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Constructivism in Tightly Coupled Human-Machine Interfaces

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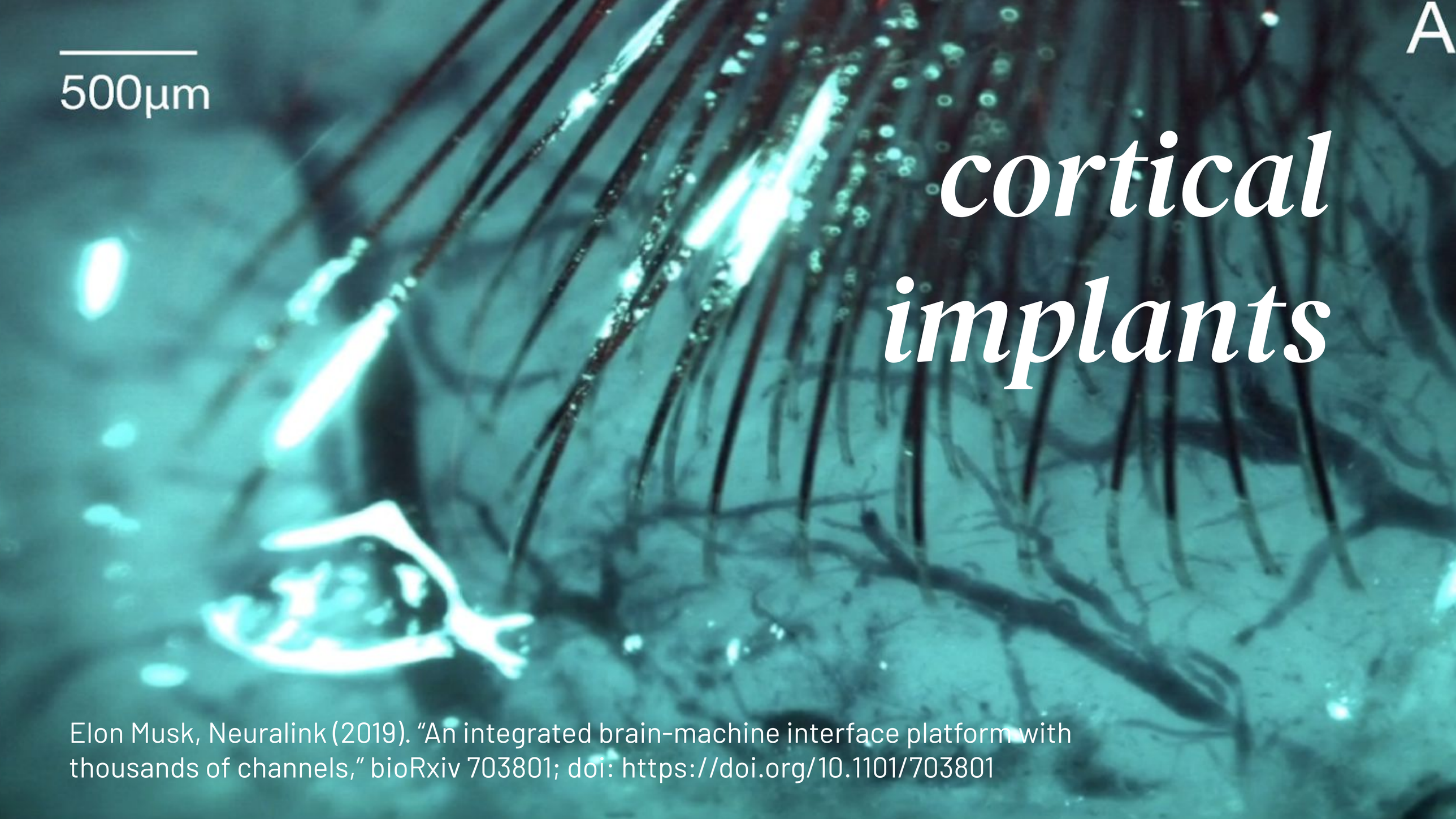
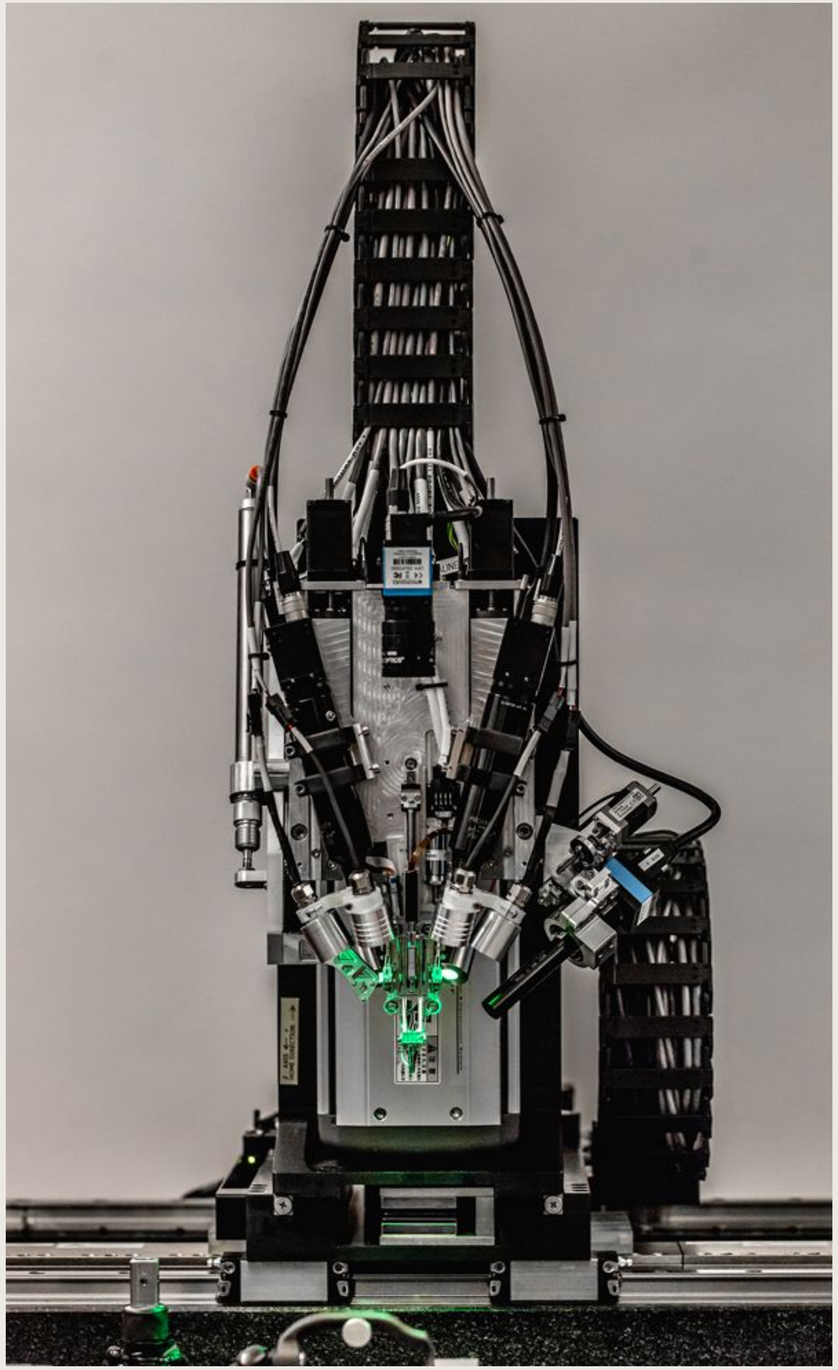
Objectives

