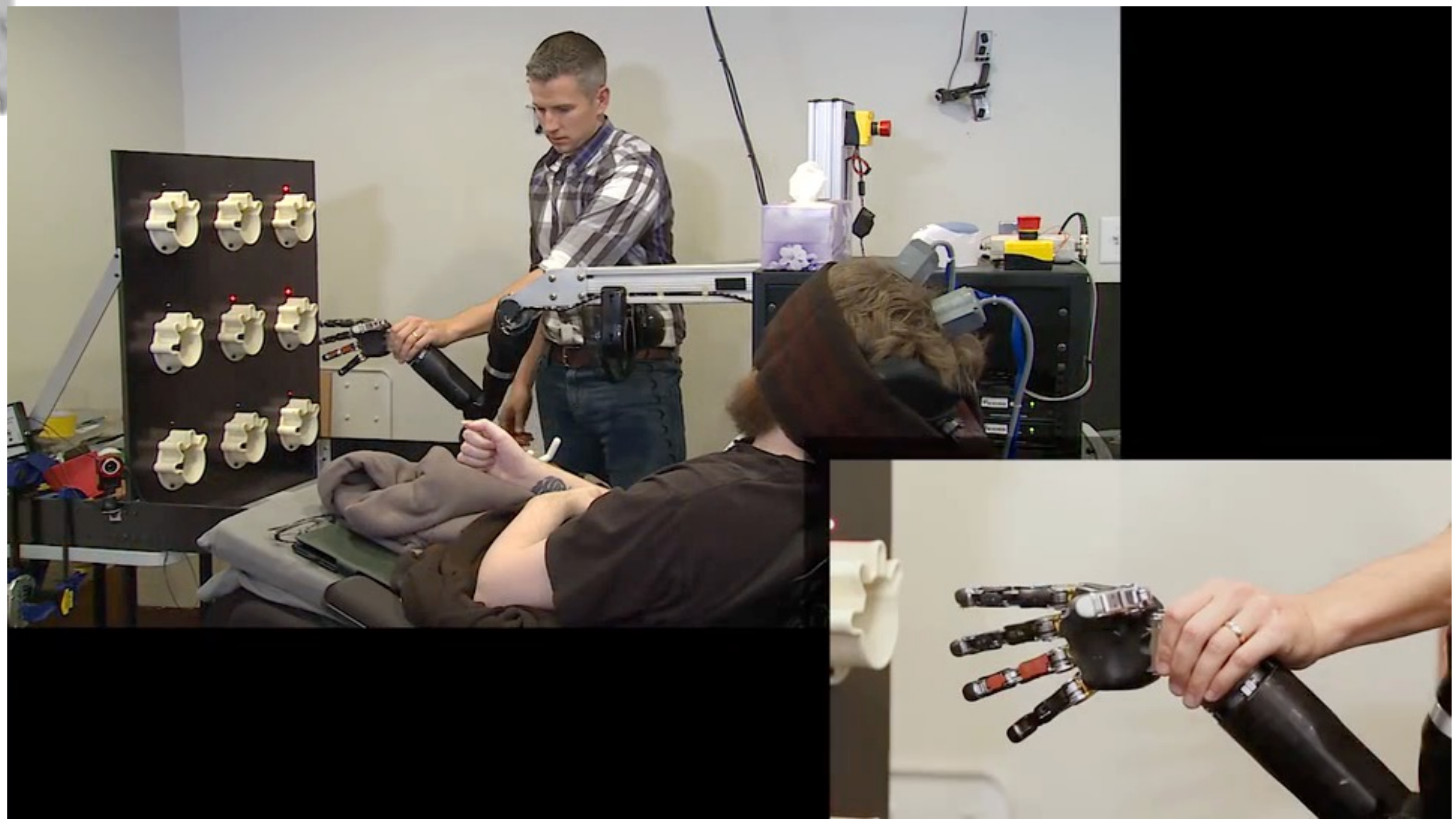
Cortical non-invasive neuromodulation



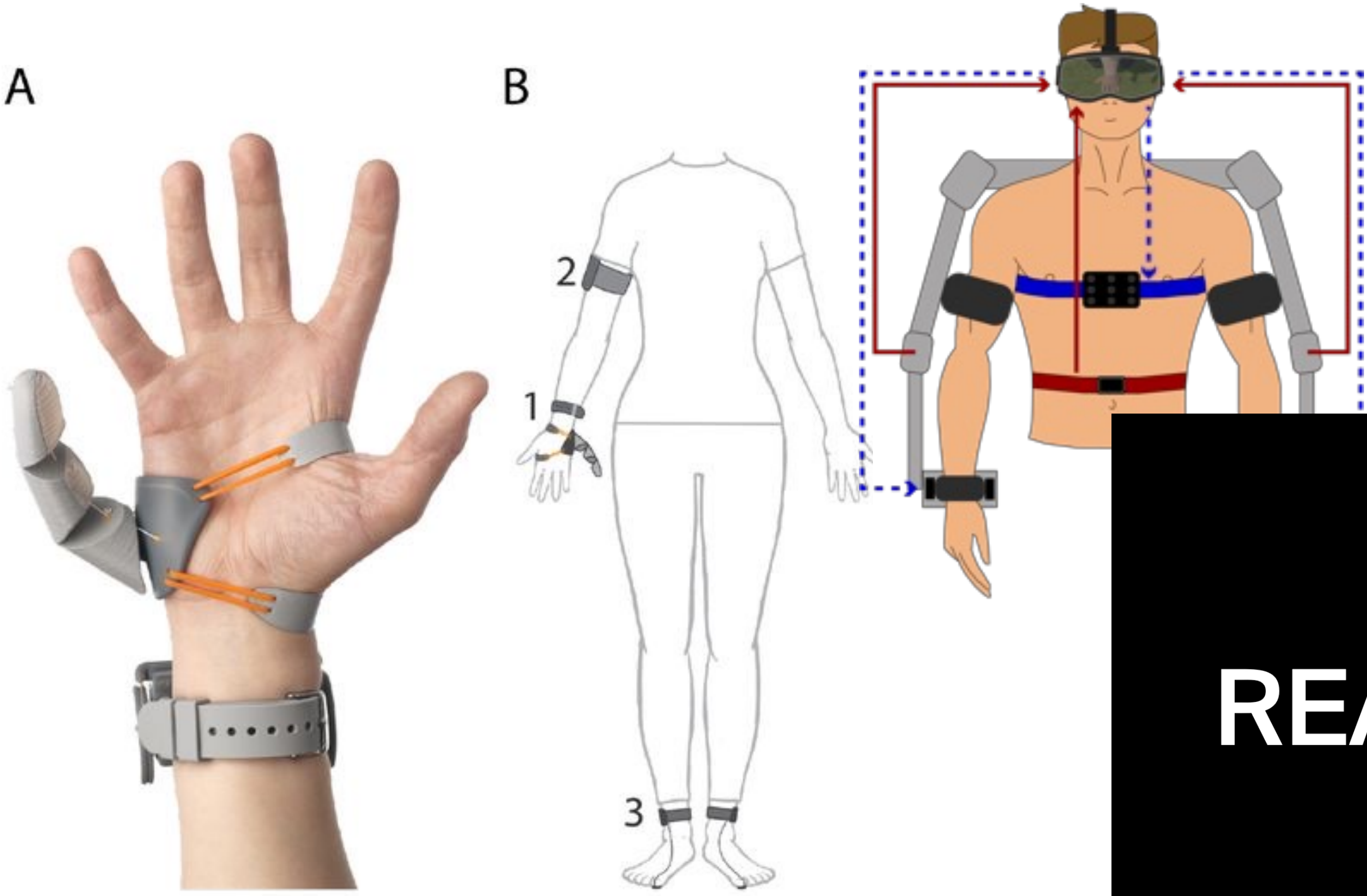


Sensory feedback





