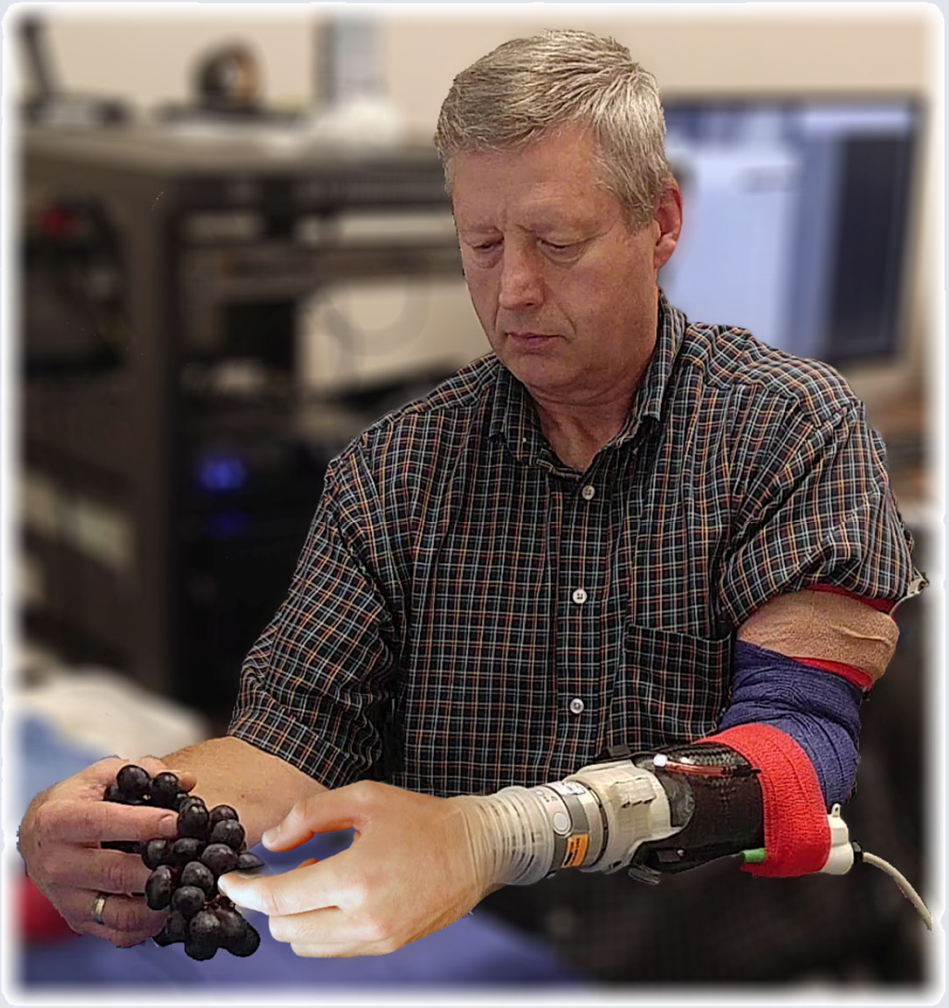
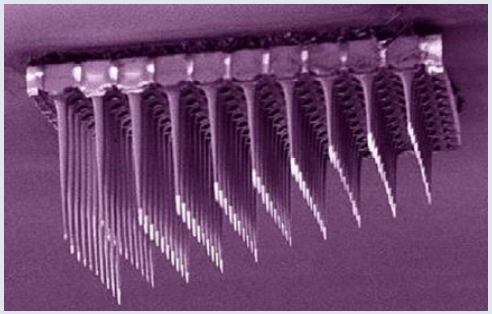
THE UNIVERSITY OF UTAH
DEPARTMENT OF BIOMEDICAL ENGINEERING

Center for Neural Interfaces

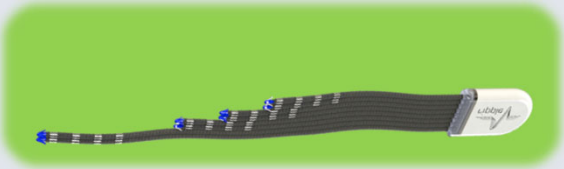
A New Hope: Restoring Naturalistic Sensorimotor Function after Hand Amputation

Gregory A. Clark, Ph.D.
Department of Biomedical Engineering, University of Utah
OSMS Ogden UT, 20-May-2022





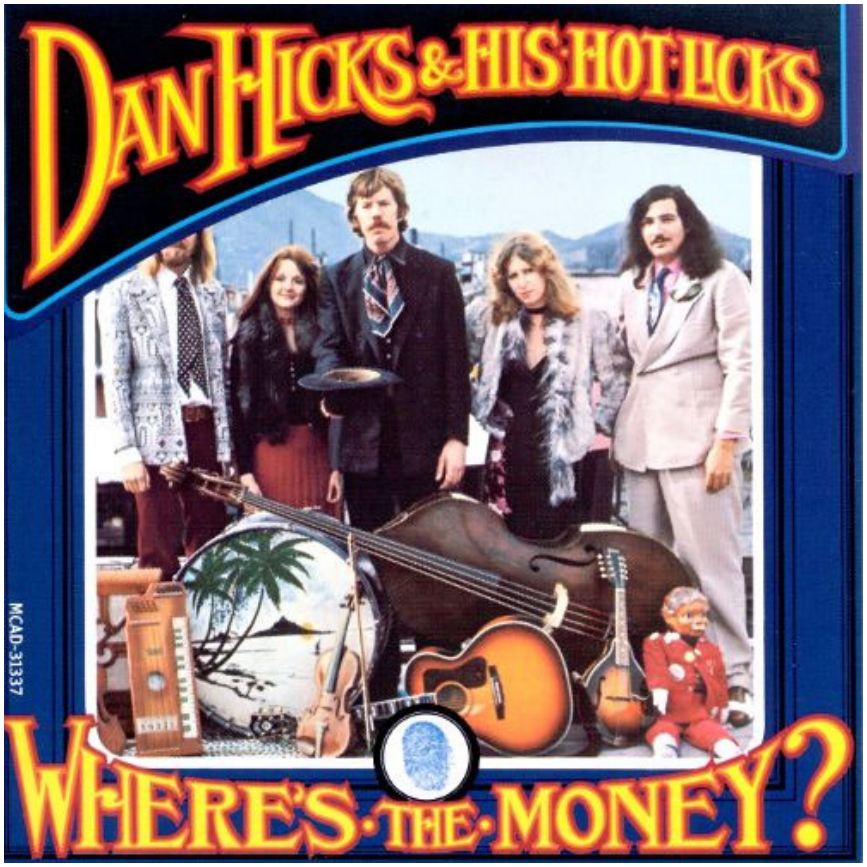
USEA
Blackrock Microsystems/
Loren Rieth



EMG leads
Ripple Neuro, LLC/
Synapse Biomedical

Conflict of Interest & Disclaimer

G. A. Clark owns a patent licensed for the Utah Slanted Electrode Array & other related patents



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The views expressed are my own, and do not necessarily reflect the views of the Univ. of Utah or my funding sources

Now What?

Tom Smart, Deseret News, Feb. 16, 2015

How do you…

- Hold a fork?
- Tie your shoes?
- Tickle your kid?

- Feel?
- Feel *whole* again?

"Losing a hand is like losing someone you love…Except that you're reminded of it every day."