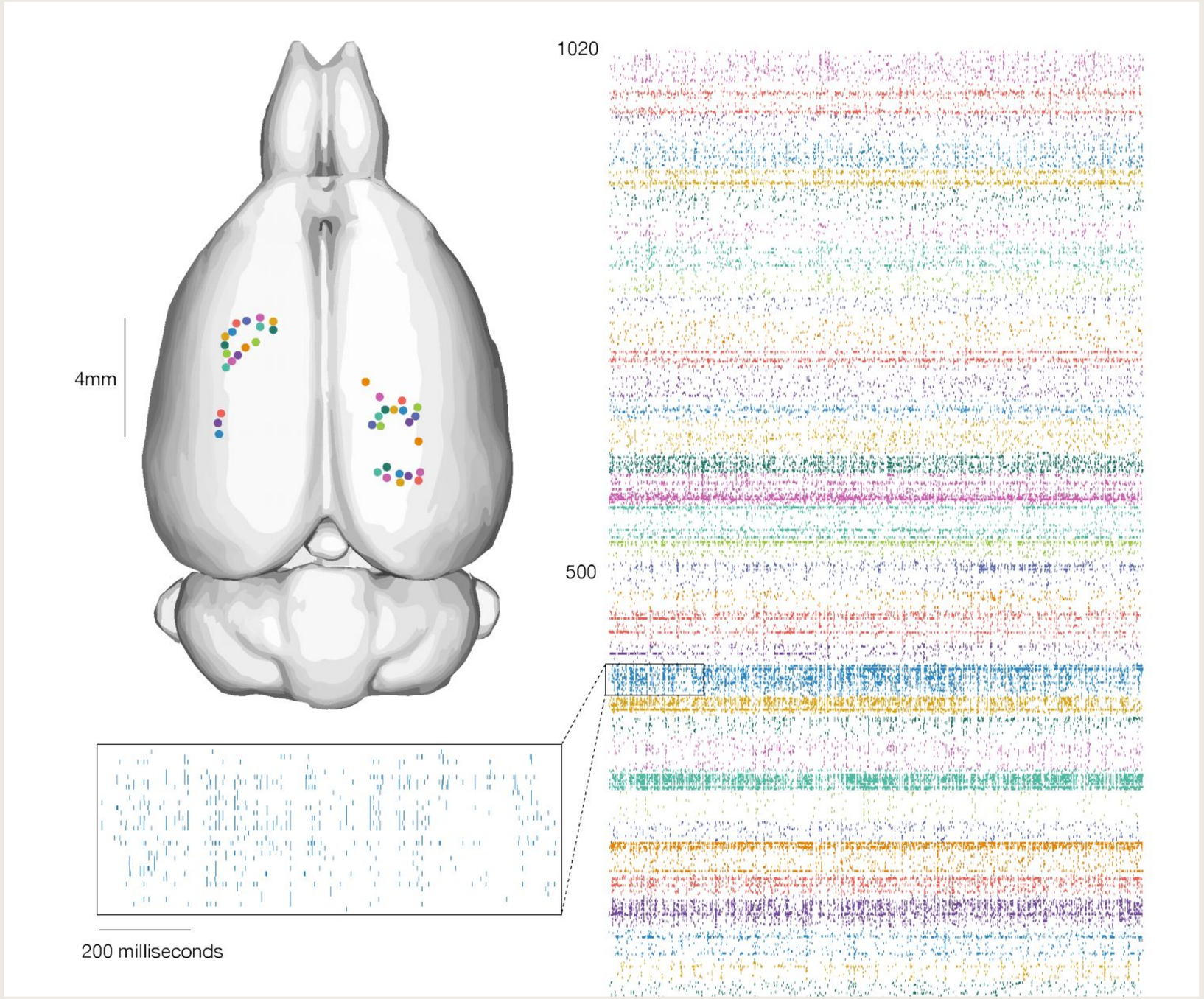
- Define *constructivism* and *tightly coupled* in the context of human-machine interfaces (sp. neuroprostheses).
- Propose that for maximum potential, tightly coupled interfaces should be *partially* or *fully constructivist*.
- Give concrete examples from our work on *constructing predictions, policies, and state* in upper-limb prosthetic interfaces.