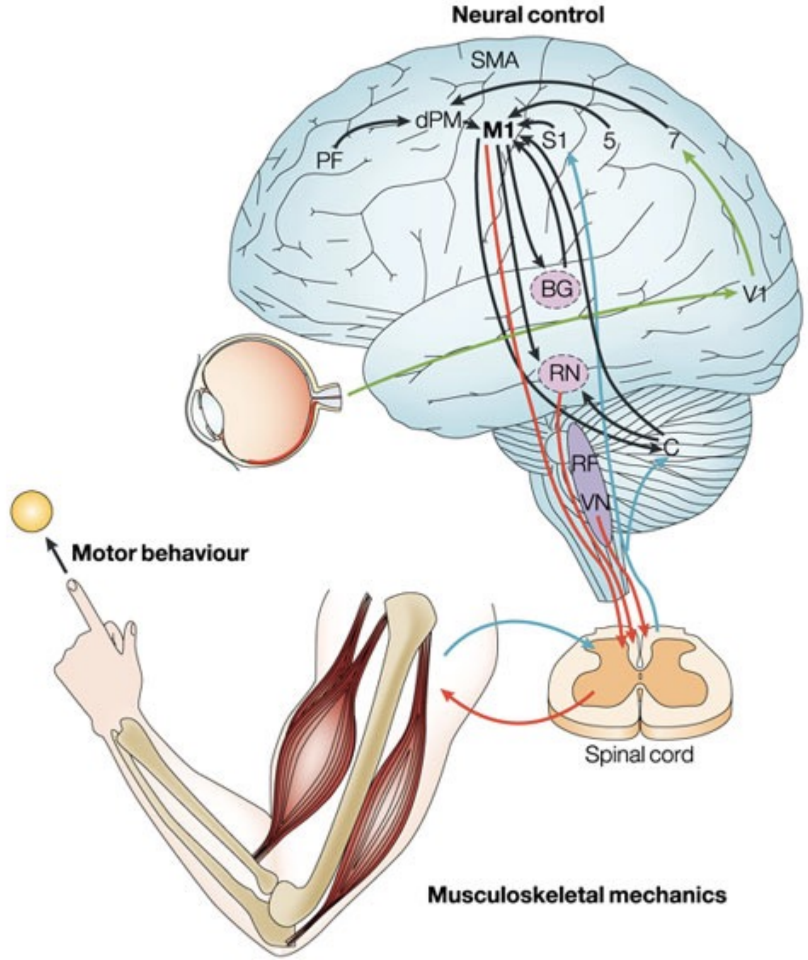
Human augmentation



REACHING TASK

How to design a sensory-motor neuroprosthesis?

