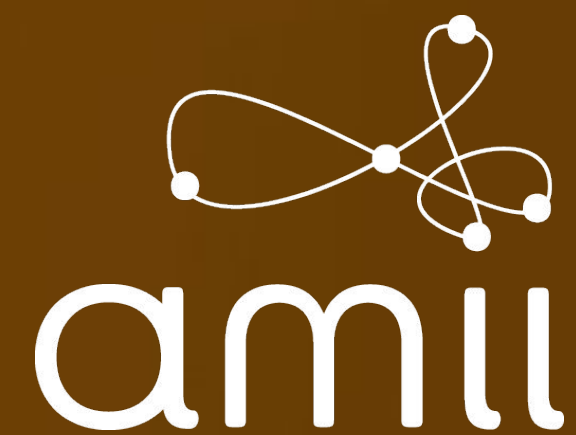


# How to Train Your (Bionic) Body Parts

Patrick M. Pilarski



**UNIVERSITY  
OF ALBERTA**







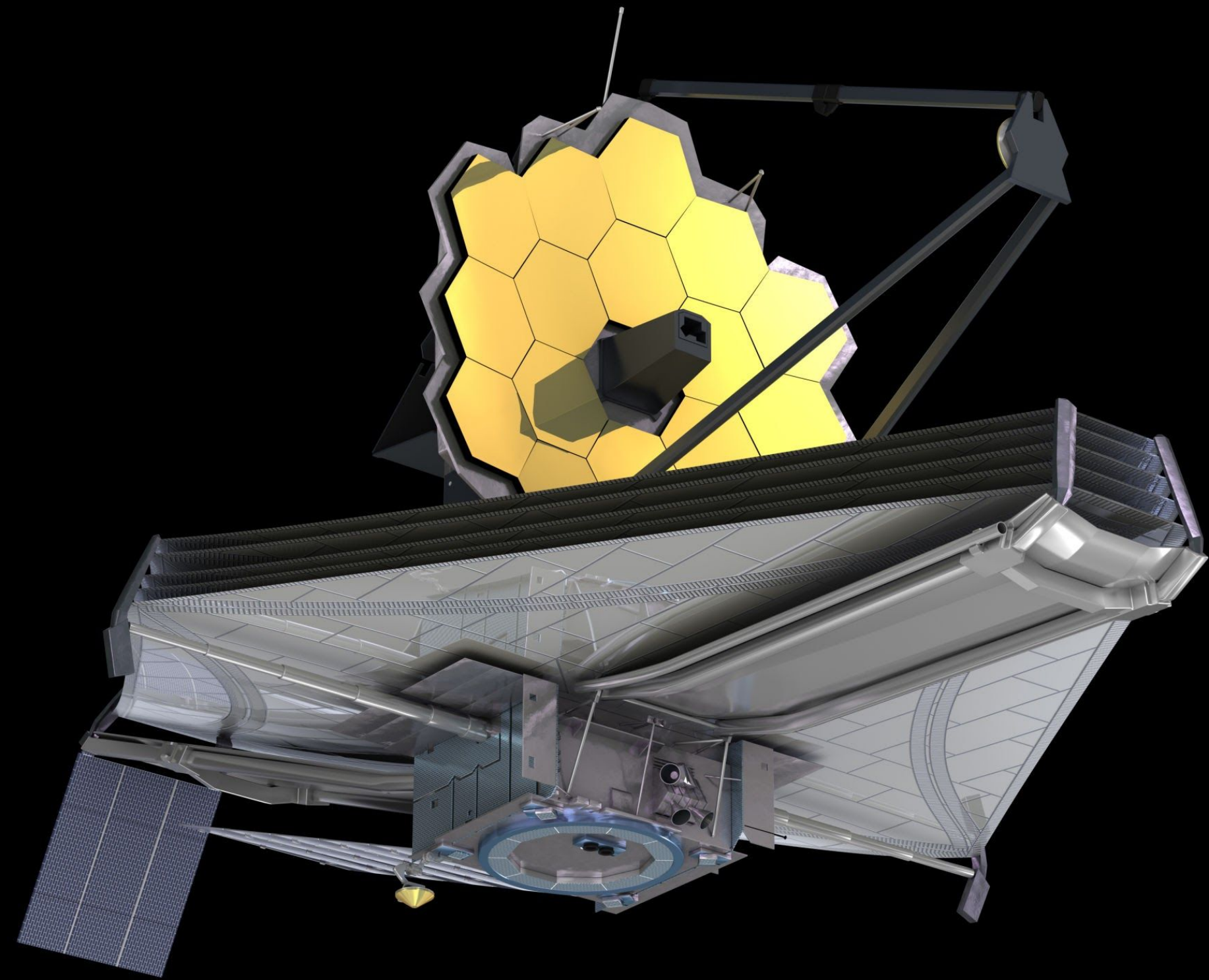
Modern Social Media  
Pieter Bruegel the Elder, 1568