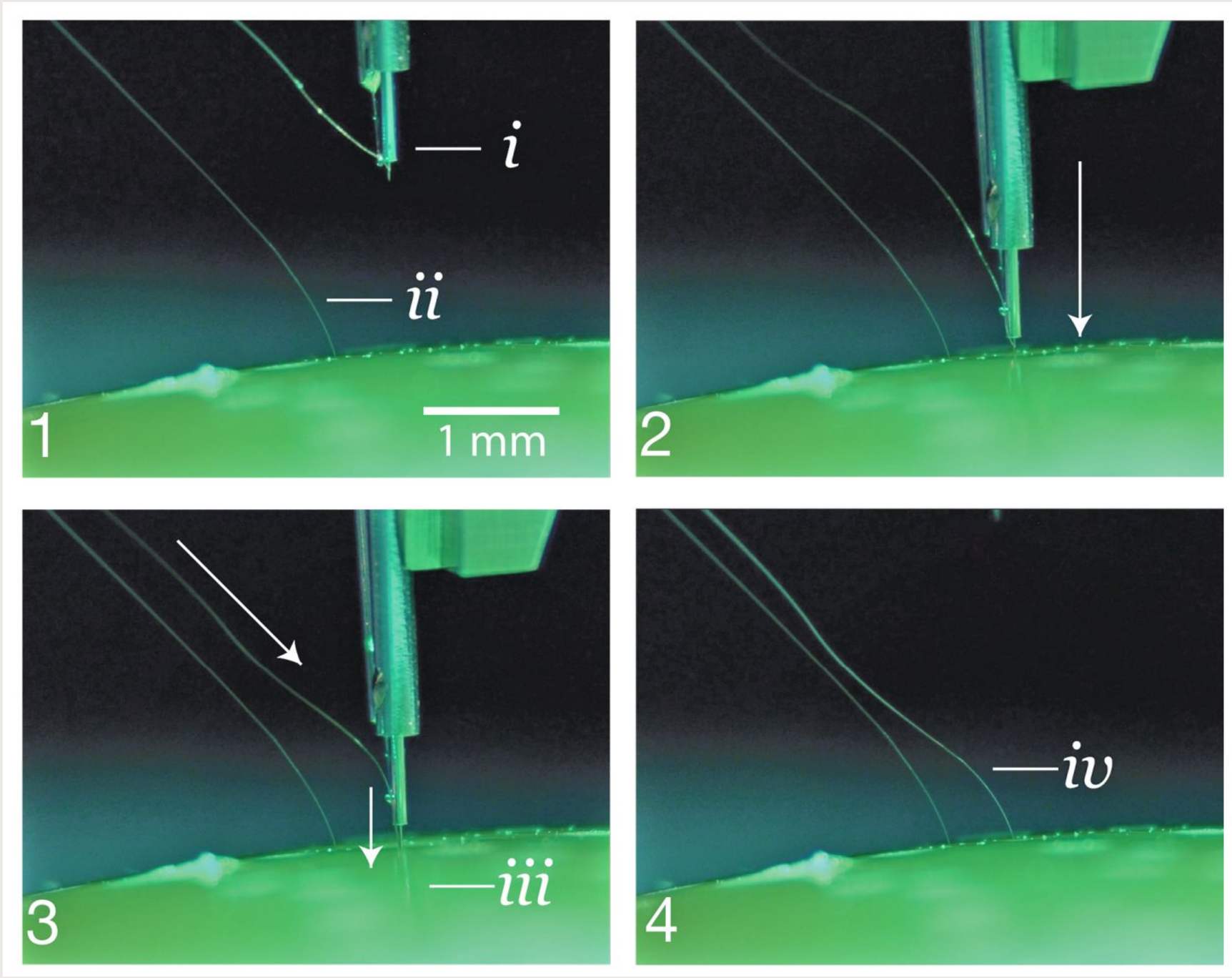


cortical implants

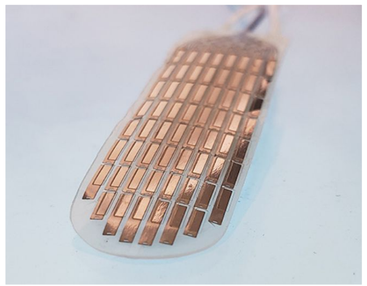
Elon Musk, Neuralink (2019). “An integrated brain-machine interface platform with thousands of channels,” bioRxiv 703801; doi: https://doi.org/10.1101/703801