- Start from natural neural control of movement
- Try to replicate it



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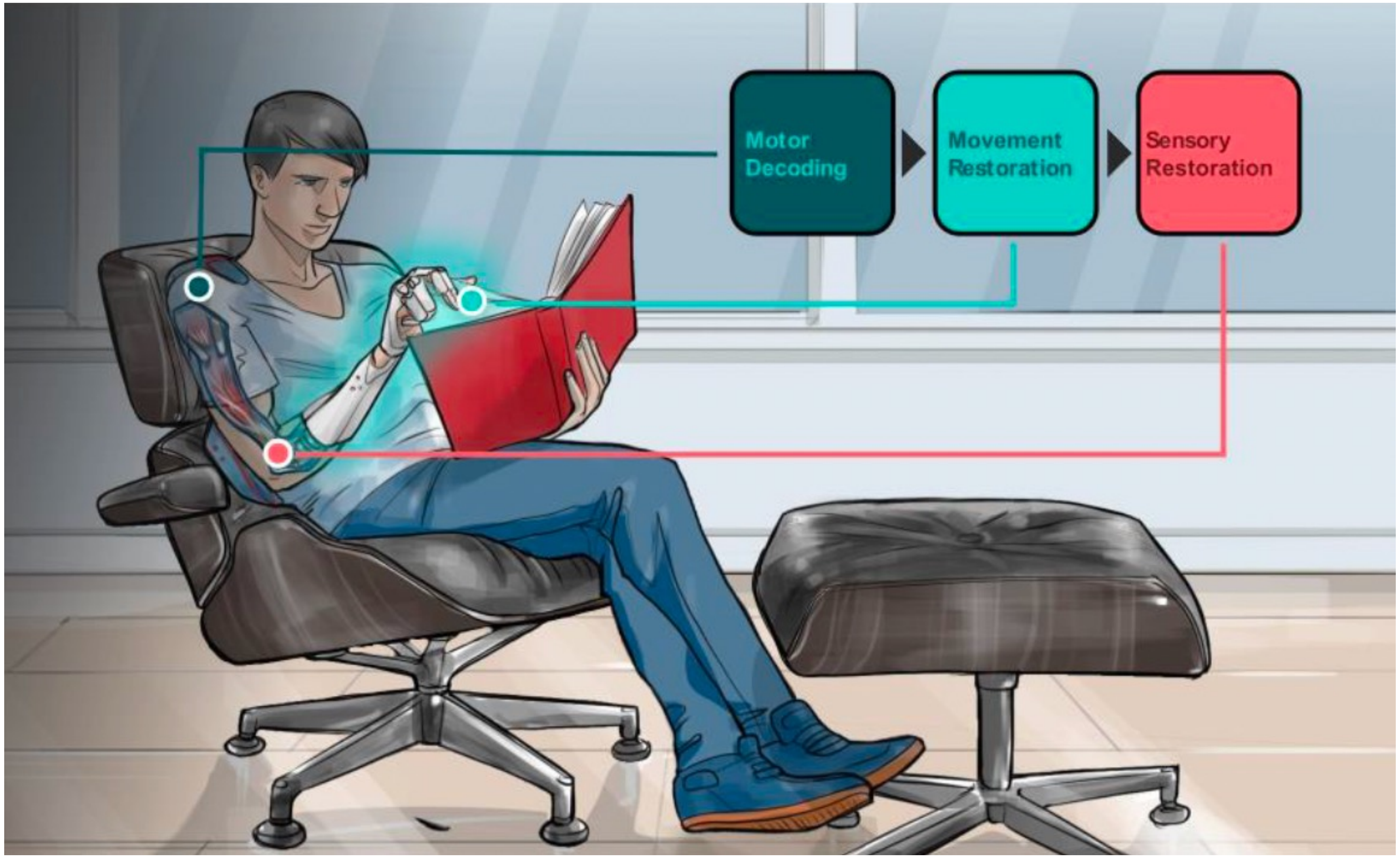