"Make Me Like I Was" ~Michael Boninger

~ Civil-War Technology

Michael Weisskopf
"Amputee Alley," Ward 57, Walter Reed

"Now"

- The major limitation is *not* the arm itself
- Lack of dextrous, intuitive control signals
- No sensory feedback
- Neural interfaces a potential solution

State of the Union Address
January 20, 2015

Utah Electrode Array

"I want Americans to win the race for the kinds of discoveries that unleash new jobs … creating revolutionary prosthetics, so that a veteran who gave his arms for his country can play catch with his kid."
~President Barack Obama

Restoring Hand Function: Star Wars Version

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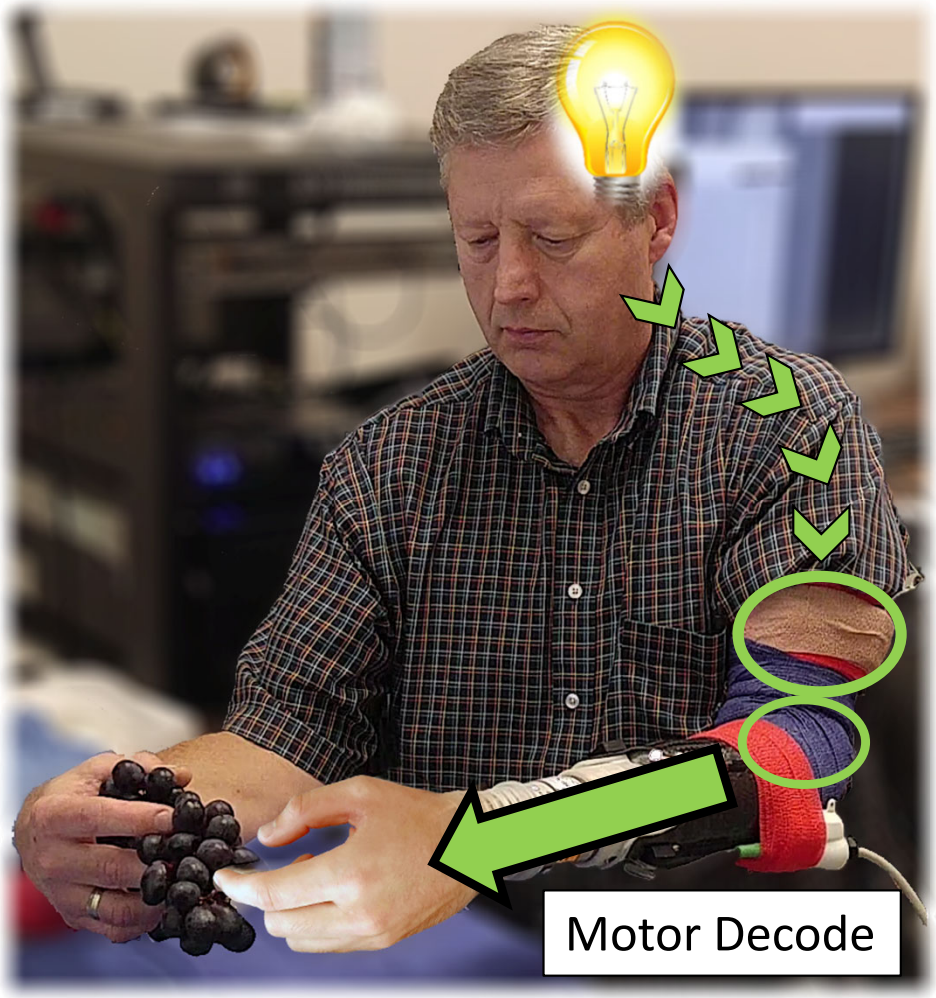
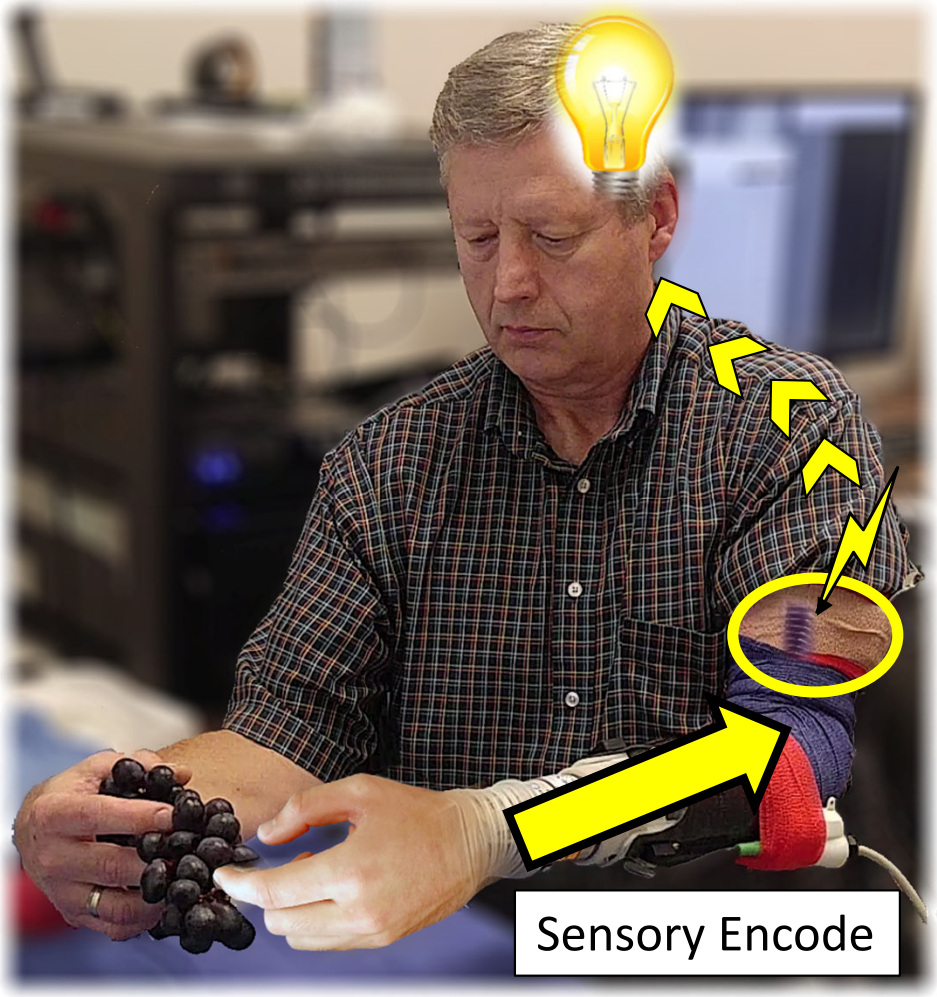
Restoring Natural Hand Function: Real-World Solution