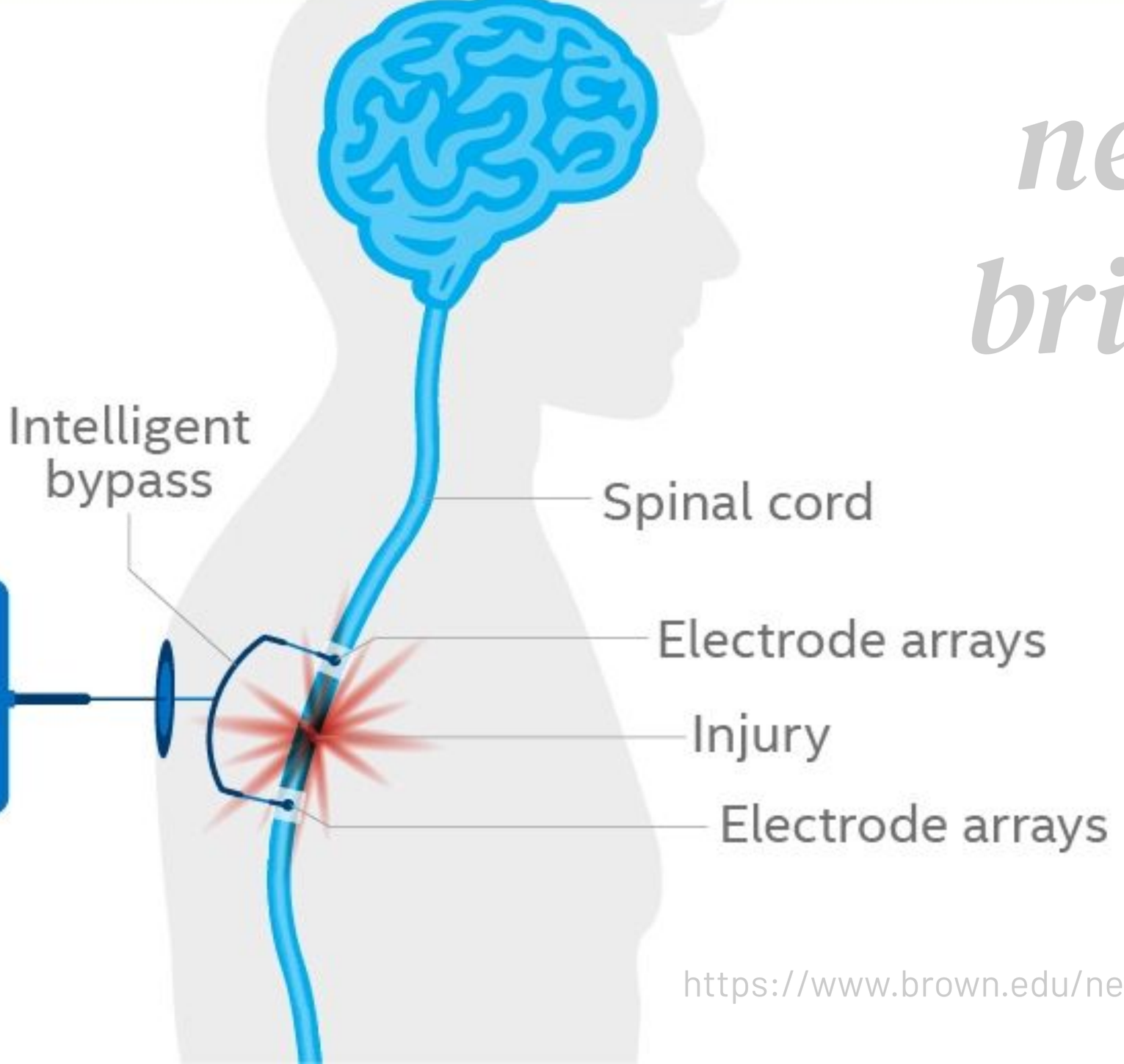



1020
4mm
500
200 milliseconds


i
ii
1 mm
1
2
3
iii
4
iv

neural bridges

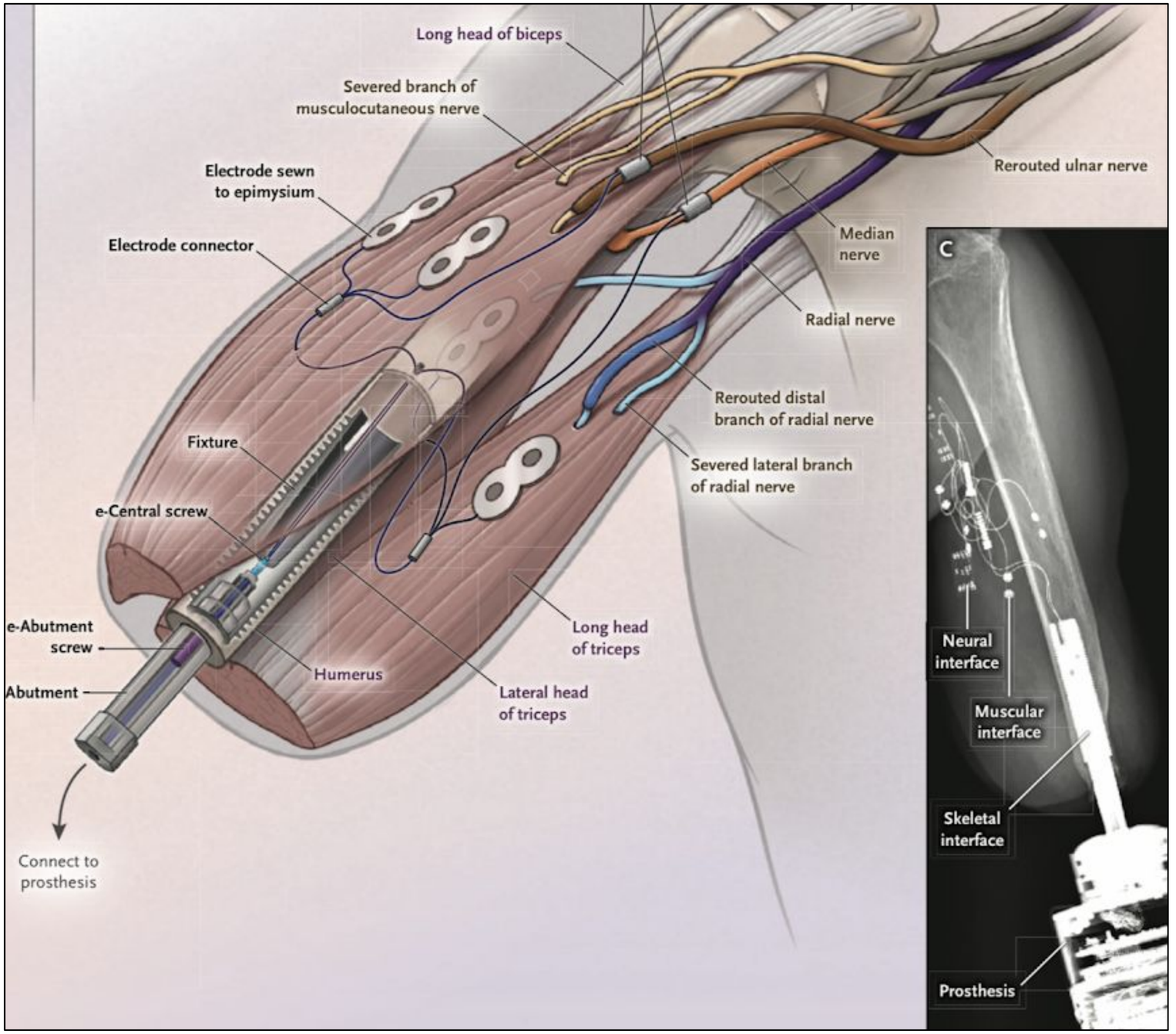




https://www.brown.edu/news/2019-10-03/isi

bone, muscle, and nerve integration

Ortiz-Catalan et al., *N Engl J Med* 2020; 382:1732-8.

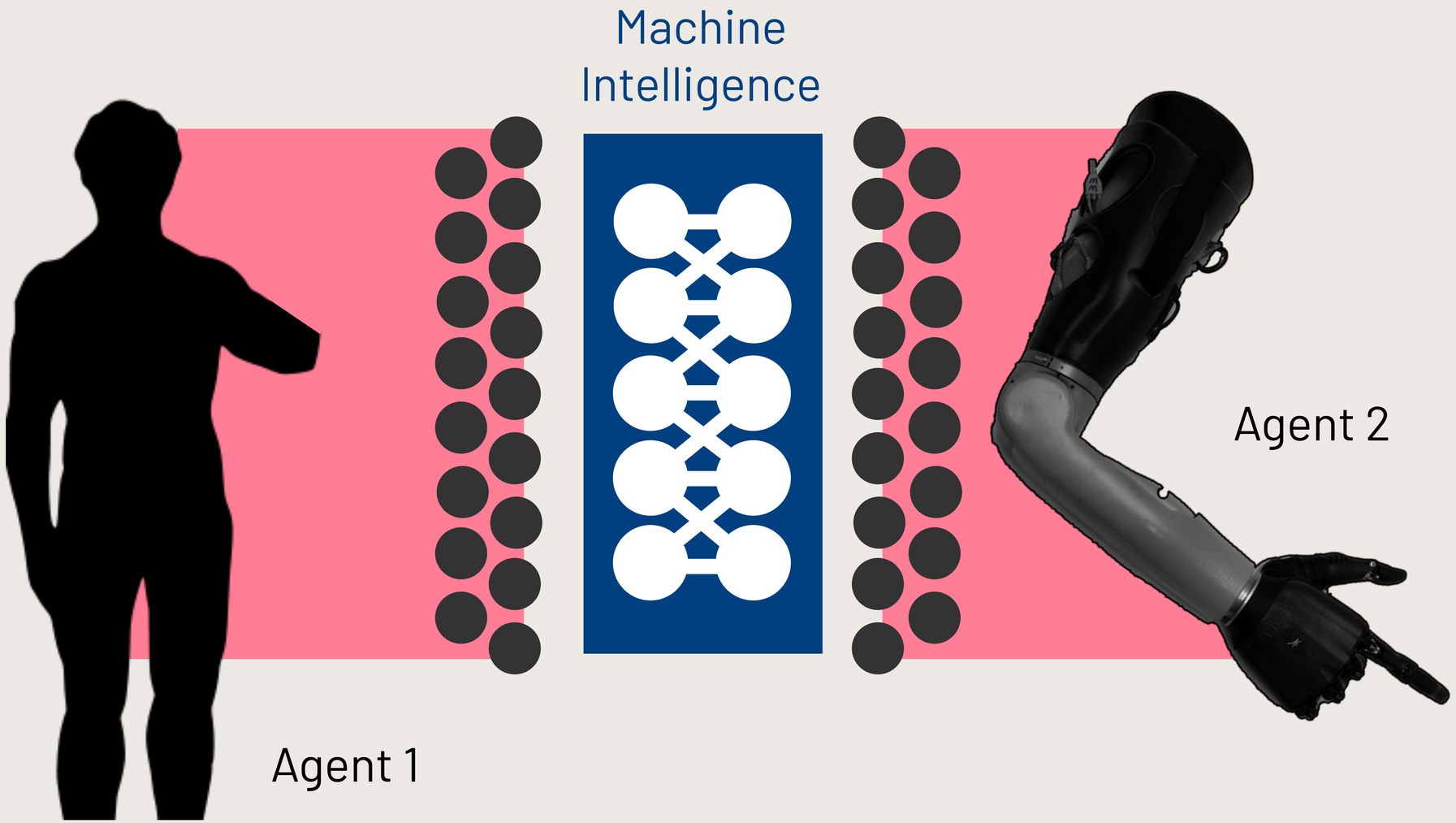


Commercial Prostheses

EEG

EMG

Consumer-Available BCI and BMI


Machine
Intelligence
Agent 1
Agent 2

Progress relies on the construction of **representations**, **predictions**, **policies**, and **models** in tightly coupled interfaces