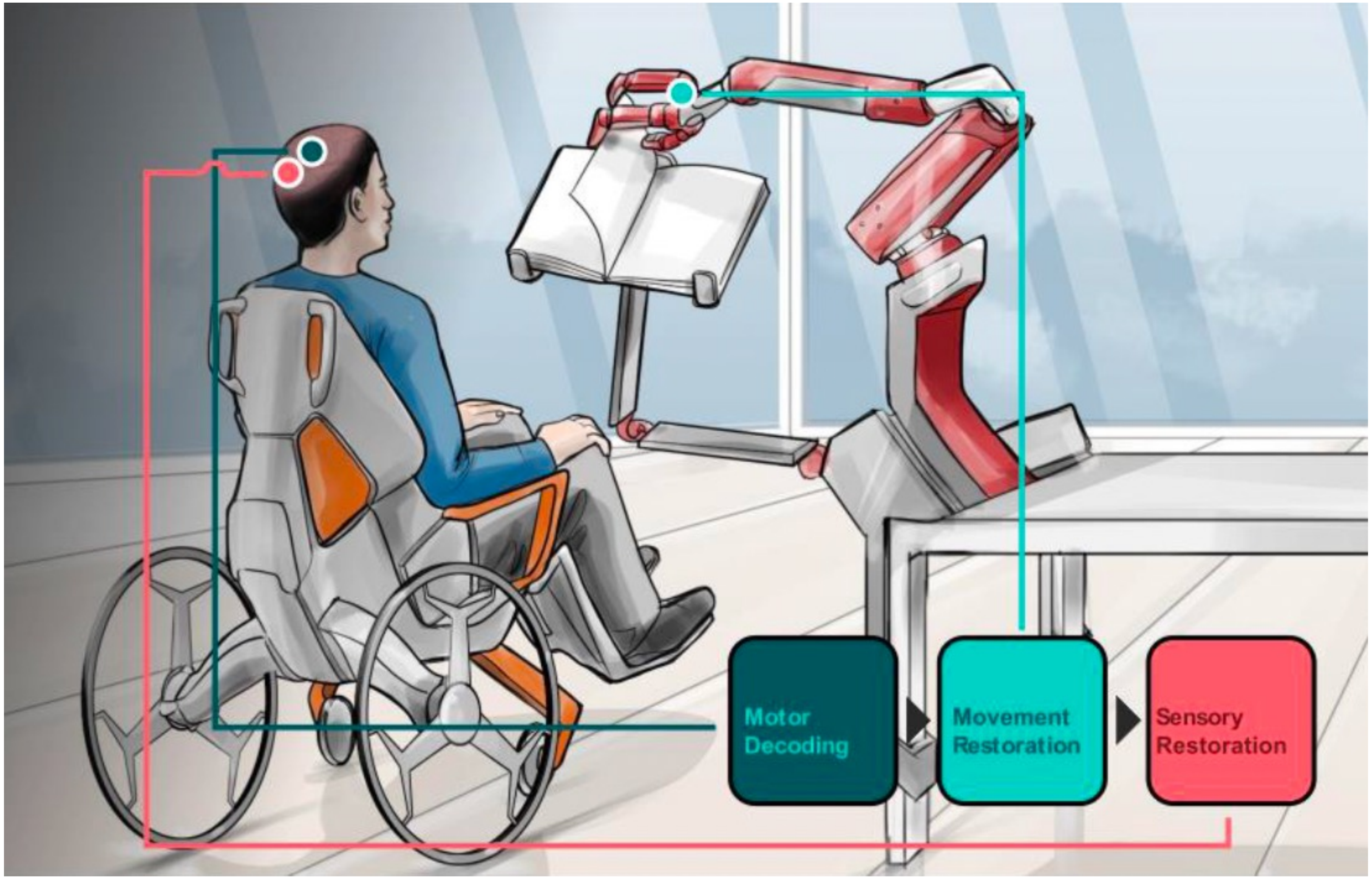
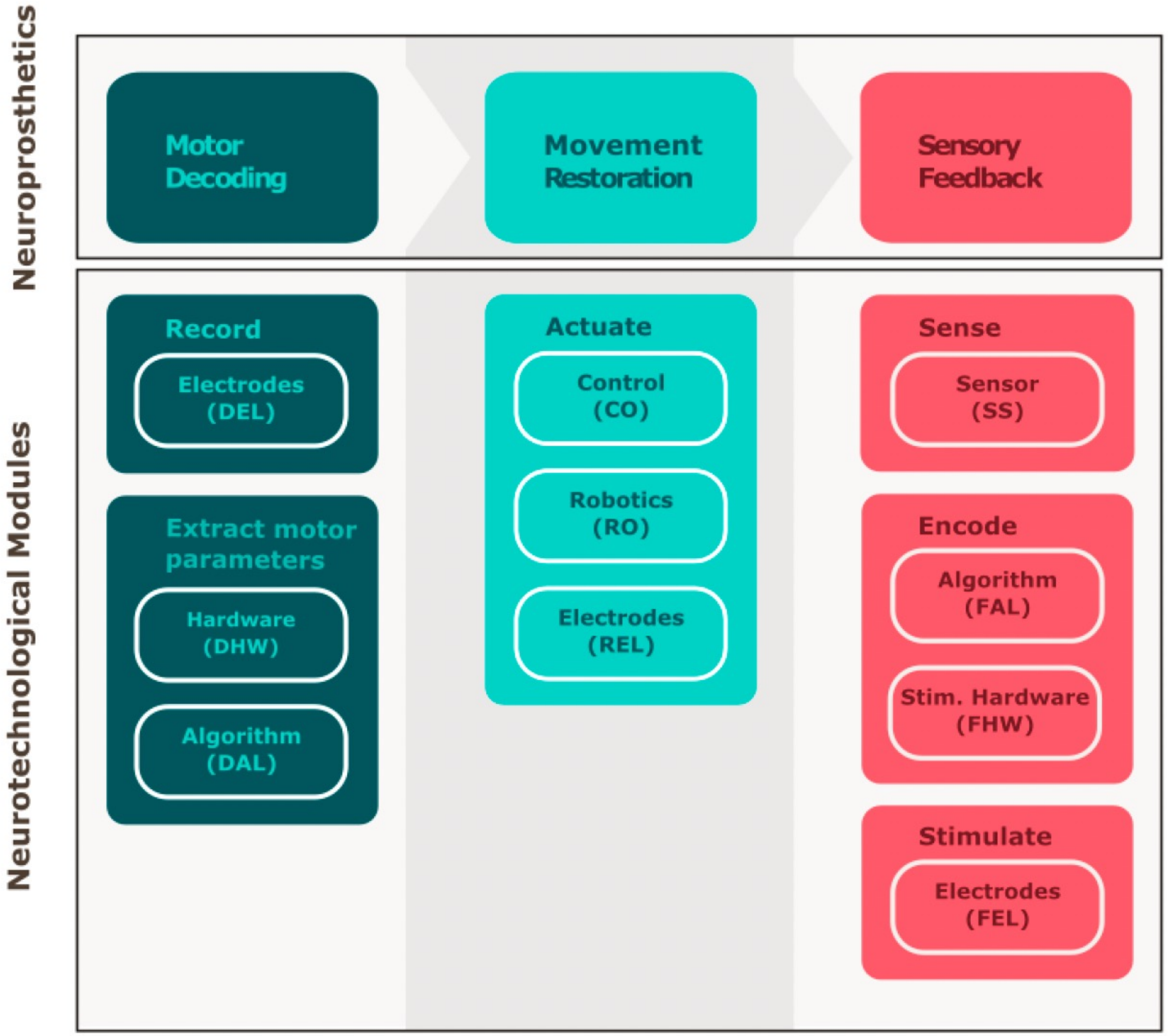
How to design a sensory-motor neuroprosthesis?