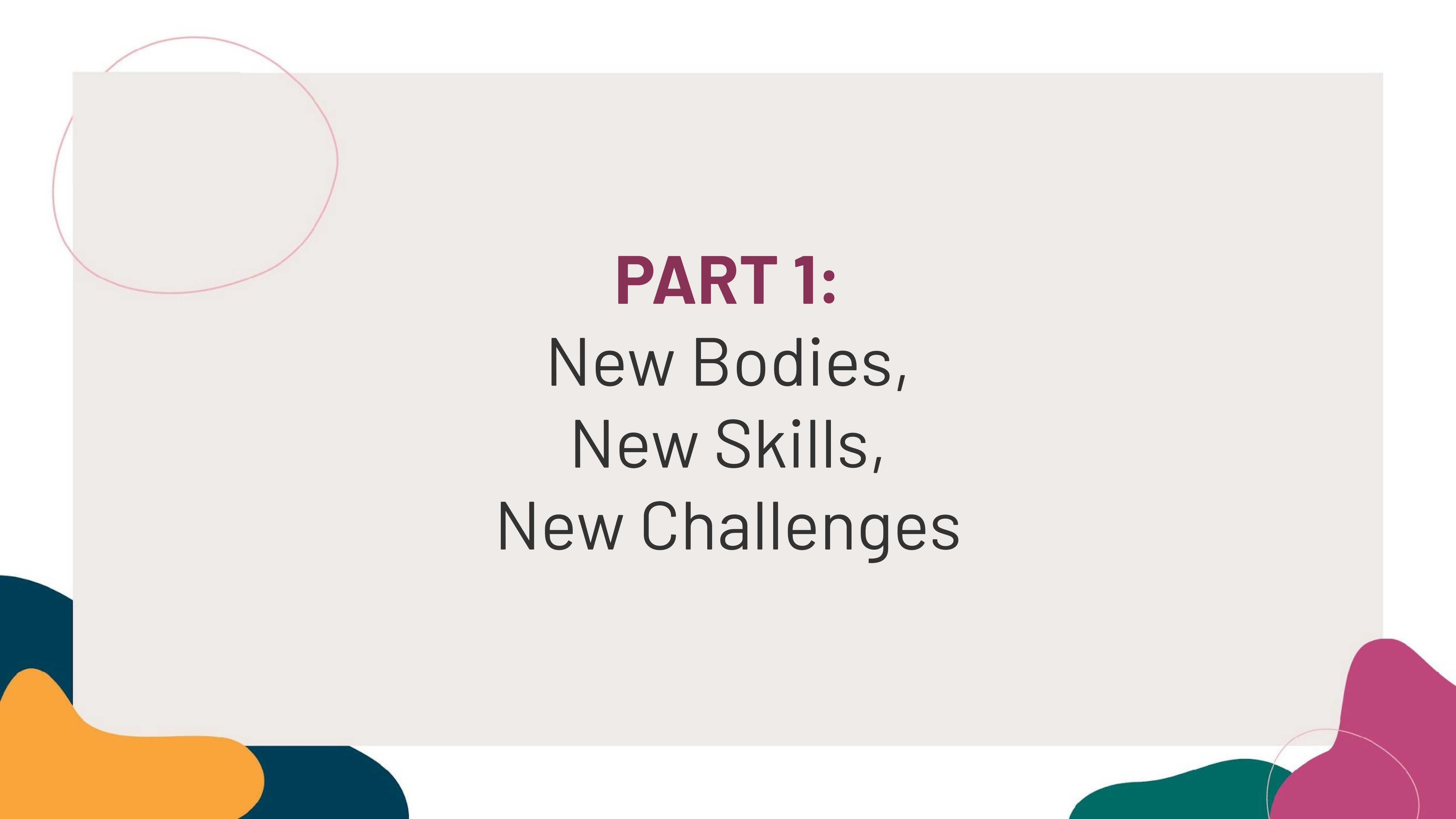


*The Blind Leading the Blind*  
Pieter Bruegel the Elder, 1568







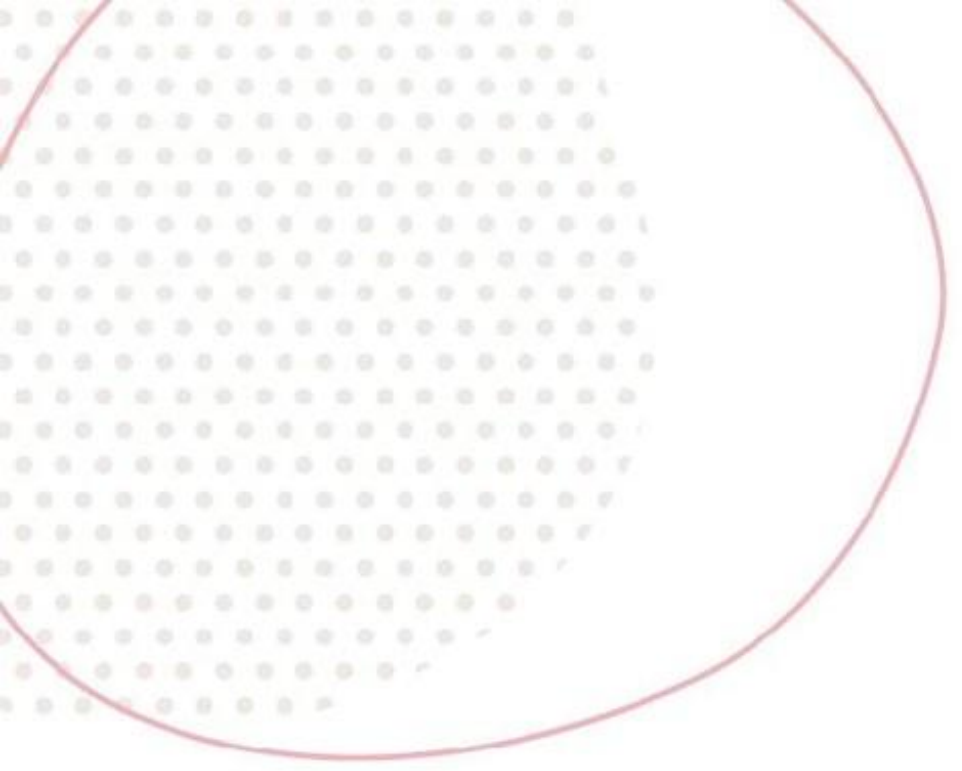


**PART 1:**  
New Bodies,  
New Skills,  
New Challenges

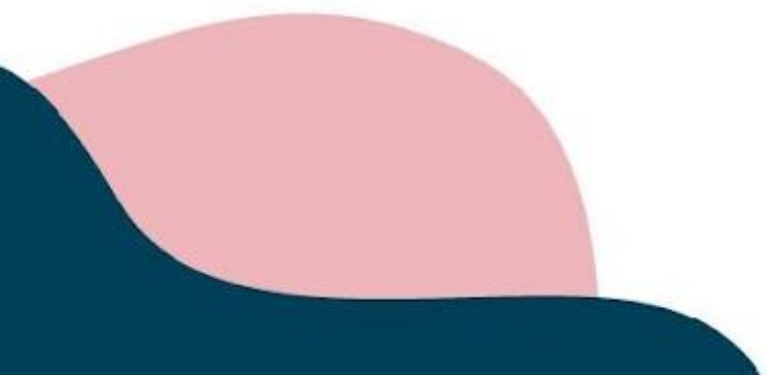




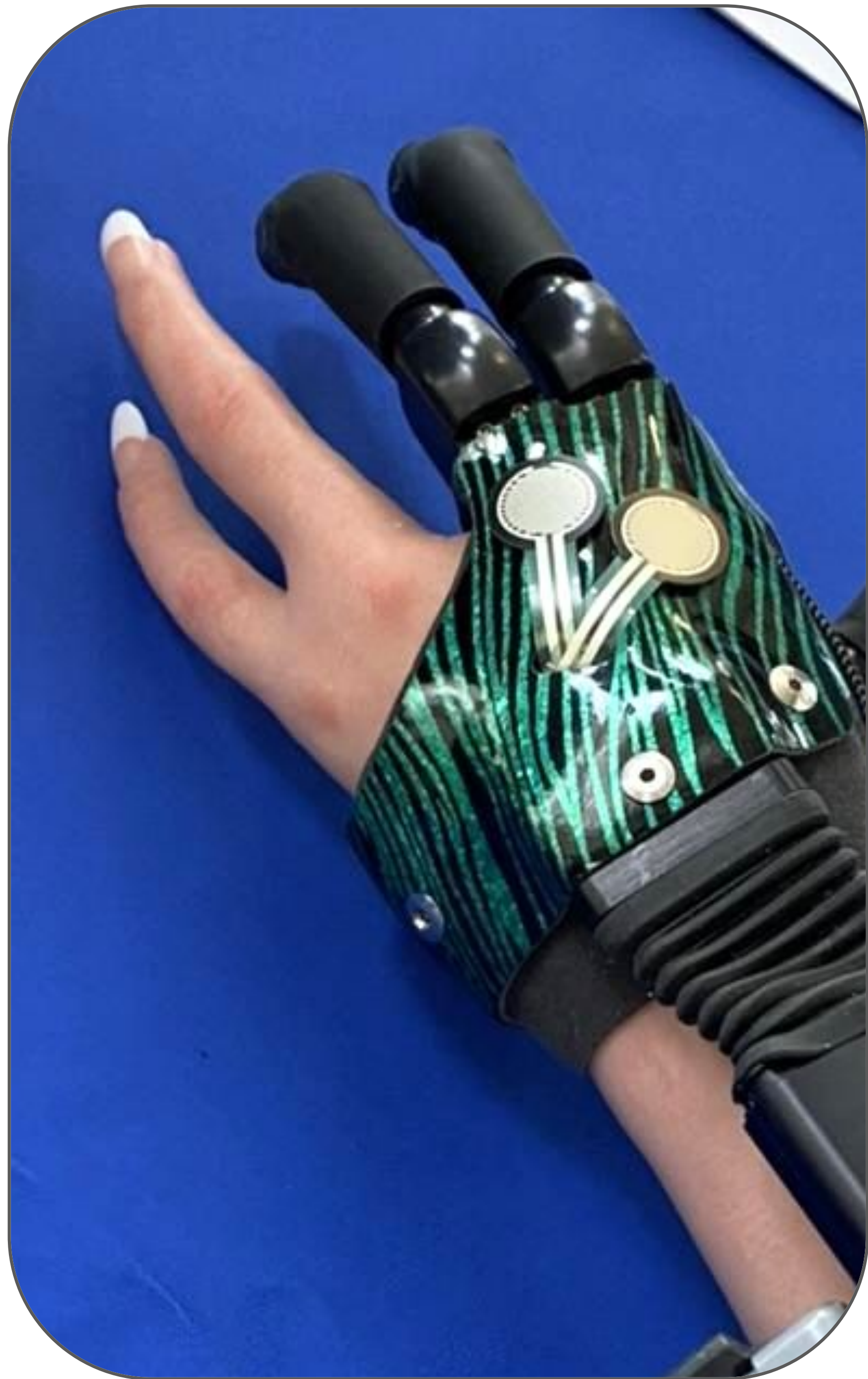




**Some are in use every day ...**





















## THE BIONIC-HAND ARMS RACE

The prosthetics industry is too focused on high-tech limbs that are complicated, costly, and often impractical.