Constructivism:

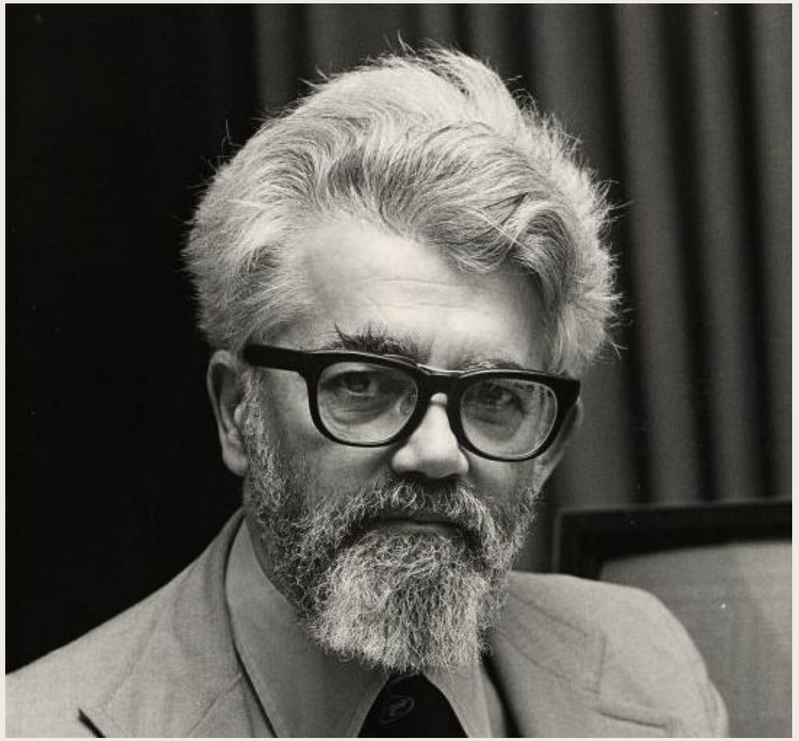
"[Intelligence] is the form of equilibrium towards which all the structures arising out of perception, habit and elementary sensori-motor mechanisms tend." Piaget, J. (1950). *The Psychology of Intelligence*. London: Routledge.

Jean Piaget
(1896–1980)

https://piaget.org/about-piaget/

Intelligence:

“... is the computational part of the ability to achieve goals in the world.”

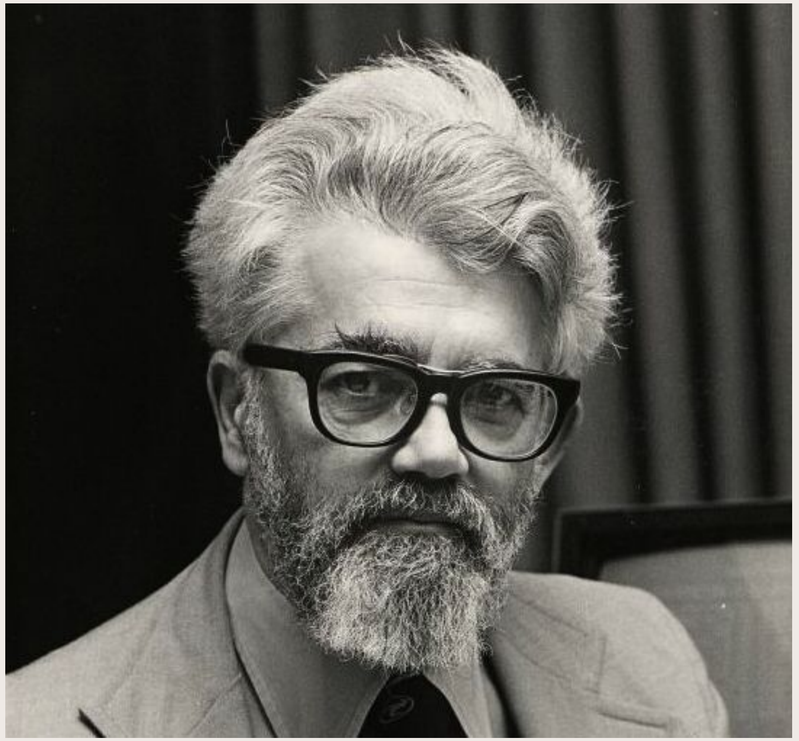


John McCarthy
(1927 – 2011)

http://jmc.stanford.edu/artificial-intelligence/index.html

Artificial Intelligence:

“... is the science and engineering of making intelligent machines, especially intelligent computer programs.”



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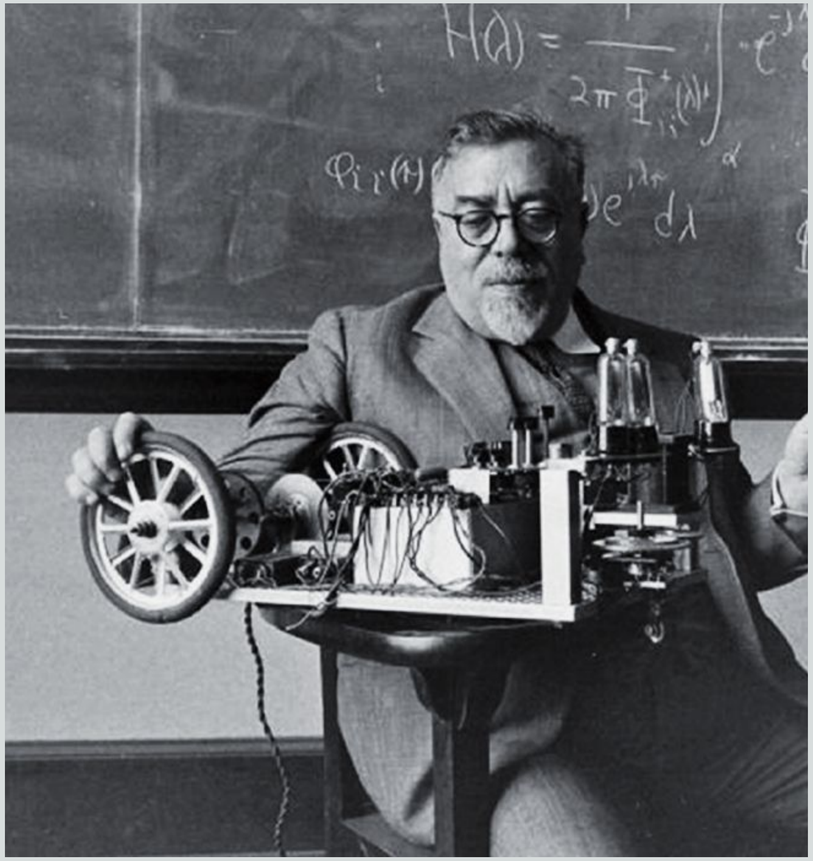