Center for
Neural
Interfaces

Closed-loop System

Motor Control ⟷ **Sensory Feedback**





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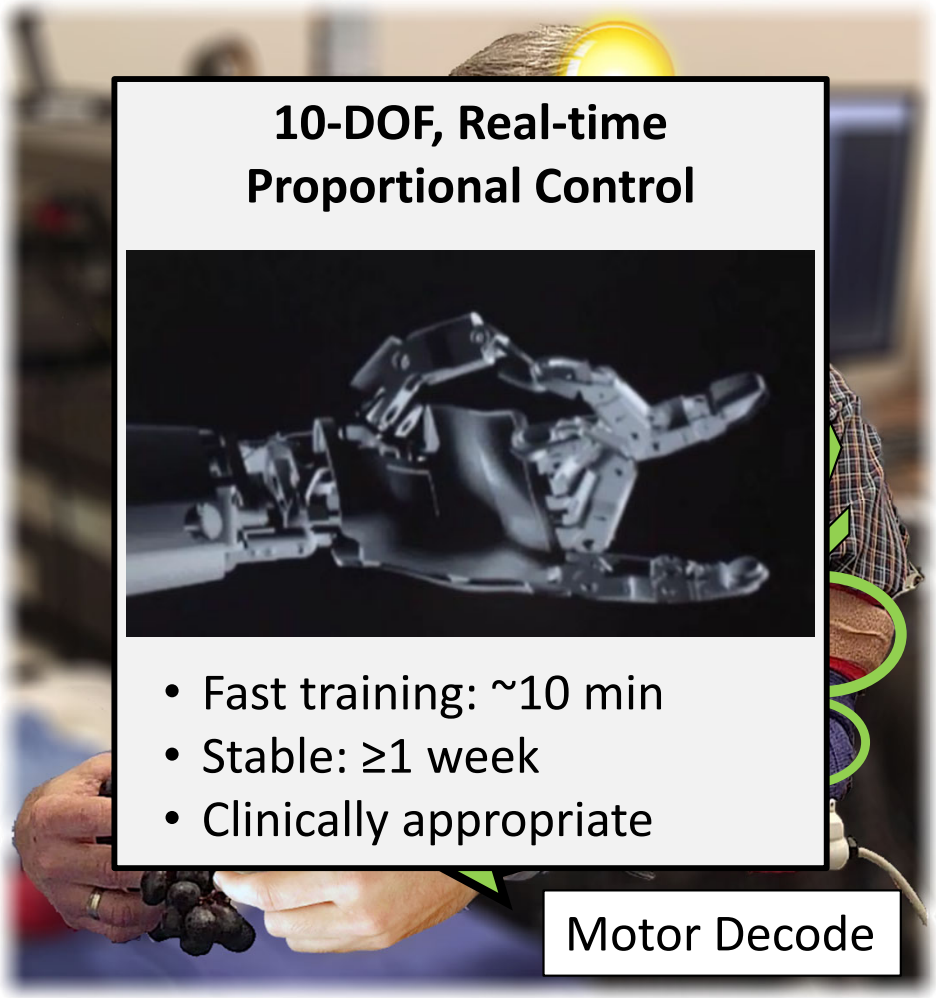

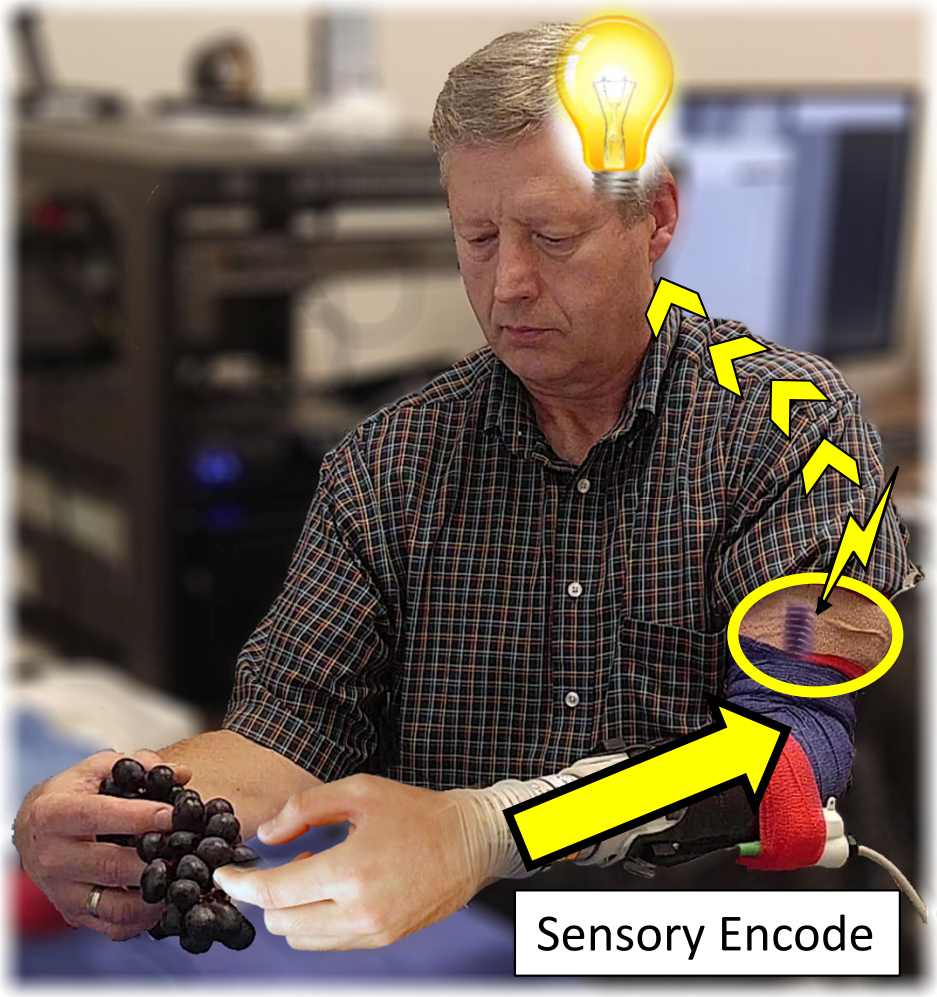

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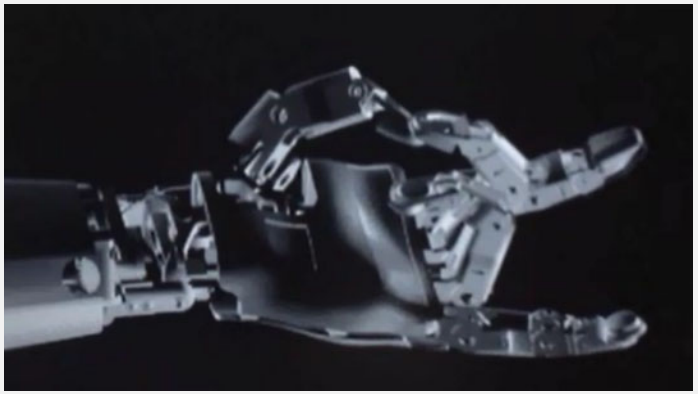
Closed-loop System

Motor Control ⟷ **Sensory Feedback**

10-DOF, Real-time Proportional Control



- Fast training: ~10 min
- Stable: ≥1 week
- Clinically appropriate

Motor Decode

Up to 131 Tactile and Proprioceptive Percepts

- Multiple submodalities
- Biomimetic activation
- Functional discrimination

Sensory Encode

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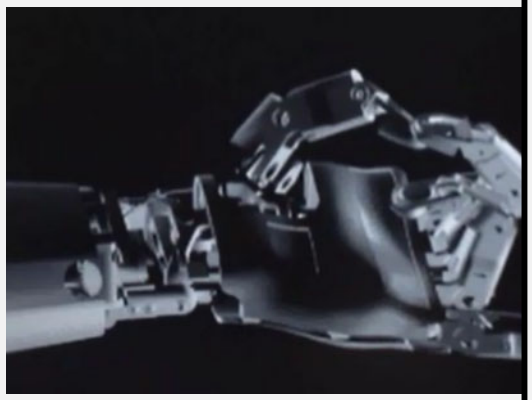
Closed-loop System

Motor Control ⟷ **Sensory Feedback**

10-DOF, Real-tim
Proportional Contr



- Fast training: ~10 mi
- Stable: ≥1 week
- Clinically appropriate

Motor Decode

Bidirectional Sensorimotor Integration

- Haptic exploration
- Real-world ADLs
- Reduced phantom pain
- Enhanced embodiment

131 Tactile and
oceptive Percepts

le submodalities
netic activation
onal discrimination

Sensory Encode

Demonstrated in Seven Human Participants

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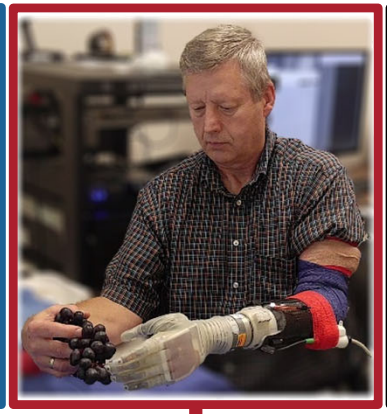