## BRITT H. YOUNG

21 AUG 2022  
*IEEE Spectrum*



The author, Britt Young, holding her Ottobock iLimb bionic arm. GABRIELA HASBUN. MAKEUP: MARIA NGUYEN FOR MAC COSMETICS; HAIR: JOAN LAQUI FOR LIVING PROOF





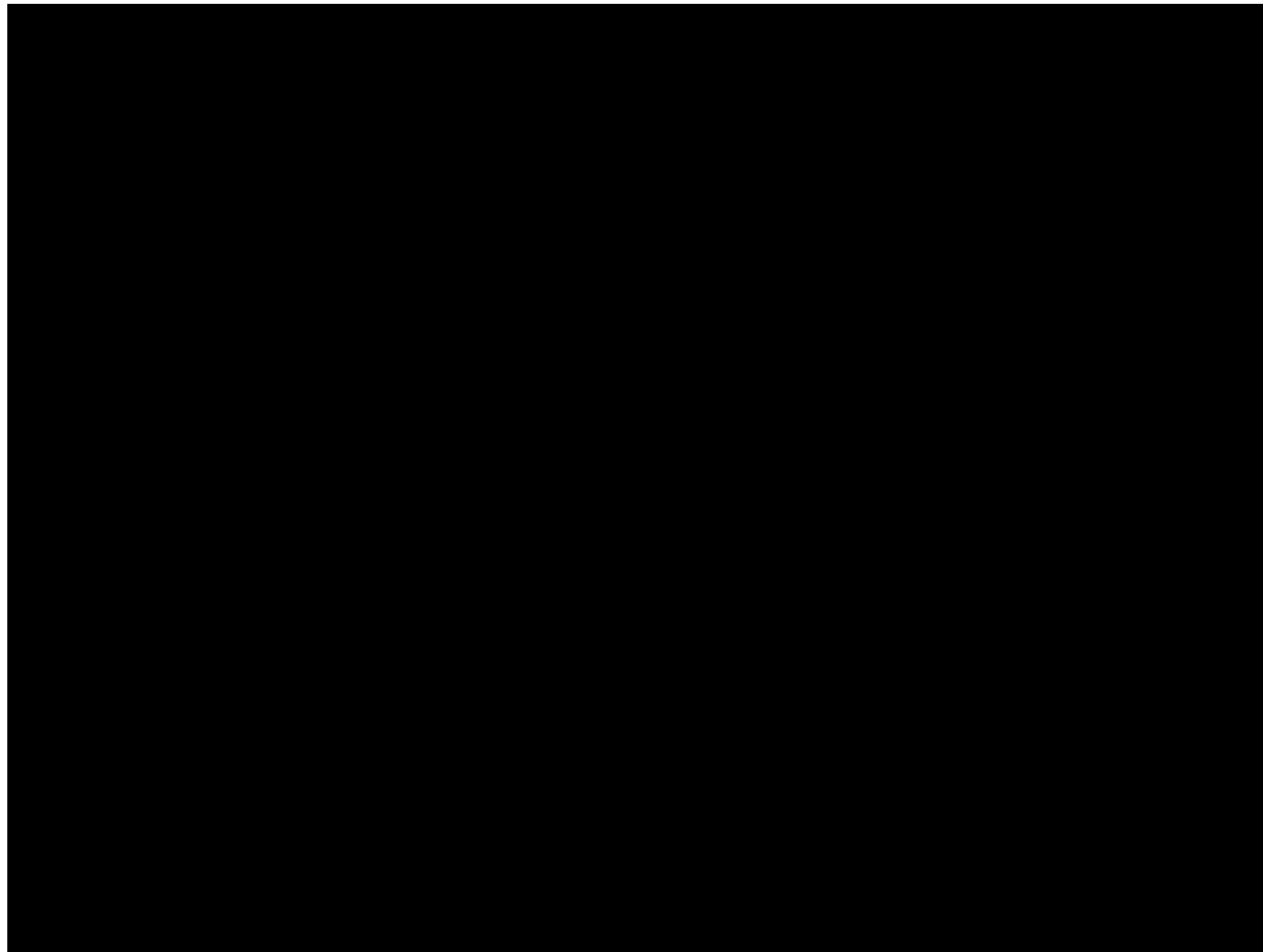
TRS makes a wide variety of body-powered prosthetic attachments for different hobbies and sports. Each attachment is specialized for a particular task, and they can be easily swapped for a variety of activities. FILLAUER TRS





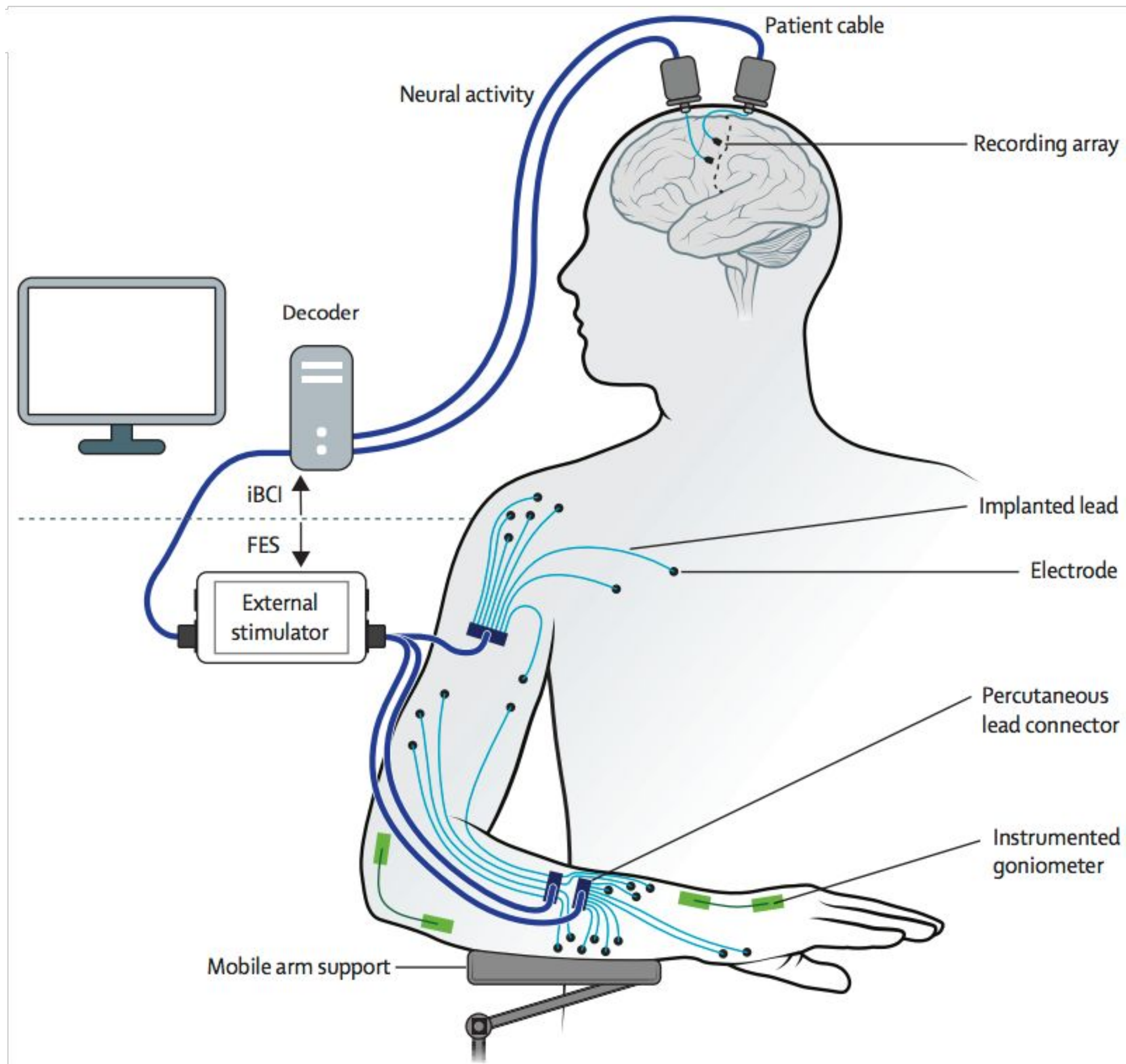
**Some are coming soon ...  
(in research and development)**





**Direct brain-computer interfaces:** study participant Jan Scheuermann feeding herself with a robotic limb (University of Pittsburgh / UPMC); <http://www.upmc.com/media/media-kit/bci/Pages/default.aspx>





**Brain-body-machine interfaces:** “Restoration of reaching and grasping movements through brain-controlled muscle stimulation in a person with tetraplegia: a proof-of-concept demonstration” Ajiboye, A Bolu et al., *The Lancet*, Volume 389 , Issue 10081, 1821-1830, 2017.