Norbert Wiener
(1894–1964)

closing loops

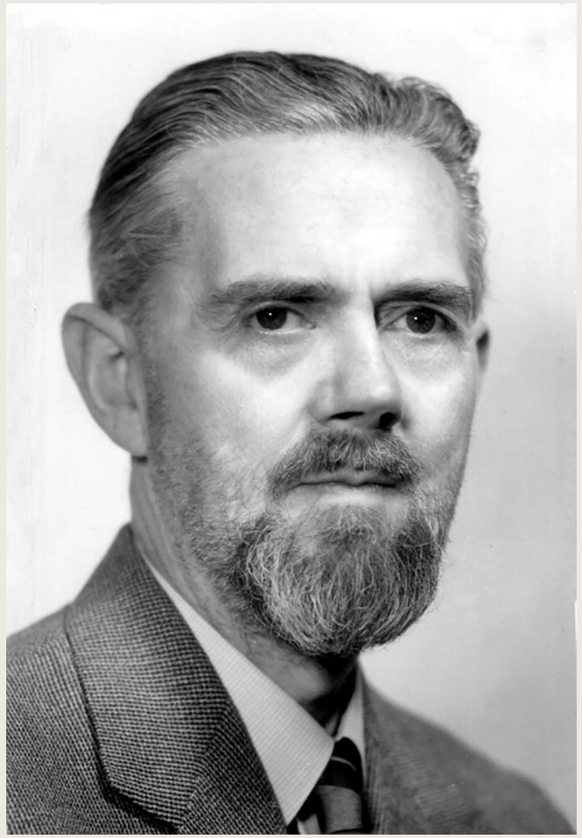
Communication and closed-loop signal passing to **autonomously align** disparate systems or parts of a system.

Wiener, N., *Cybernetics: Or Control and Communication in the Animal and the Machine*, New York: John Wiley & Sons, 1948.

"... amplifying the ability to select or choose between one of many options amplifies intellect, and this selection builds on a framework of **two systems with a communication channel open between them**."

Ashby, W.R., *An Introduction to Cybernetics*, Chapman and Hall, London, UK, 1956.

communication



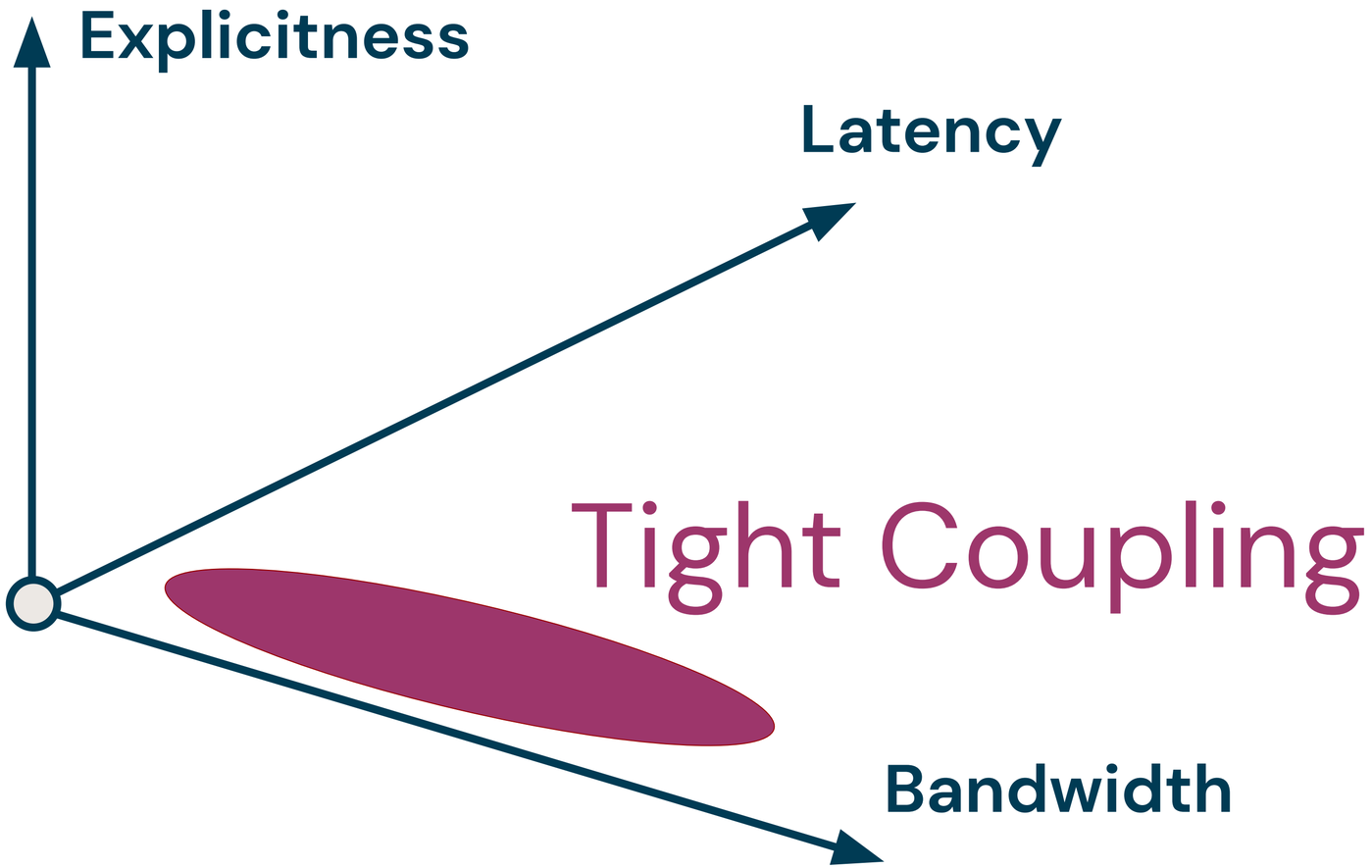
William Ross Ashby
(1903–1972)

Joseph Carl Robnett Licklider (1915–1990)

"The hope is that, in not too many years, **human brains and computing machines will be coupled together very tightly**, and that the resulting partnership will think as no human brain has ever thought and process data in a way not approached by the information-handling machines we know today."