S6

Traumatic amputation

13 years prior to implant

14-month implant

S7

Elective amputation

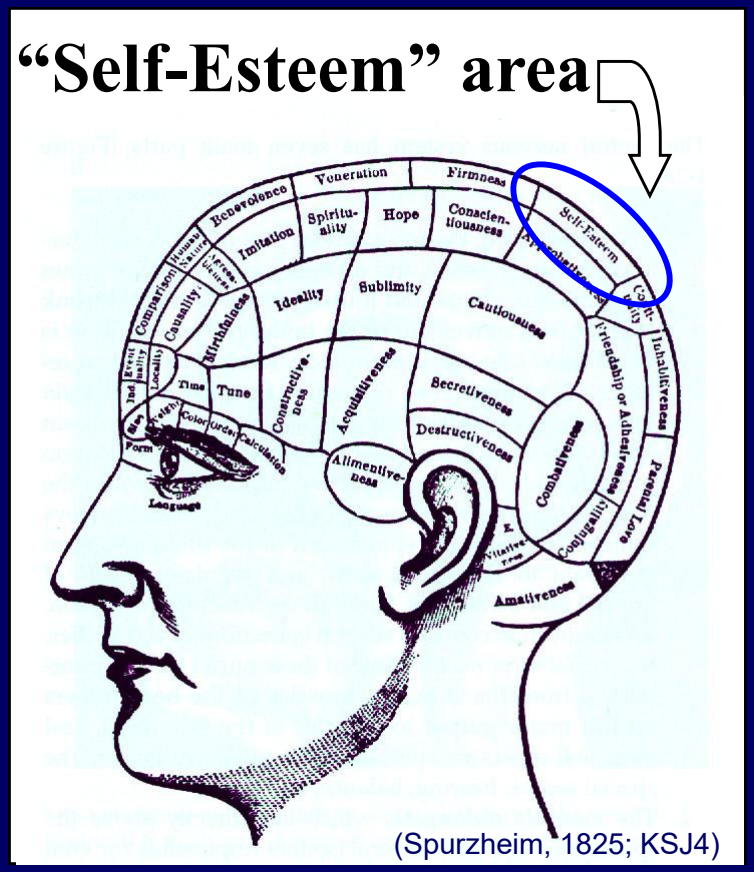
Devices implanted *during* amputation

17-month implant

Location, Location, Location:
Where should one interface to the nervous system?

Central vs. Peripheral Motor Interfaces

Brains are smart



"Brain-Computer Interfaces"

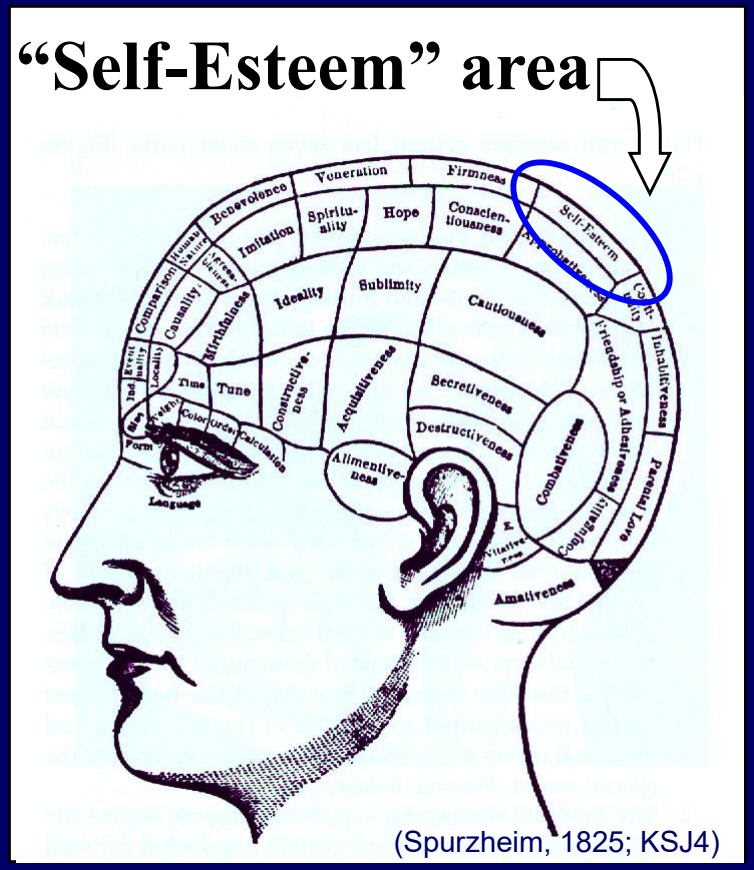
A New Brain-Computer Interface to Help Patients with ALS and Spinal Cord Injuries Communicate

By Dr. Ali Ahsan | Published on May 18, 2021
Reviewed By Gilmore Health | On: May 18, 2021

A new brain-computer interface (BCI) was developed recently that is believed to be quicker and more accurate than the previous BCIs and it uses handwriting as an underlying principle to type texts on the computer. In this BCI, a person mentally writes letters, words, or sentences and the algorithms of the BCI's computer record the activities within the brain and train themselves according to the neural patterns. This system can then write new sentences in real-time as the person mentally writes sentences. Previously, the main focus of BCI was on improving motor skills like grasping and using point and click typing to generate text on a computer screen.

Central vs. Peripheral Motor Interfaces

Brains are smart



"Brain-Computer Interfaces"