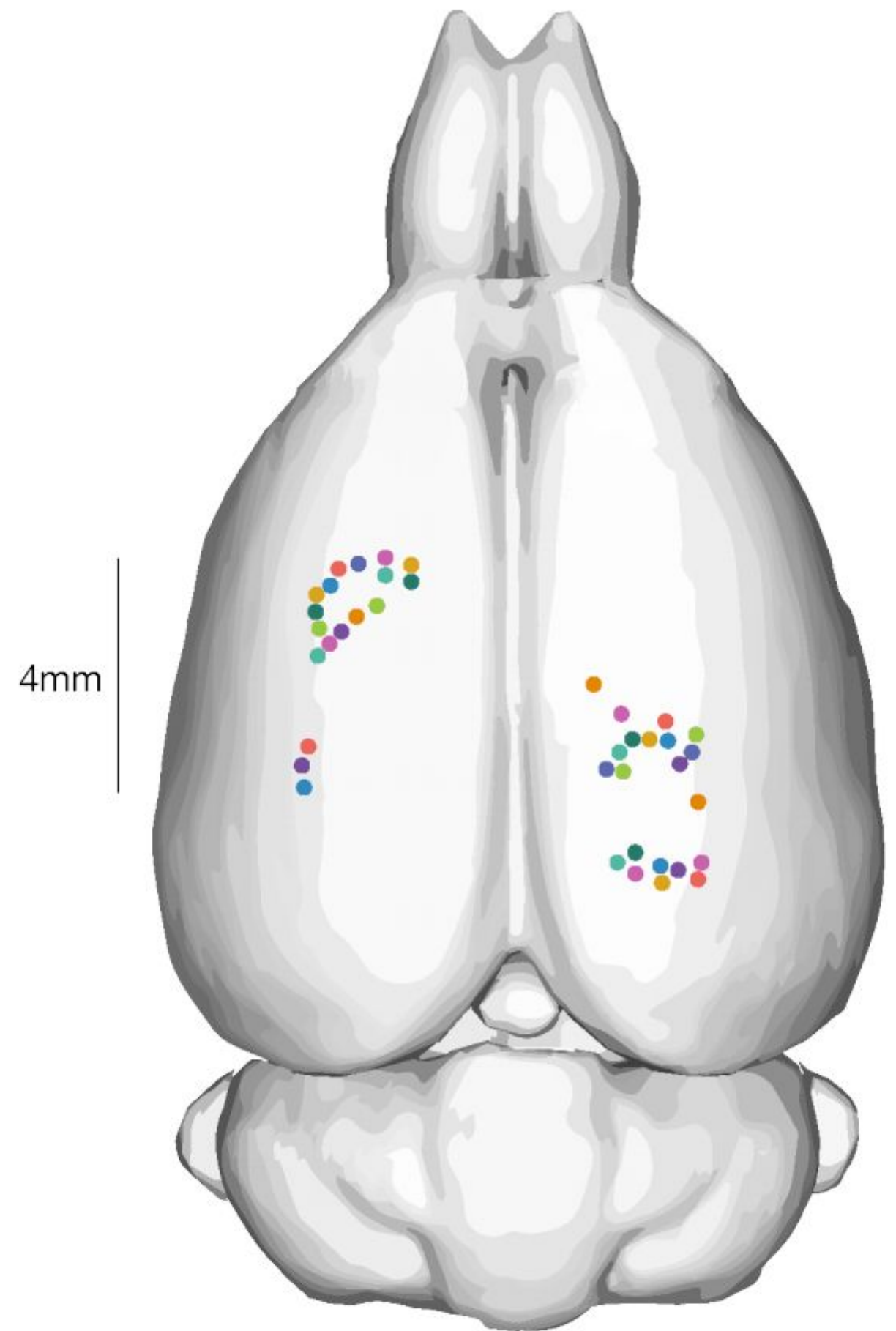
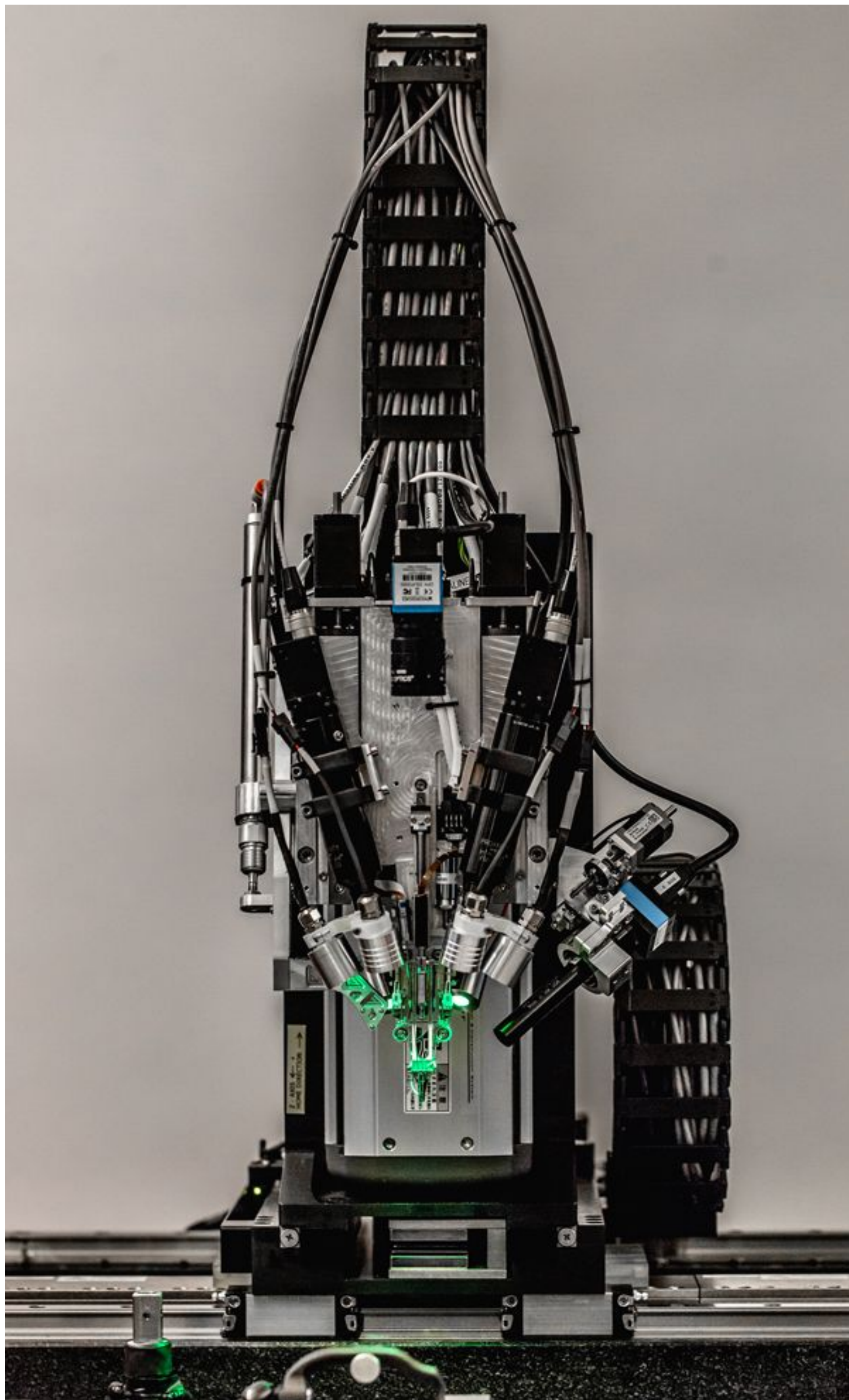
A fluorescence micrograph showing a brain with a neural implant. The implant is a long, thin, dark structure with several bright, glowing segments. The brain tissue is stained with a blue-green dye, highlighting the neural structures. A scale bar in the top left corner indicates 500 micrometers. The letter 'A' is in the top right corner.