Licklider, J.C.R., "Man-Computer Symbiosis", *IRE Transactions on Human Factors in Electronics*, vol. HFE-1, 4-11, Mar 1960.

tight coupling



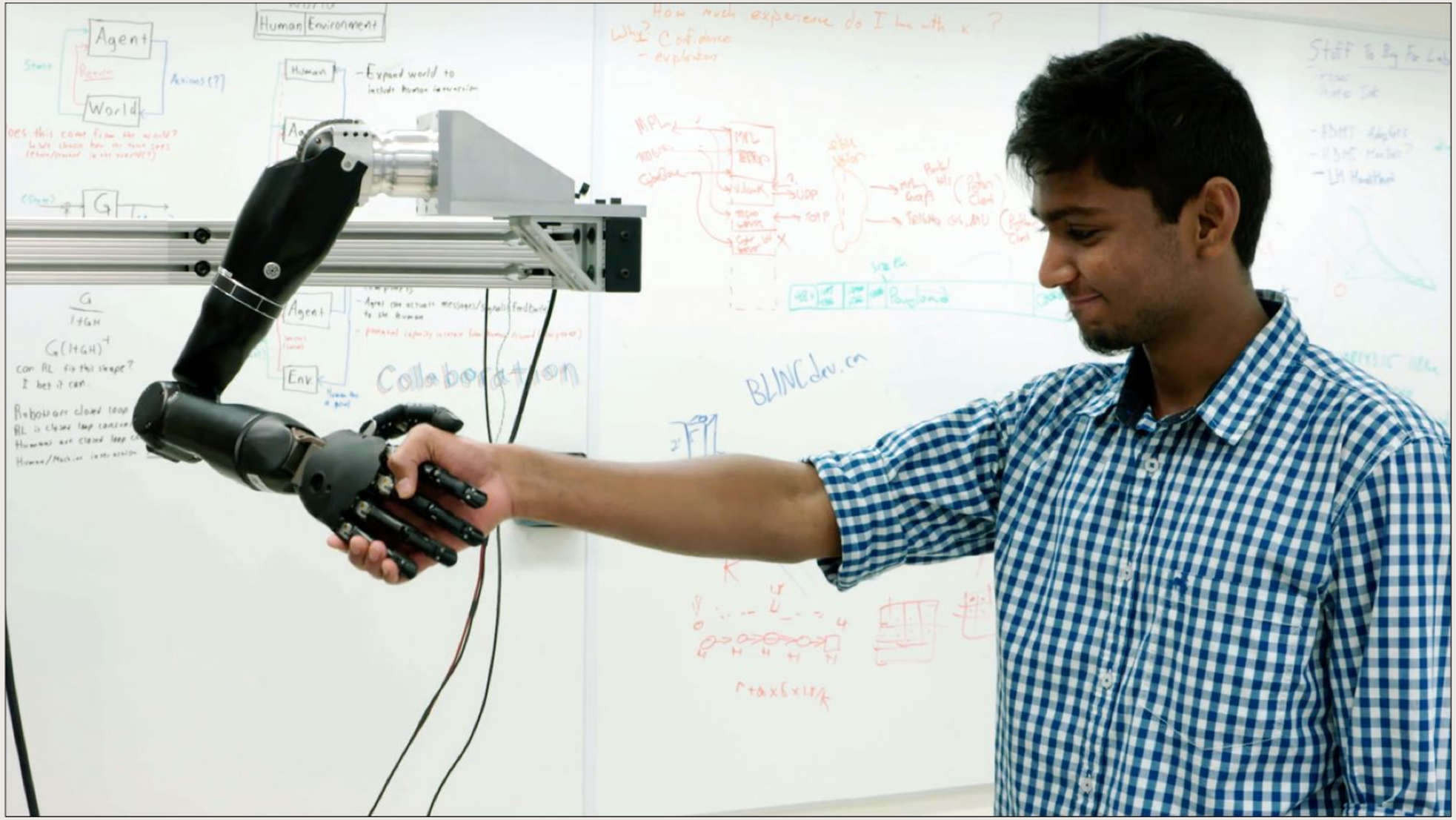
Pilarski and Sutton (2012) AAAI FS.

A constructivist perspective to tightly coupled interfaces supports **adaptation** and **sculpting to individual agents** (machine and human) and their unique flow of daily life.

Main Considerations / Starting Points

Train/test or continual learning?	Continual learning
Pre-trained or tabula rasa?	~~No~~ Minimize prior biases*
Relationship or a code channel?	Evolving relationship

File photo by *The Canadian Press*/Amber Bracken, 2019



BLINC Lab / SMART Network

August 2016

Examples: 2011-2021

Identifying patterns with TIDBD	Gunther 2020
GVF collections predicting surprise	Gunther 2018, Pilarski 2016
LfD from a contralateral limb	Vasan 2017, Vasan 2018
Learned feedback	Parker 2014, 2019
Learned joint synergies	Pilarski 2013, Sherstan 2015
RL policies from human reward	Pilarski 2011
Pavlovian control in SCI	Dalrymple 2020

Examples: 2011-2021

Constructed based on sensorimotor interactions with an individual and what they do, not an objective "task"

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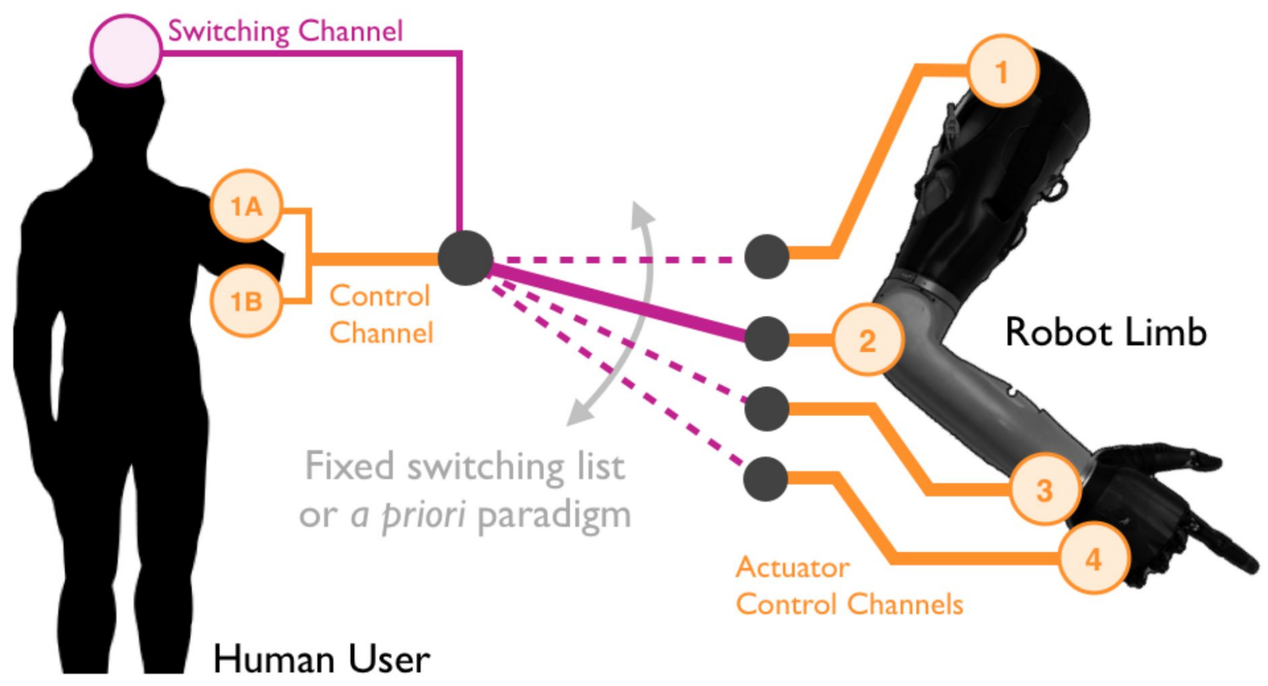
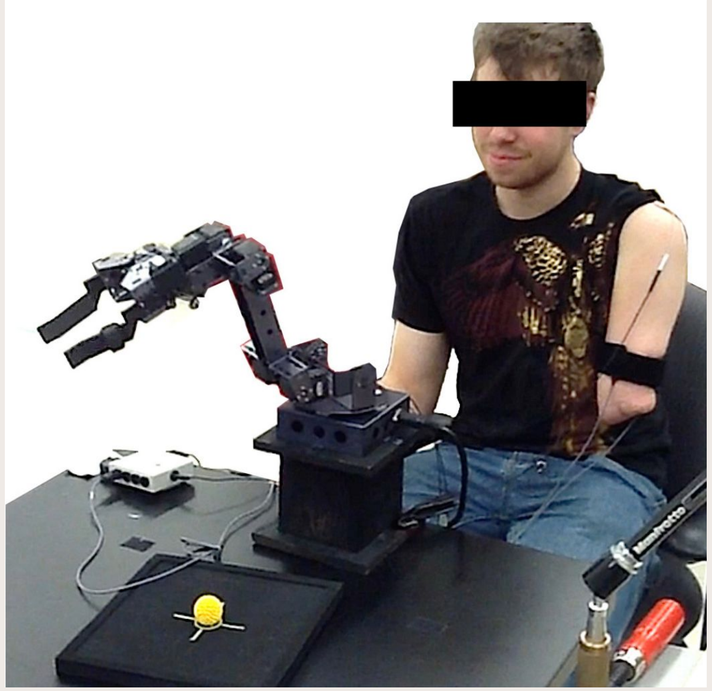
Communciative Capital