Central vs. Peripheral Motor Interfaces

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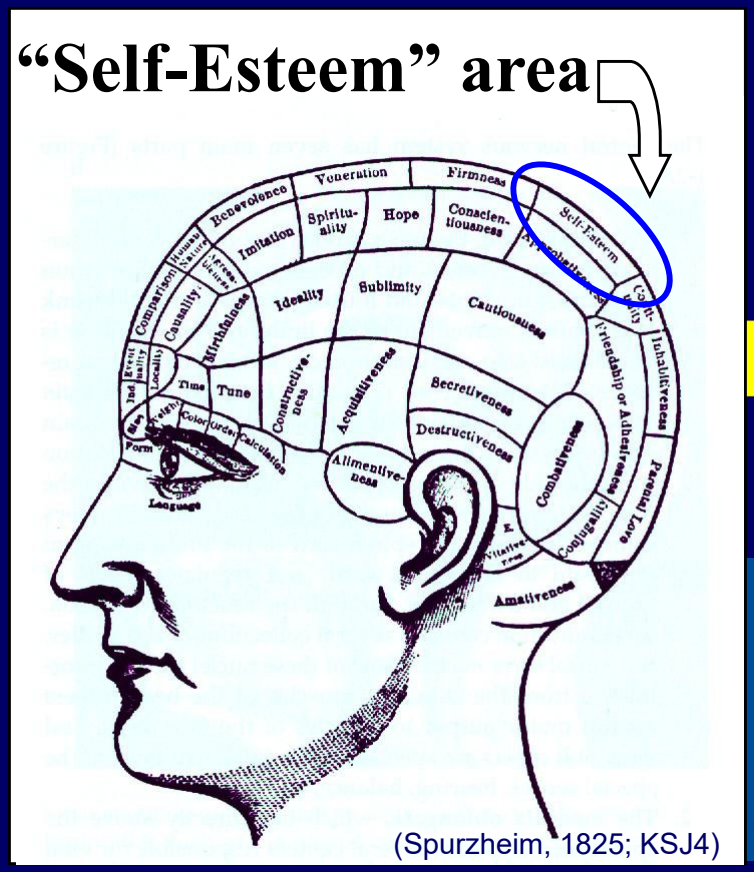
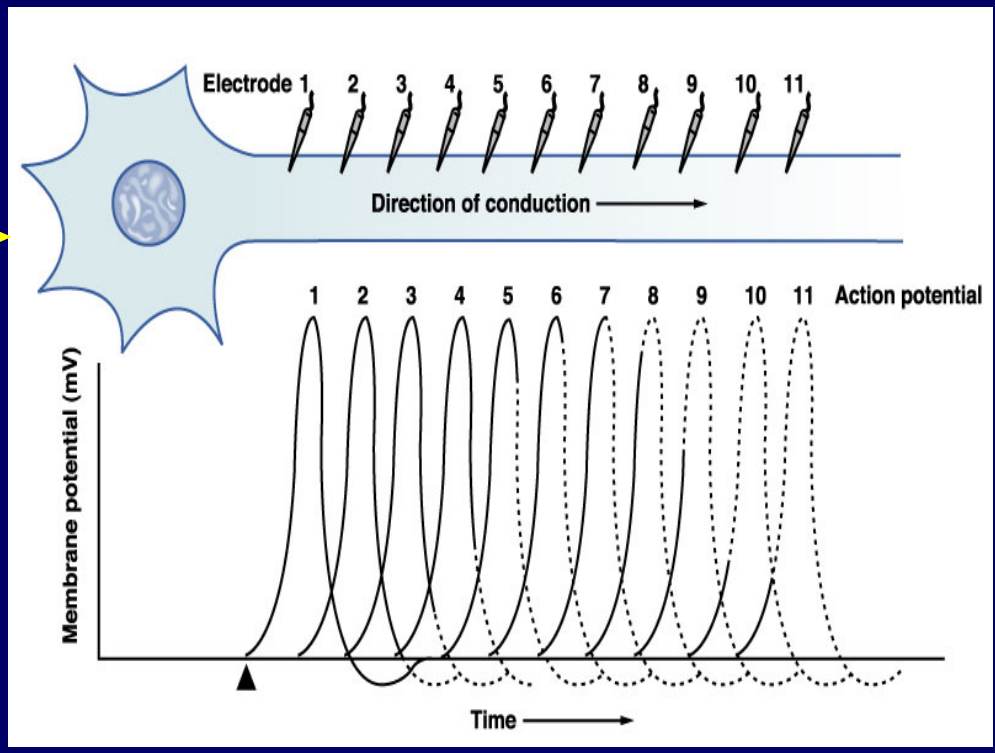


"Brain-Computer Interfaces"

Nerves are dumb

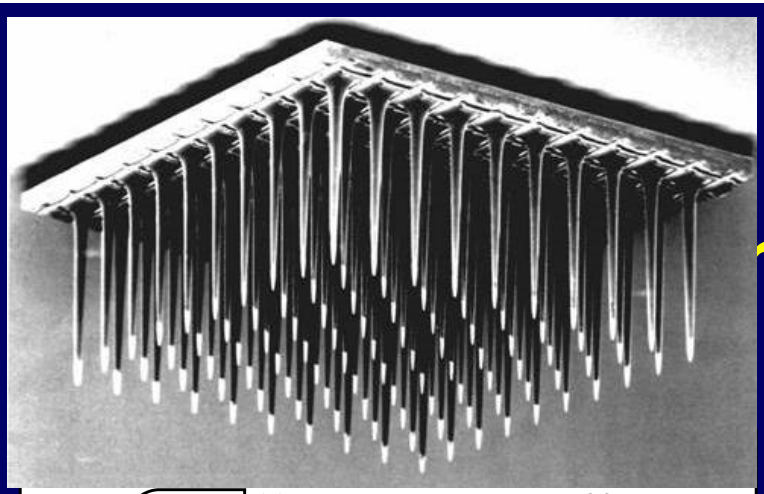
(The axon doesn't think—
it only ax." -G. Bishop)