500 $\mu$ m

# *modern cortical implants*

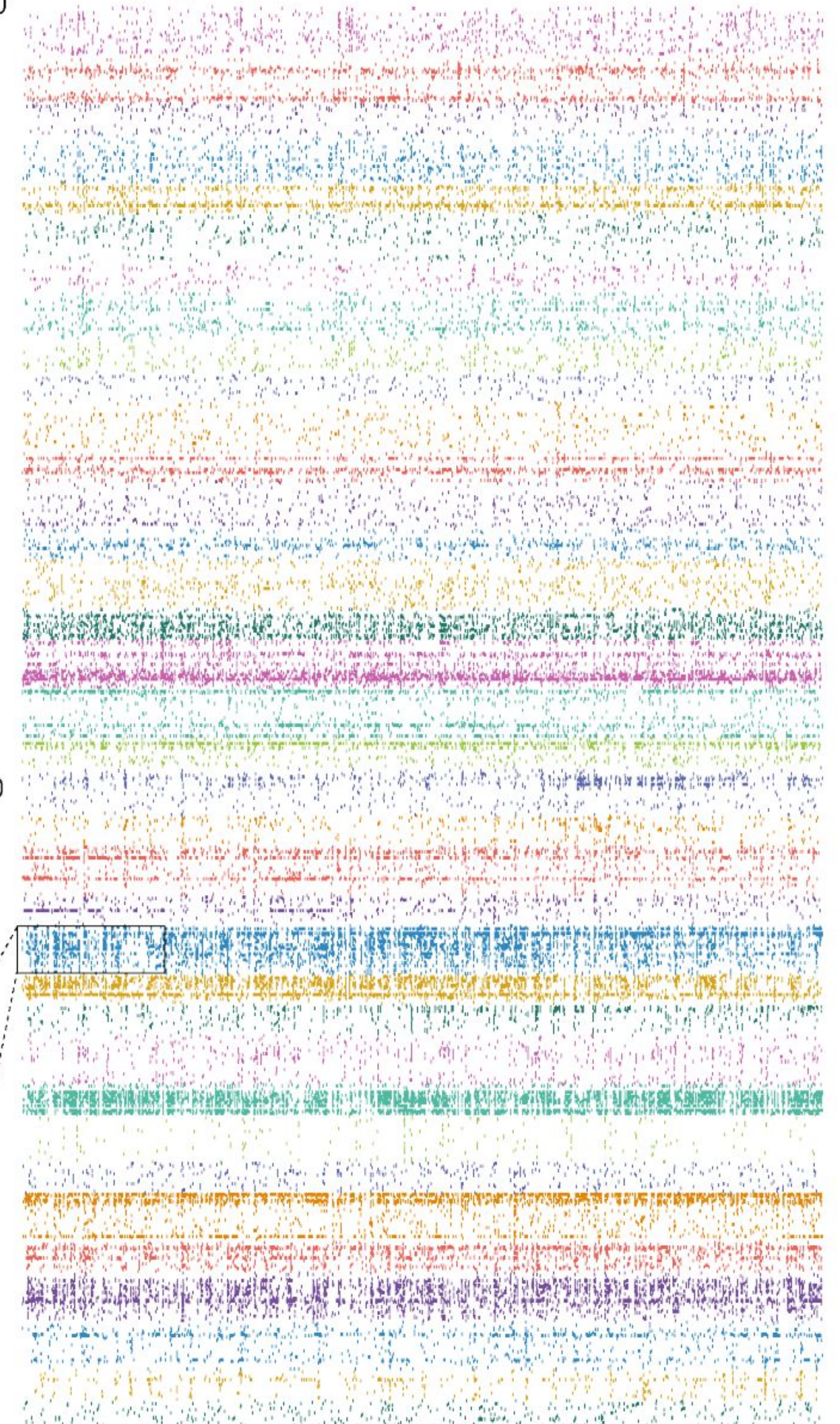
Elon Musk, Neuralink (2019). "An integrated brain-machine interface platform with thousands of channels," bioRxiv 703801; doi: <https://doi.org/10.1101/703801>