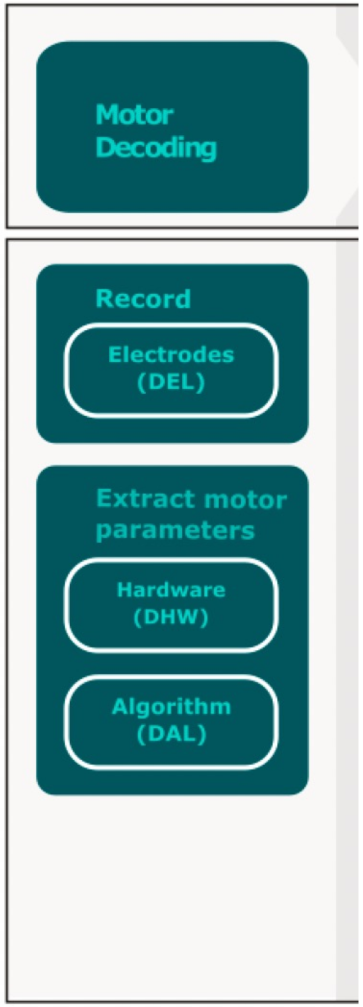
How to design a sensory-motor neuroprosthesis?



Neurotechnology modules



Motor decoding



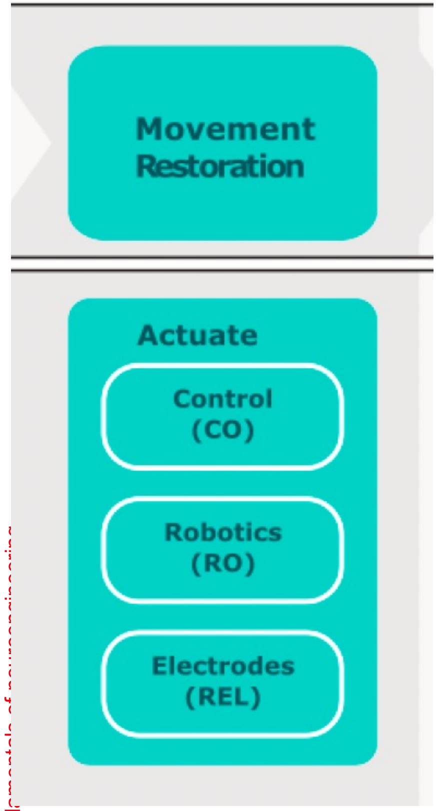
Understand the intention of the subject: grasping task? Locomotion speed? Etc.

Interface with the neuromuscular system to record electrophysiological or kinematic signals

Hardware to process the signals recorded

Software to process the signals recorded

Movement restoration



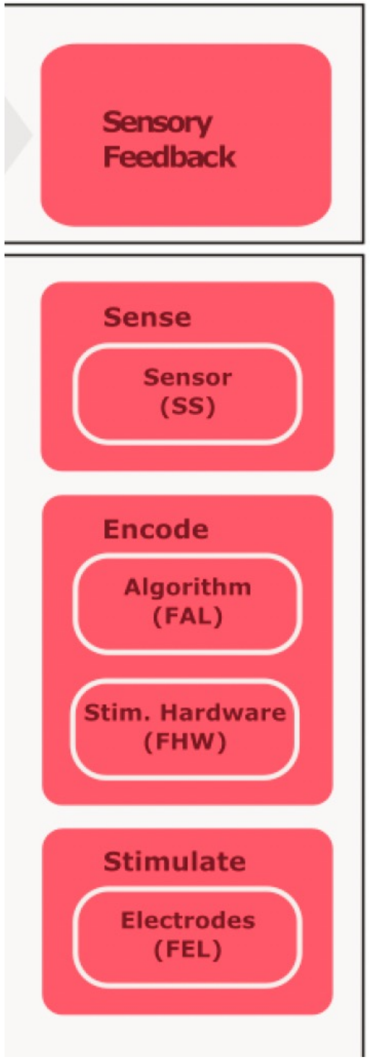
Restore specific movements impaired by neurological disorders or traumatic injuries

Use the motor intention detected to control the different actuation systems

Restore movements using robotic systems

Restore movements using electrical stimulation (muscle activation)

Sensory feedback



Restore the possibility to gather information about the world and the subject: touch? proproception? Temperature? Etc.