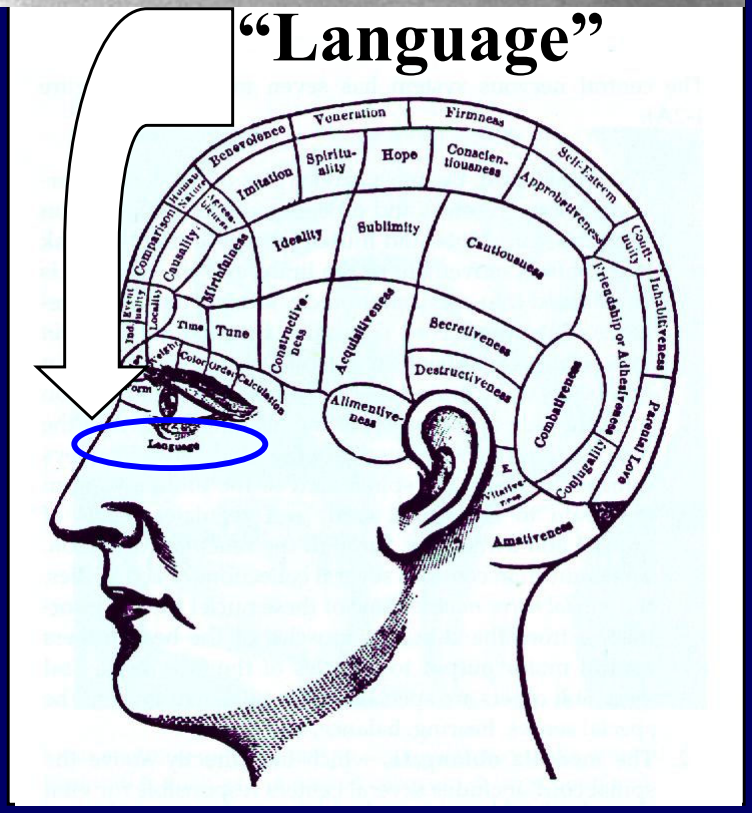
FINAL COMMON PATHWAY

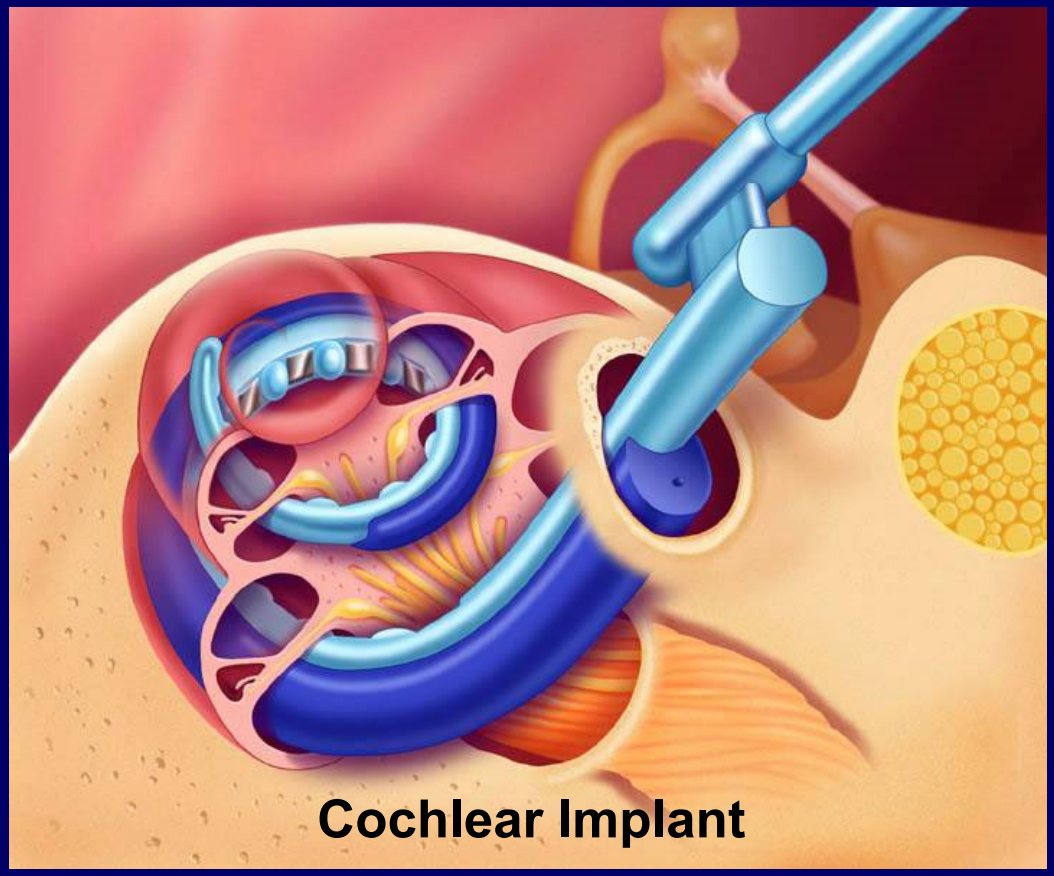
Motor: CNS → muscle, 1:1

Sensory: CNS ← body



Let the CNS Do The ncode For Us





Successful speech perception without knowing the code!
Just provide the basic elements of sound.

Claudia Mitchell
Targeted Reinnervation Patient

What does the ***person*** want?

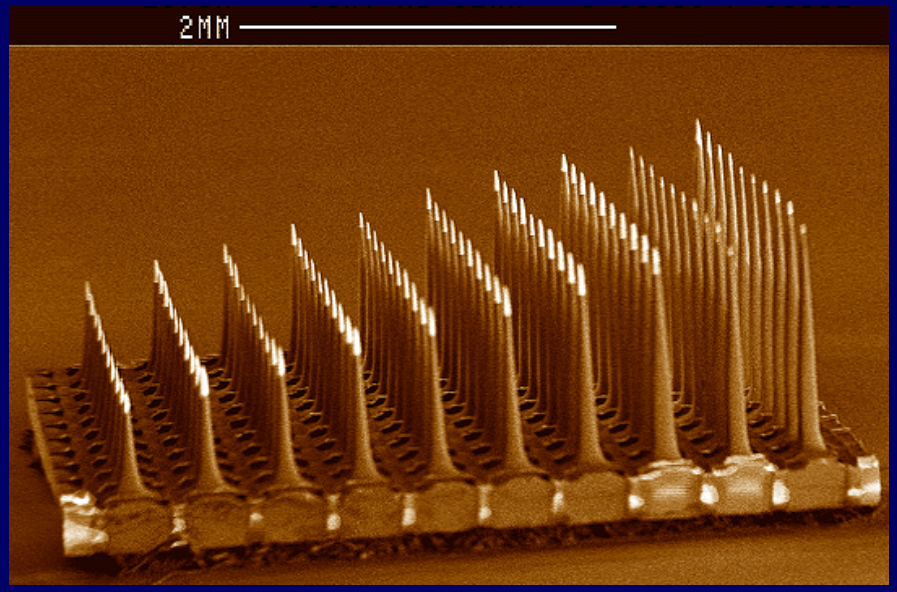
"I told Doc he can do whatever he wants to my arm, but he ain't messing with my head."

Muscle Memory. Ben McGrath. *New Yorker,* July 30, 2007. Photograph by Martin Schoeller.

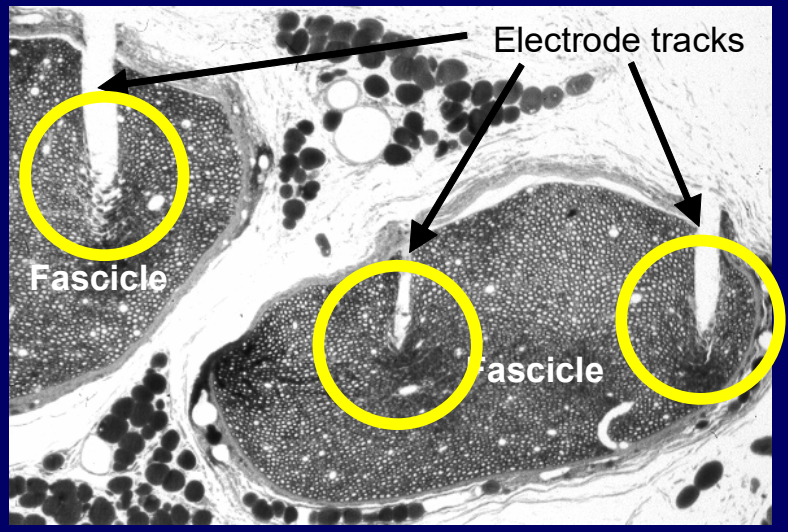
Safety & Patient Acceptance
"First, Do No Harm"

- PNS
  - "Go ahead and stick it in my nerve. I'm not using it anyway."
- CNS
  - "Go ahead and stick it in my brain. I'm not using it anyway."

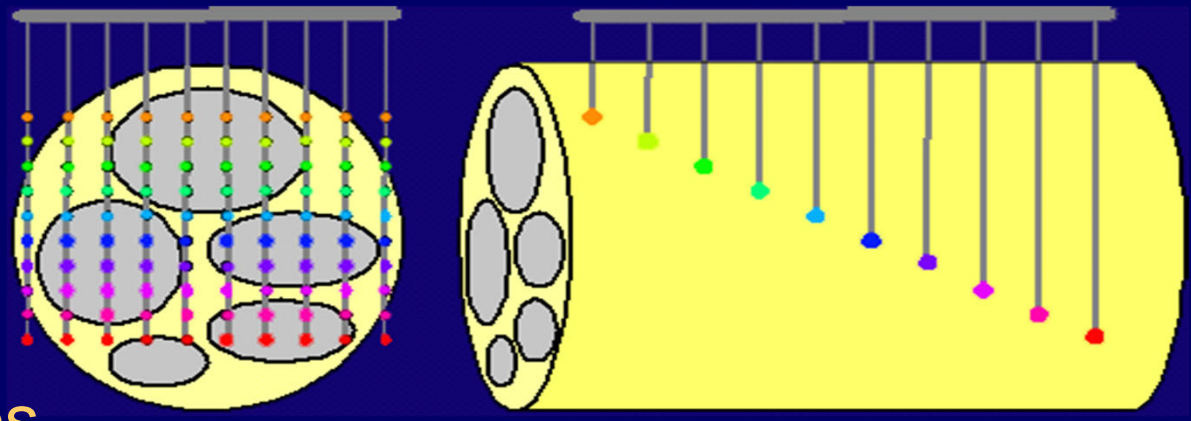
USEA: 100-Electrode Intrafascicular Array



USEA (10 x 10)