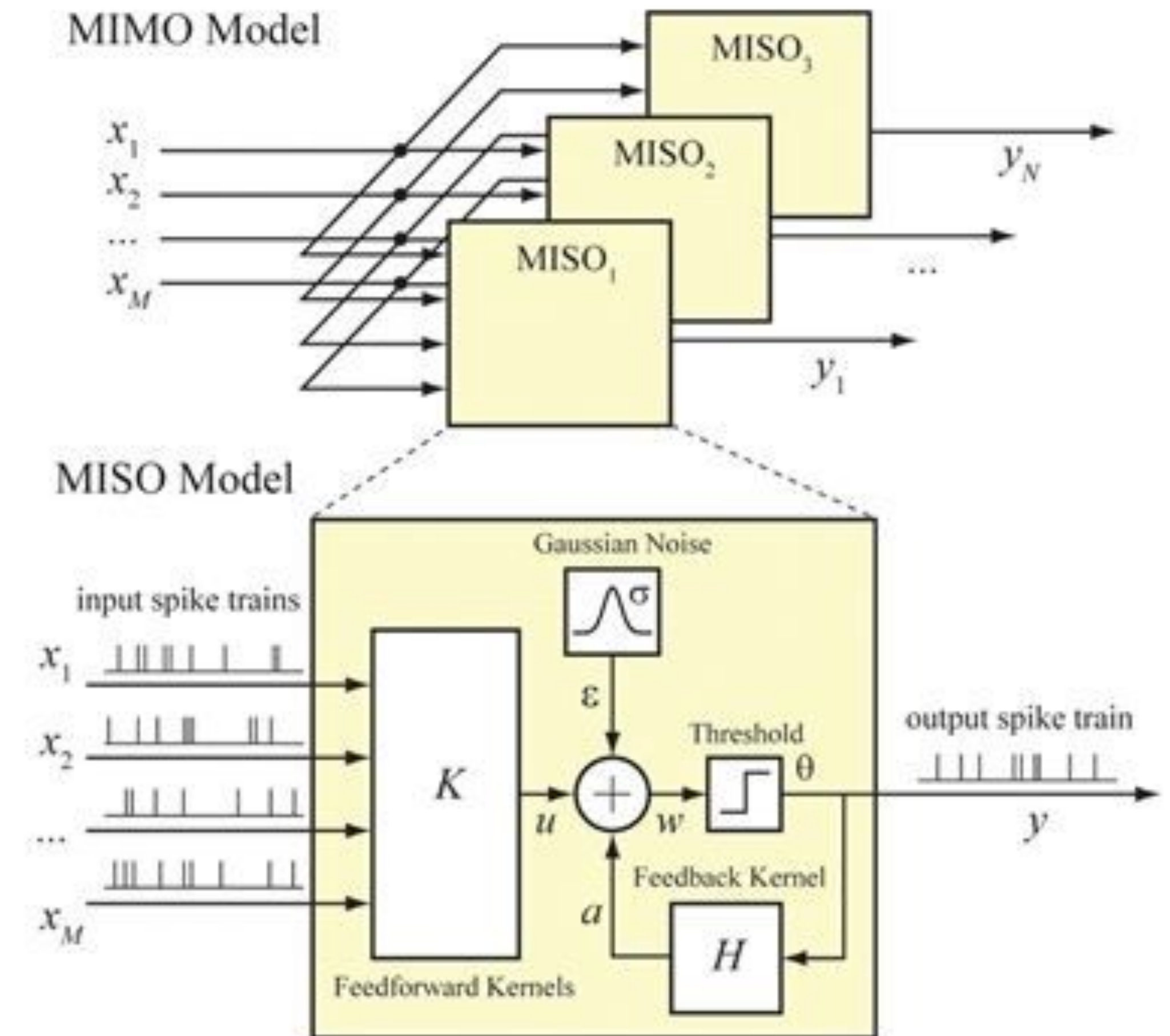
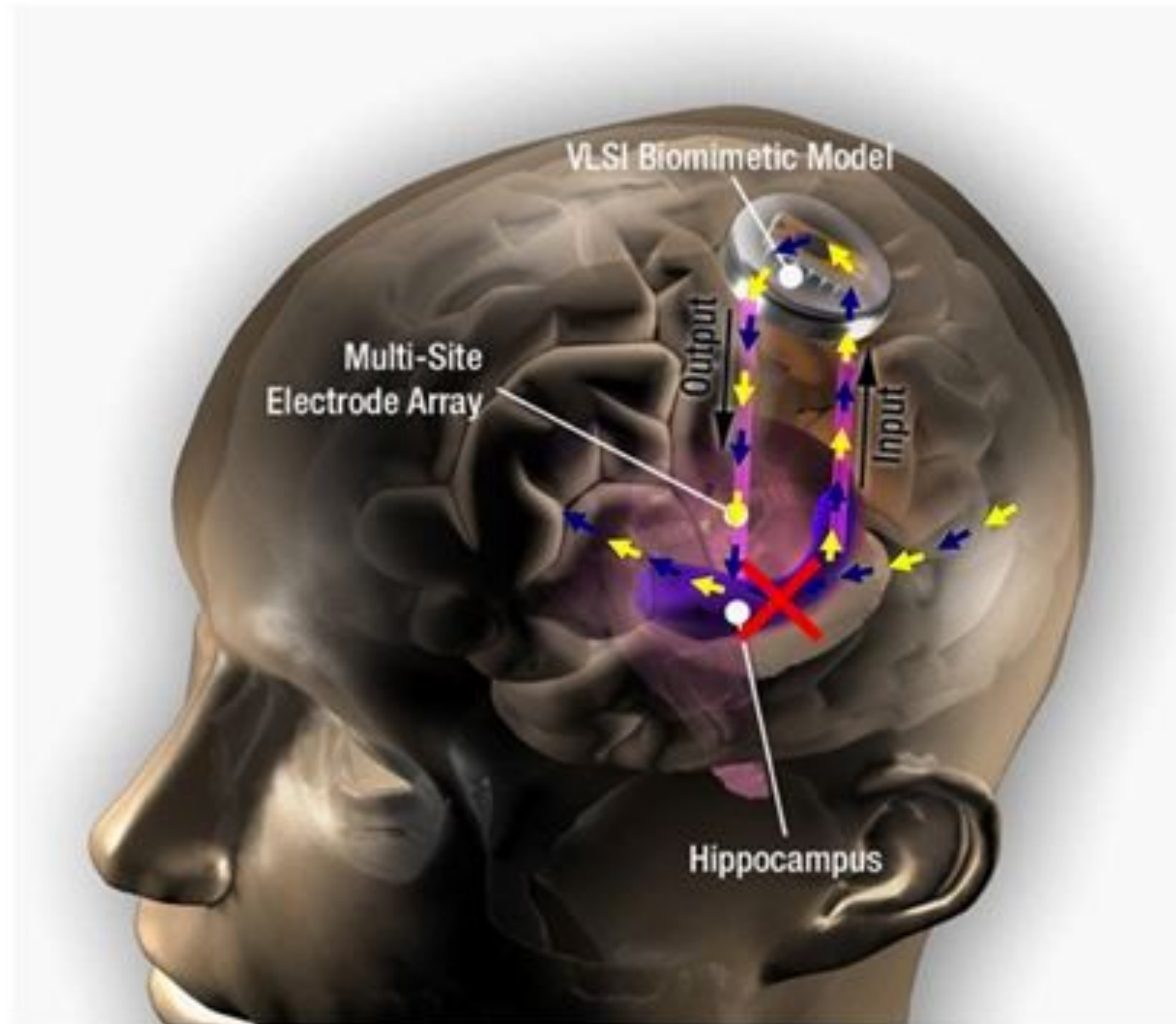


200 milliseconds

1020







**Direct brain-computer interfaces:** *memory prostheses* from the Center for Neural Engineering, Viterbi School of Engineering. <https://cne.usc.edu/neural-prosthesis-for-hippocampal-memory-function/> and IEEE Trans Neural Syst Rehabil Eng. 2018, 26(2):272-280.

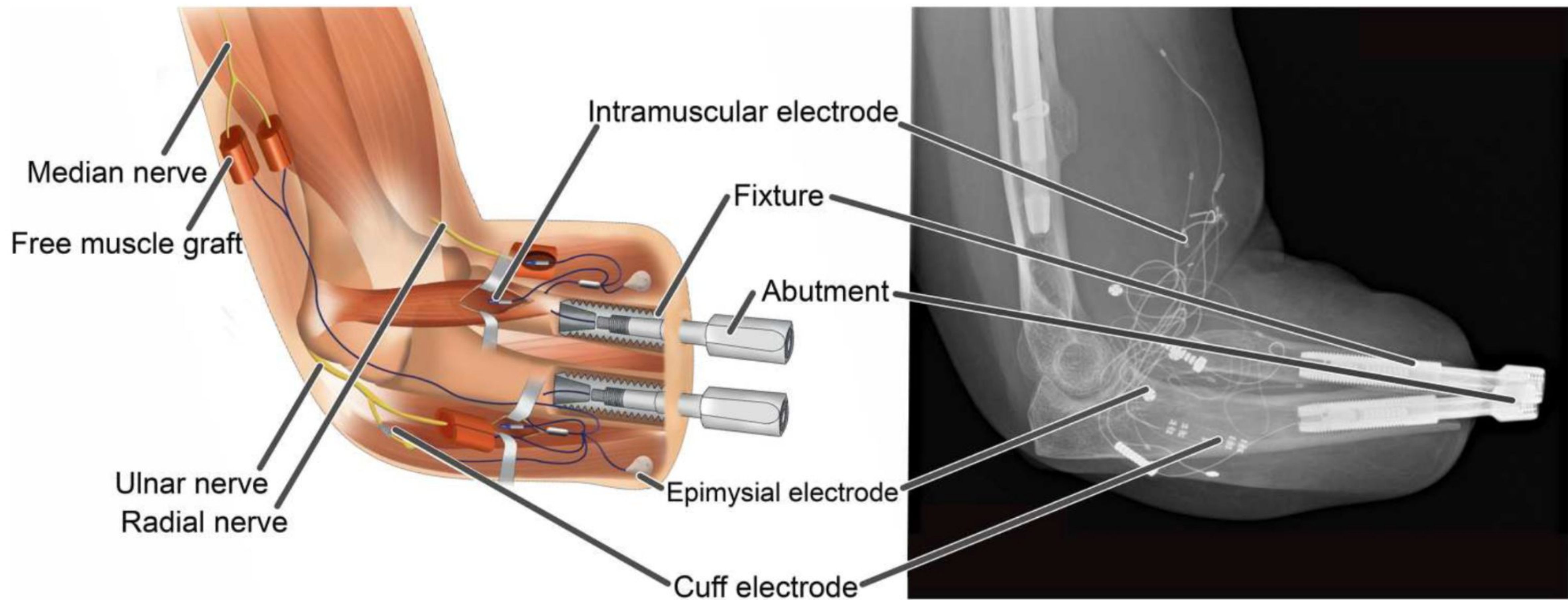




**Brain-body-machine interfaces:** "Amputee Makes History with APL's Modular Prosthetic Limb" (JHU Applied Physics Laboratory); <https://youtu.be/9N0ncx2jU0Q>