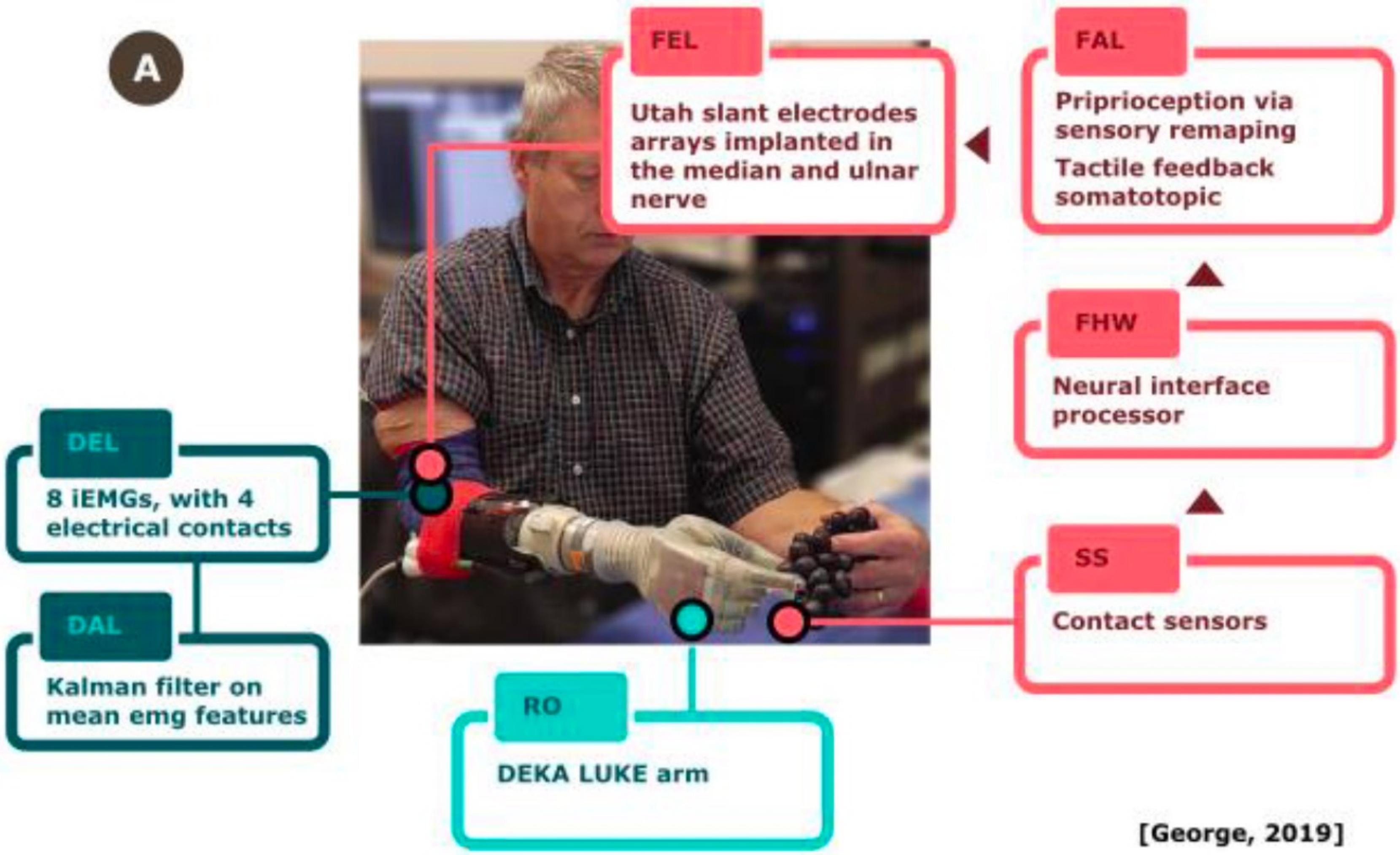
Artificial sensors to record information about the world and the subject

Software to translate the artificial sensory information into electrical stimulation parameters

Hardware to stimulate the nervous system or the skin

Interface with the neuromuscular system or the skin to deliver the artificial sensation

Examples of Neuroprostheses



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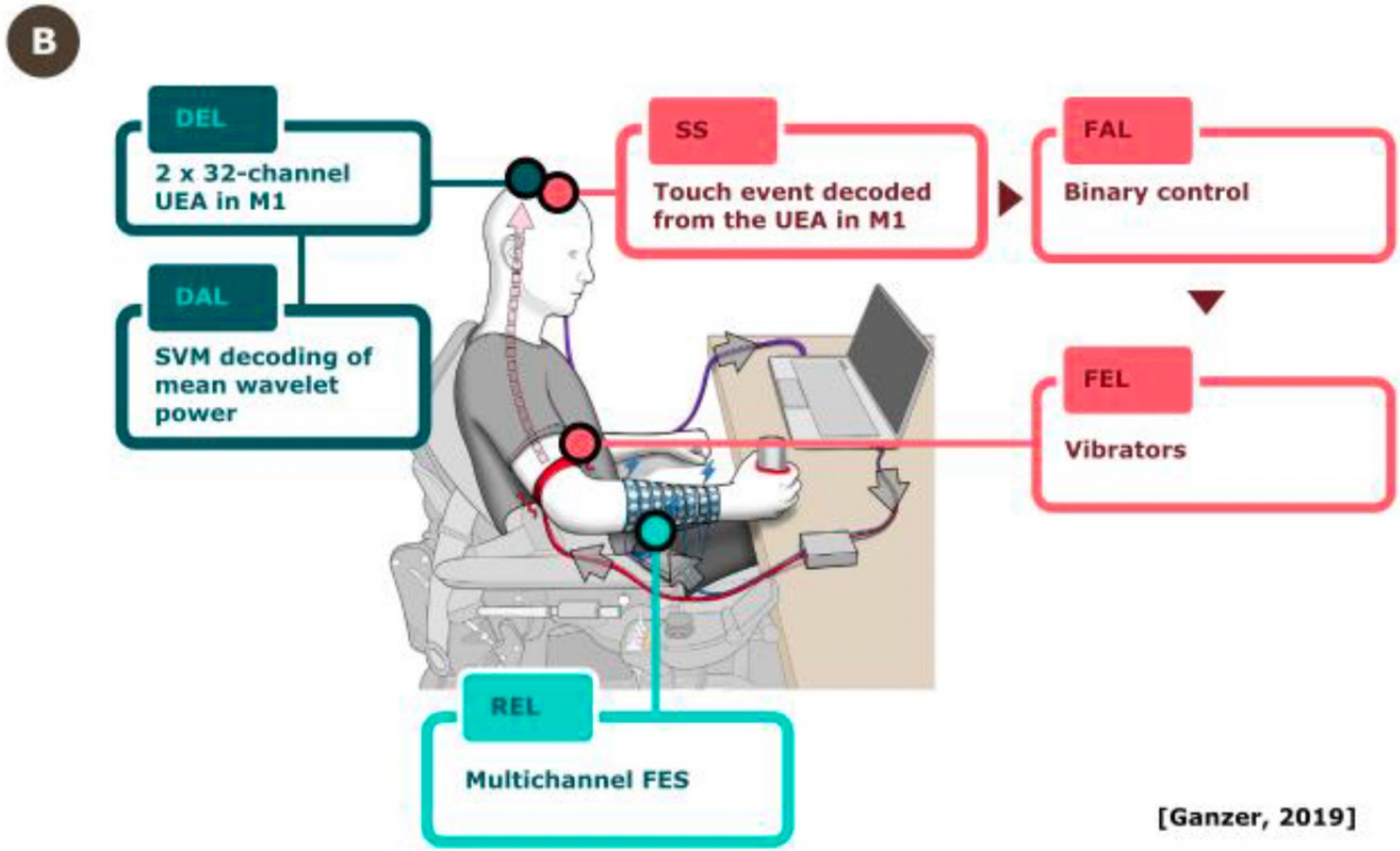
Examples of Neuroprostheses