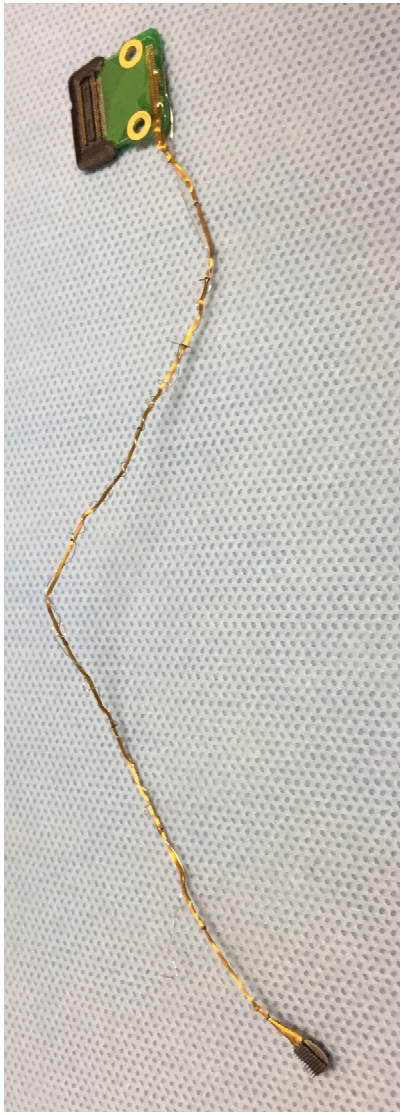


- Selective
- Comprehensive
  - ✓ Width
  - ✓ Depth
- Simple decodes & encodes



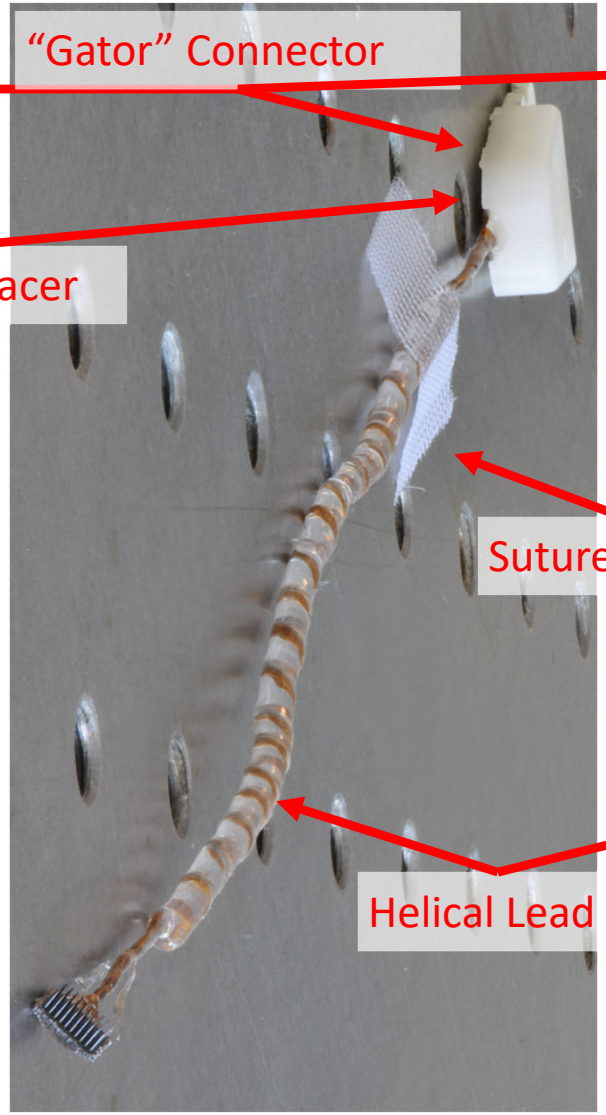
A. Branner, R. Normann et al., 2004

Substantive Microscopic & Macroscopic USEA Improvements

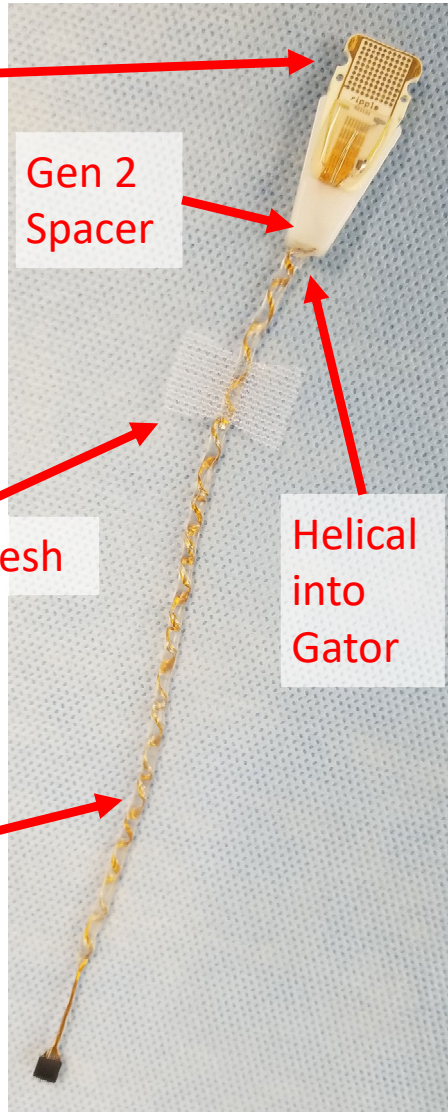


Pre-HAPTIX
USEA

HAPTIX Subject 1
USEA – 3 months



HAPTIX Subject 2
USEA – 14 months



HAPTIX Subject 3
USEA – 17 months

Helical Wire Bundle Reduces Broken Lead Wires

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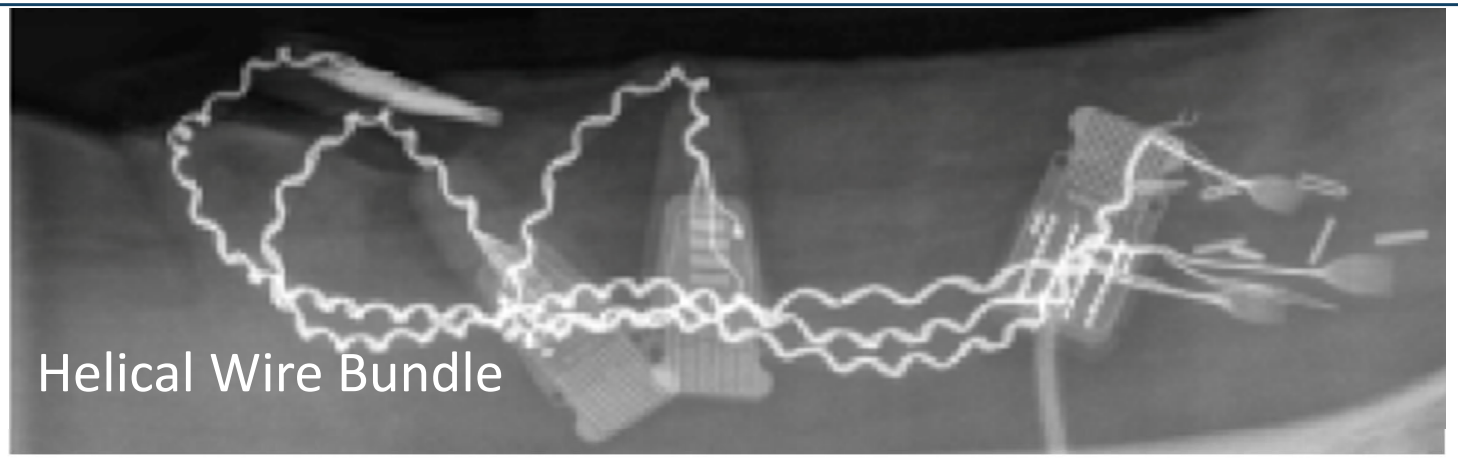
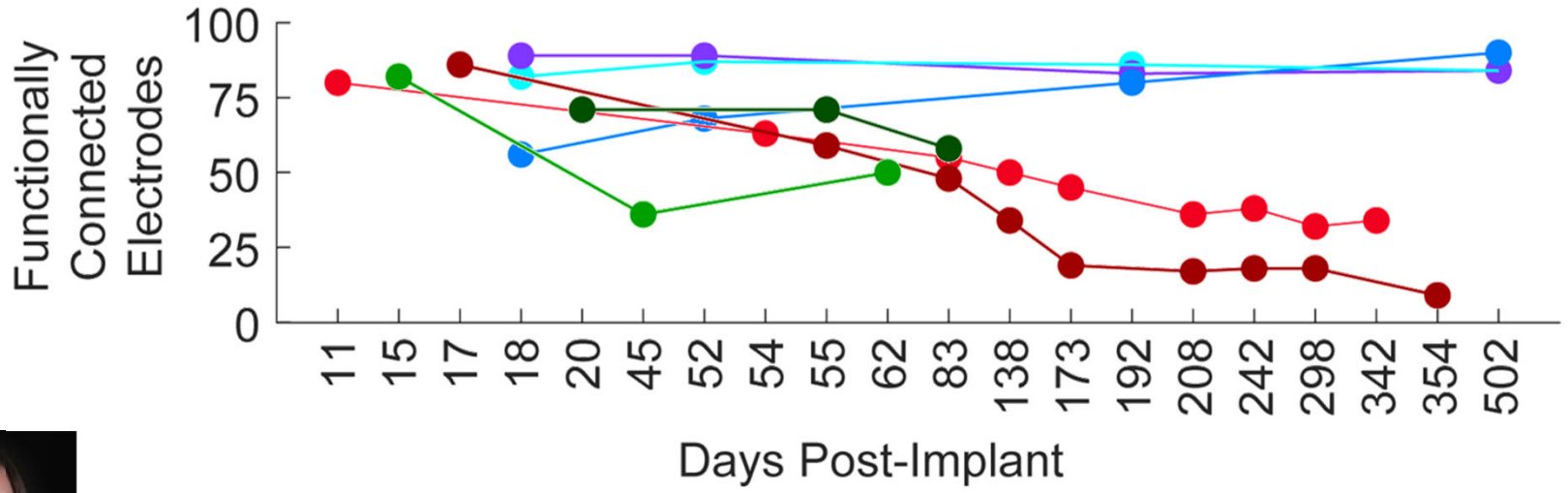
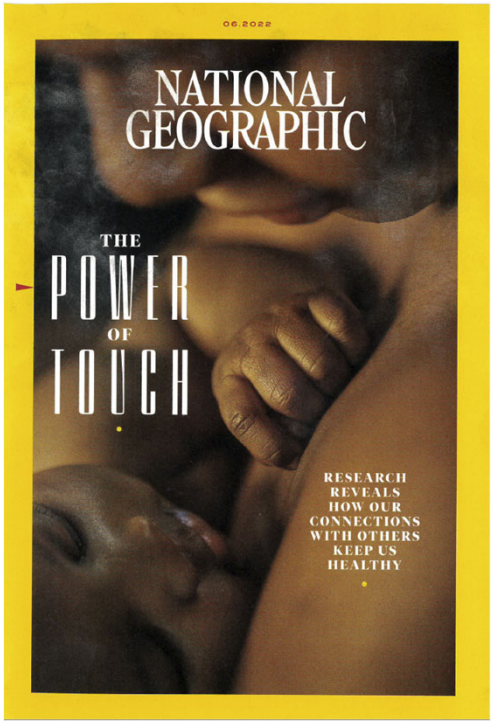