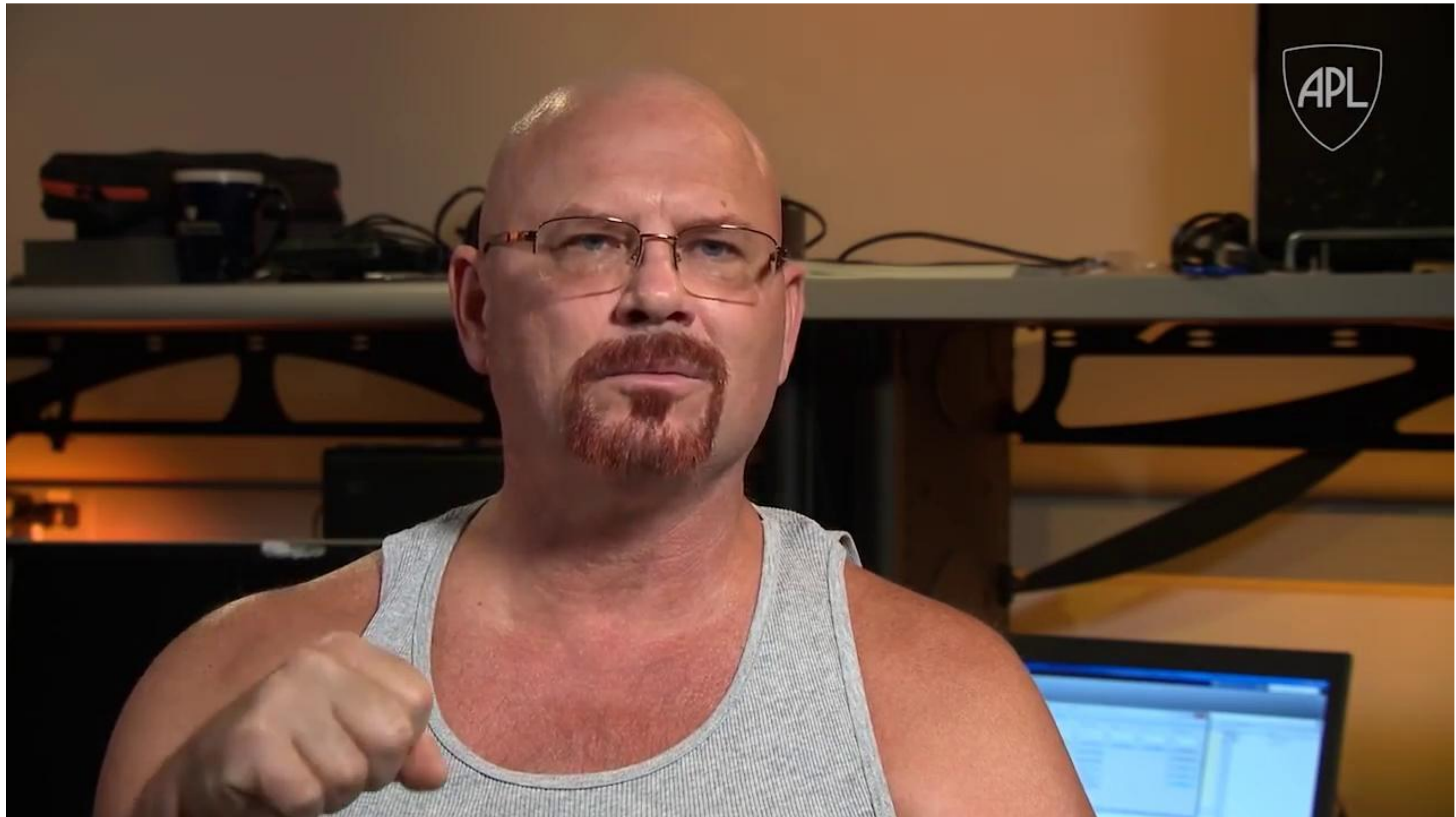


# *bone, muscle, and nerve integration*



Max Ortiz-Catalan et al.,  
*Sci. Robot.* 8, eadf7360 (2023).

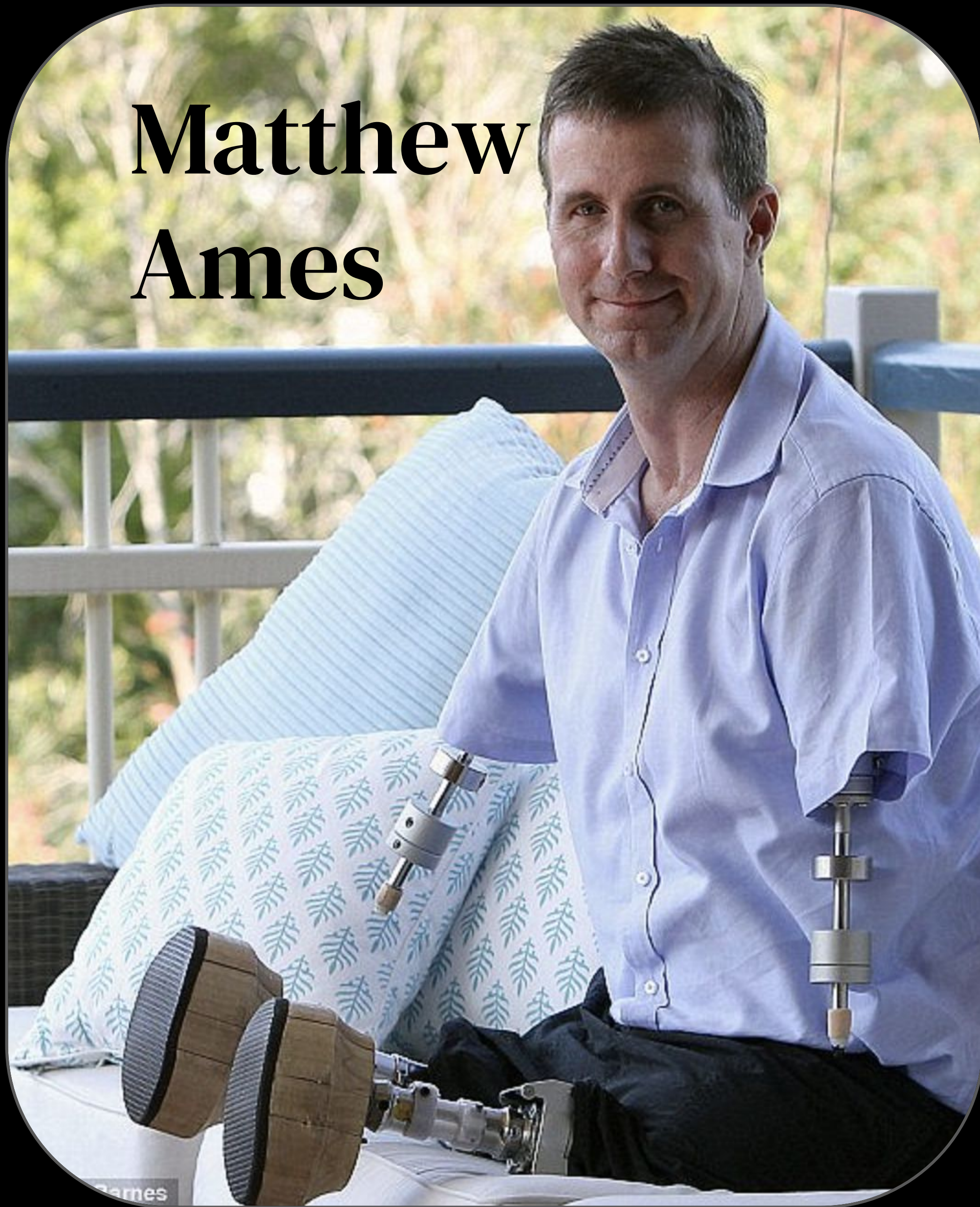




**Brain-body-machine interfaces:** “APL’s Modular Prosthetic Limb Reaches New Levels of Operability” (JHU Applied Physics Laboratory); <https://youtu.be/-0srXv0Qlu0>



# Matthew Ames



<https://www.dailymail.co.uk/news/article-3100224/It-happen-shouldn-t-Father-four-arms-legs-amputated-sore-throat-turned-life-threatening-virus-sue-doctors-treated-him.html>

<https://www.couriermail.com.au/lifestyle/qweekend/matthew-ames-opens-up-on-his-life-today-10-years-after-losing-his-limbs-to-sepsis/news-story/1309e86a50559c4f75f04606d204cd3f>