[Ganzer, 2019]

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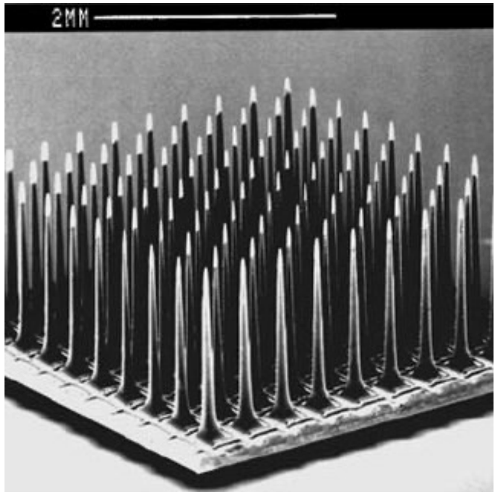
Reusing (DEL-FEL)

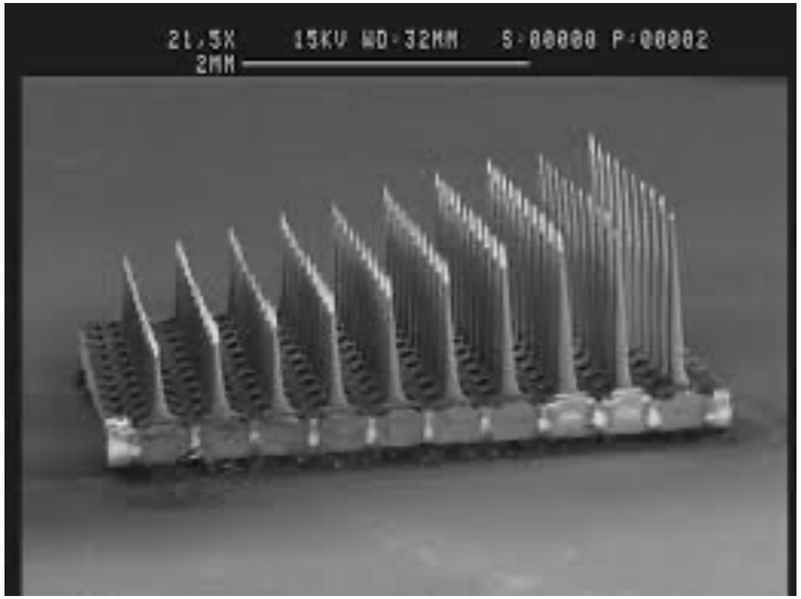
Utah Array



Motor (cortical) decoding

Sensory (cortical) feedback

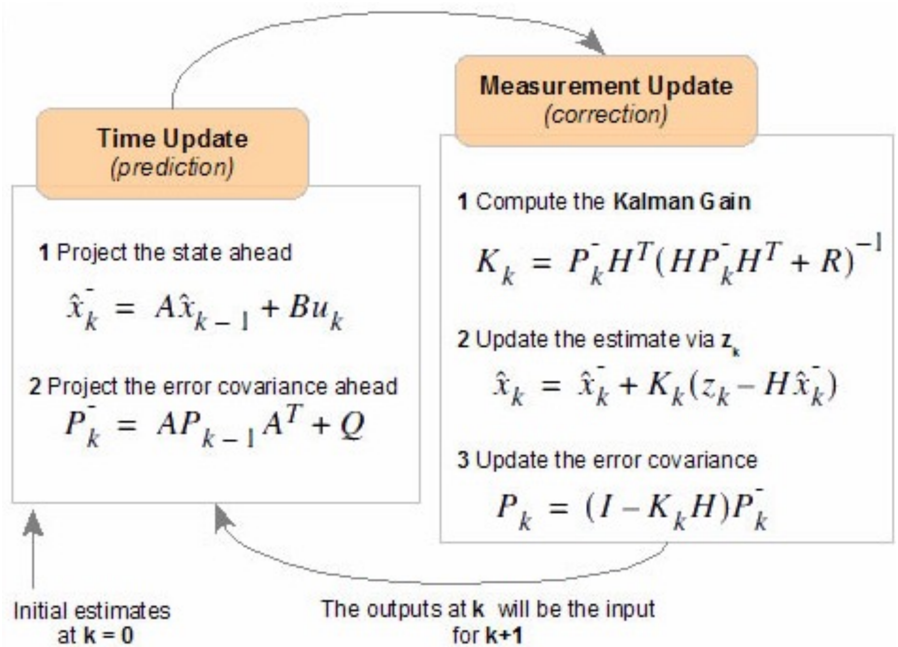
SLANTED Utah Array



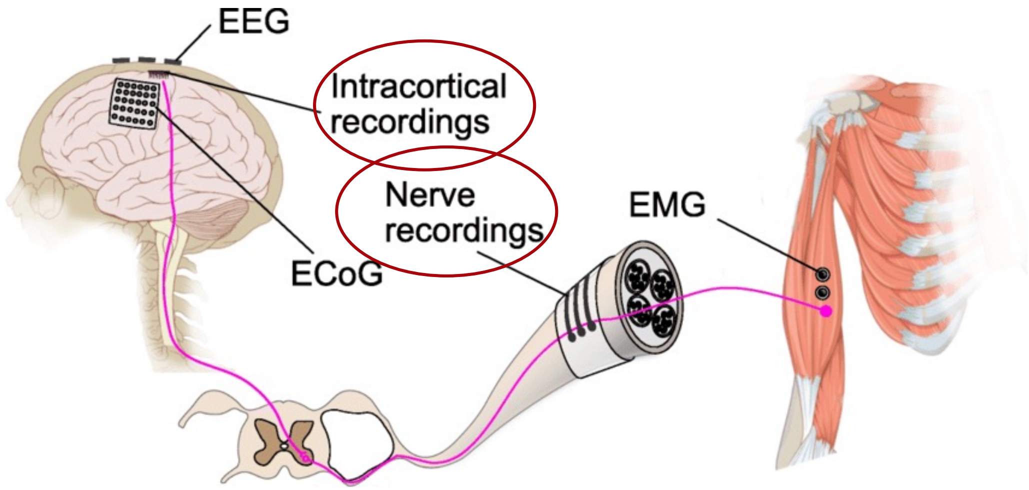