Loren Rieth

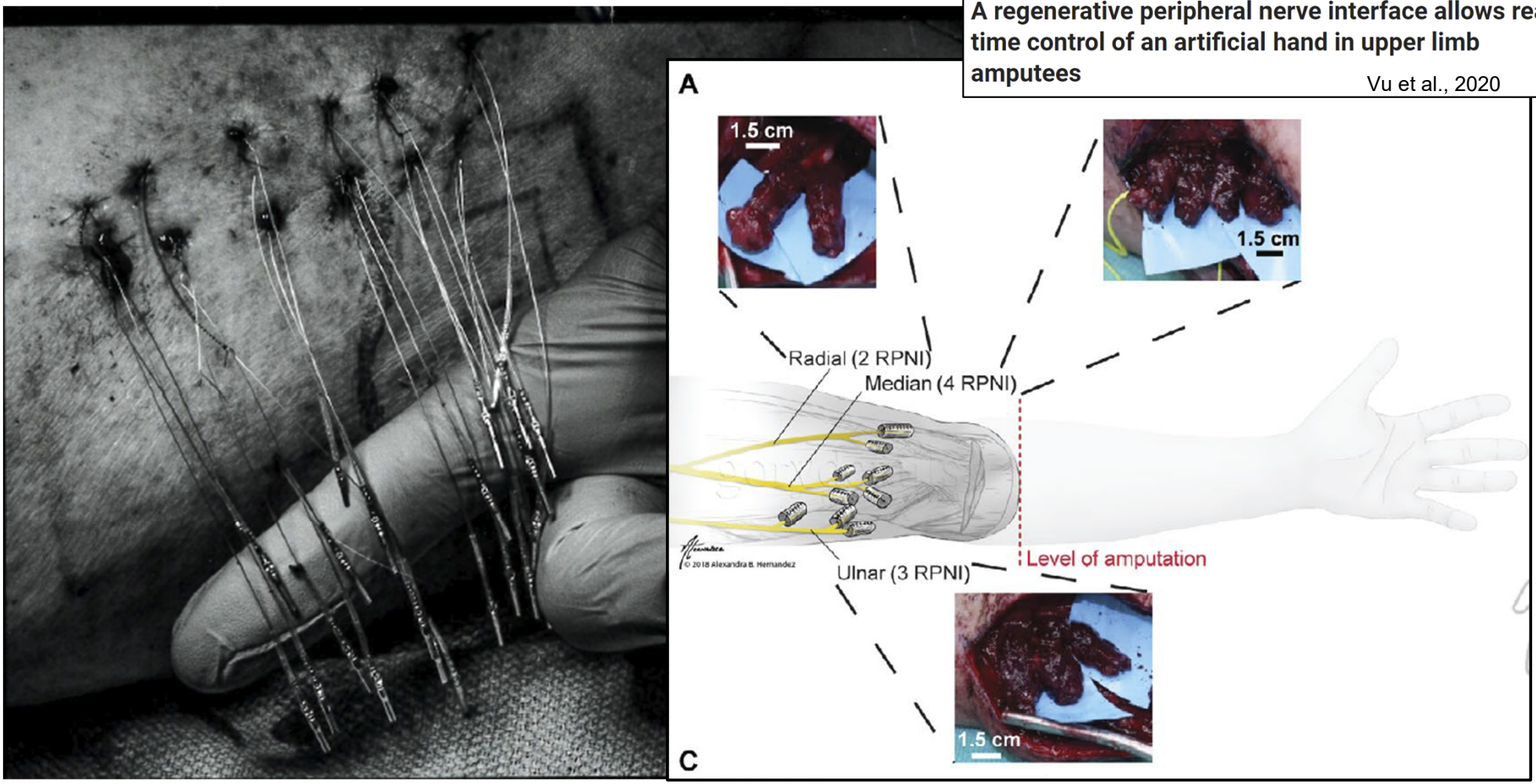
George et al., *J. Neural Eng.,*

New EMG Electrodes



- Paul Cederna, U. Michigan; FDA right to reference
- Based on Synapse Biomedical diaphragm pacing electrodes
  - Highly reliable

New EMG Electrodes (& RPNIs)



Science Translational Medicine

HOME > SCIENCE TRANSLATIONAL MEDICINE > VOL. 12, NO. 533 > A REGENERATIVE PERIPHERAL NERVE INTERFACE ALLOWS REAL-TIME CONTROL OF AN

RESEARCH ARTICLE | NEUROTECHNOLOGY

A regenerative peripheral nerve interface allows real-time control of an artificial hand in upper limb amputees

Vu et al., 2020

- Paul Cederna, U. Michigan; FDA right to reference
- Based on Synapse Biomedical diaphragm pacing electrodes
  - Highly reliable
- Regenerative Peripheral Nerve Interfaces (RPNIs)
  - pPovide strong, isolated motor signals under volitional control