P. M. Pilarski, R. S. Sutton, K. W. Mathewson, et al. “Communicative Capital for Prosthetic Agents,” arXiv:1711.03676 [cs.AI] (arXiv): 33 pages, 2017.

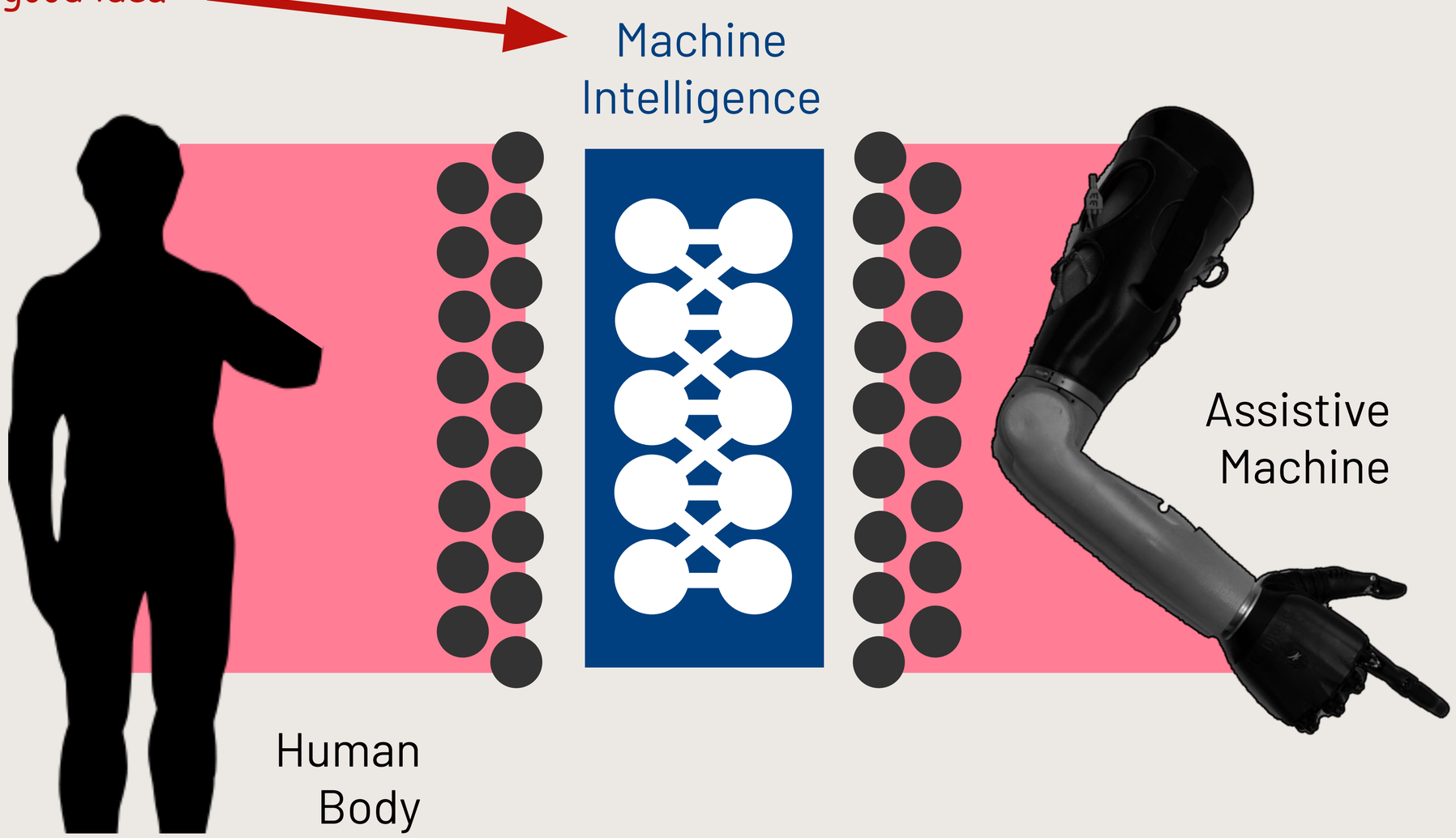




Adaptive & Autonomous Switching

A. L. Edwards, et al. *Prosthetics & Orthotics International*, vol. 40, no. 5, 573–581, 2016.
A. L. Edwards, et al., *6th IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics (BioRob2016)*, June 26-29, 2016, Singapore, pp. 514–521
A.L. Edwards, et al., *1st Multidisciplinary Conference on Reinforcement Learning and Decision Making (RLDM)*, Oct. 25–27, Princeton, New Jersey, USA, 2013.

Constructing this during continual interaction is a good idea



Summary

Constructing **representations**, **predictions**, **policies**, and **models** from ongoing experience lets tightly coupled interfaces **align & specialize** to individual human (or machine) agents and needs.

Thank you…

… and (hopefully) time for questions and discussion!

For a birds-eye overview: P. M. Pilarski, R. S. Sutton, K. W. Mathewson, et al. “Communicative Capital for Prosthetic Agents,” arXiv:1711.03676 [cs.AI], 2017.

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BLINC
BIONIC LIMBS FOR IMPROVED NATURAL CONTROL

DeepMind

SMART NETWORK
Sensory Motor Adaptive Rehabilitation Technology