Motor (peripheral) decoding

Sensory (peripheral) feedback

Reusing (DAL)

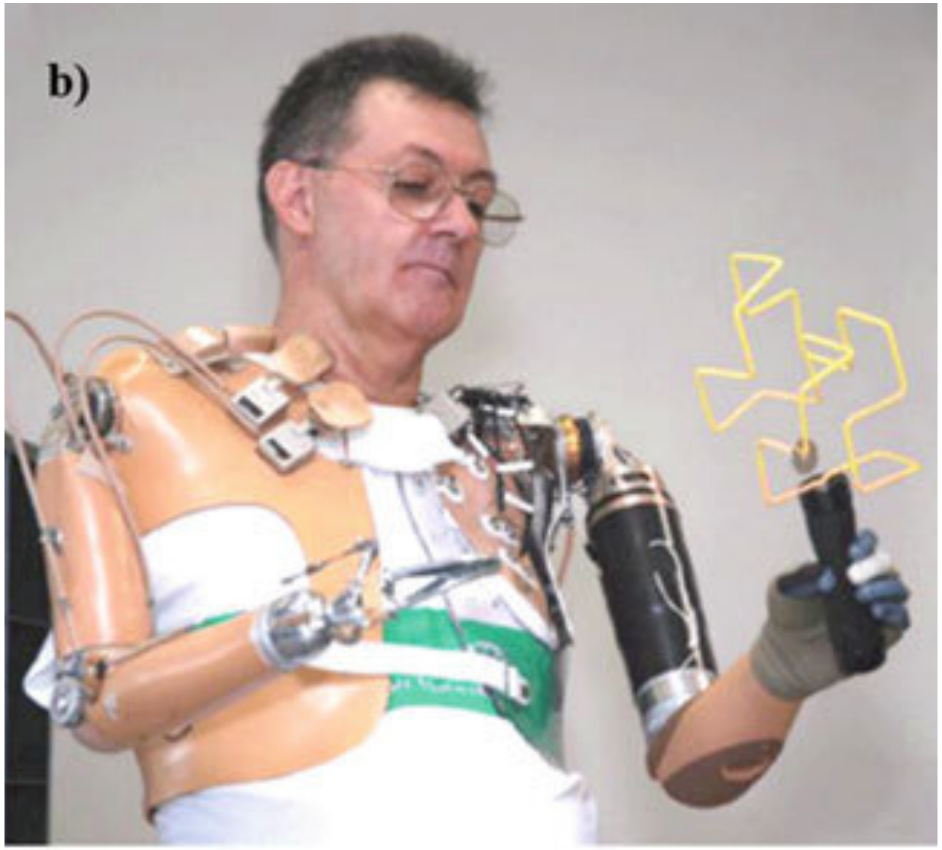


Kalman filter



Decoding motor commands from cortical and peripheral signals

Exploiting modularity



How to restore bidirectinal sensory-motor control
in people with shoulder amputation?