# Matthew Ames



<https://www.bionicsgamechangers.com/seven-years-on-the-journey-of-matthew-ames/>

<https://www.couriermail.com.au/lifestyle/qweekend/matthew-ames-opens-up-on-his-life-today-10-years-after-losing-his-limbs-to-sepsis/news-story/1309e86a50559c4f75f04606d204cd3f>

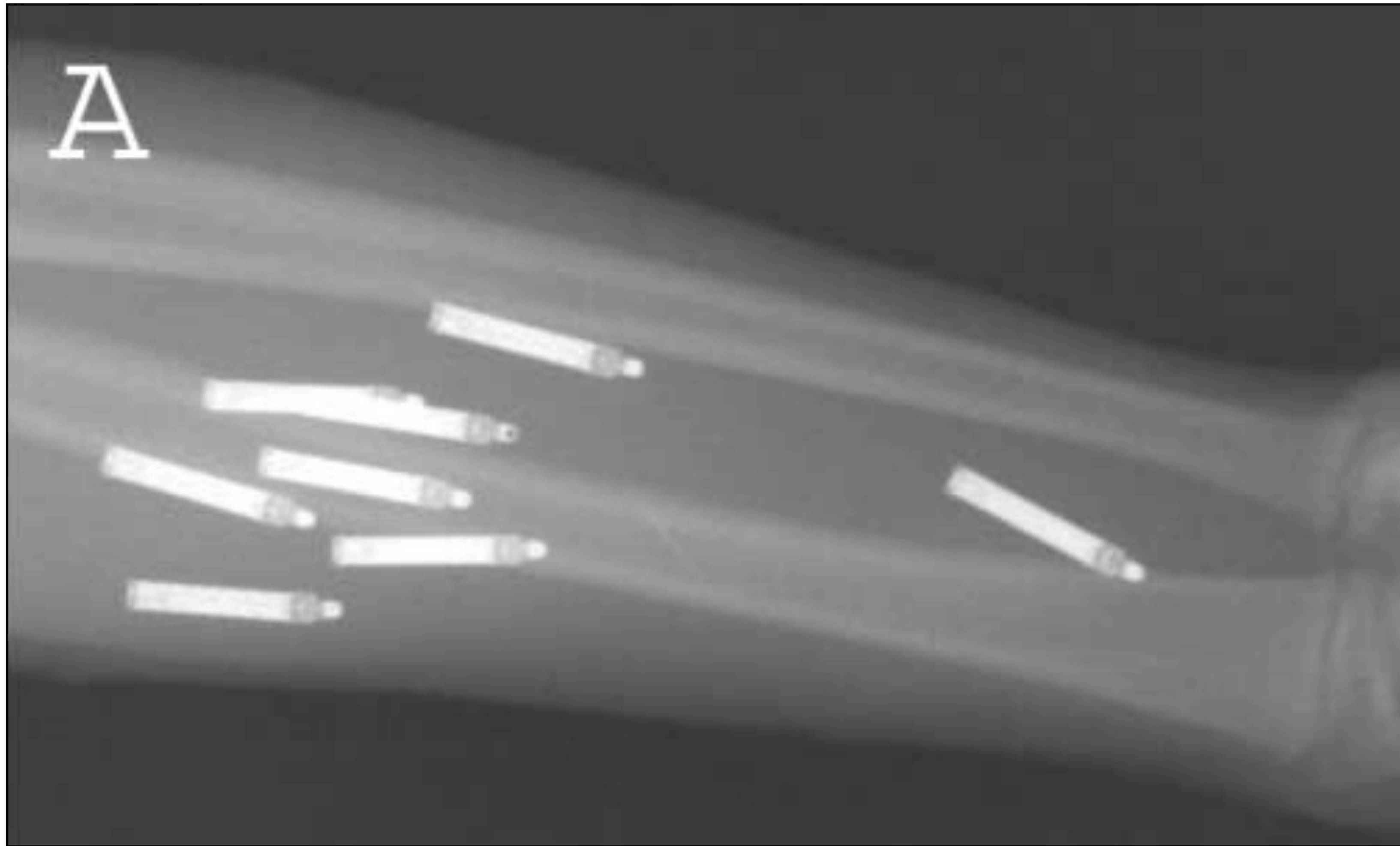






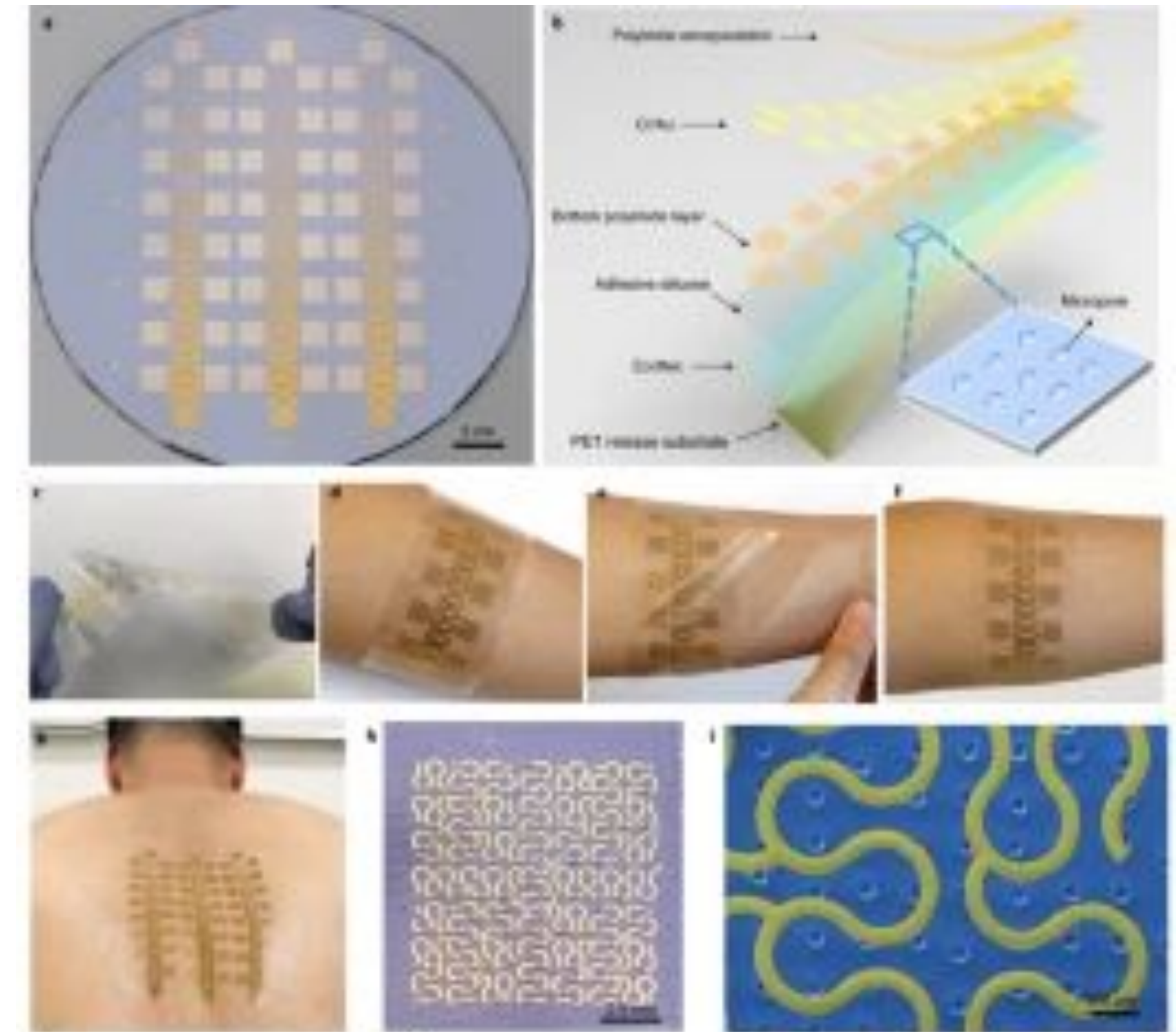
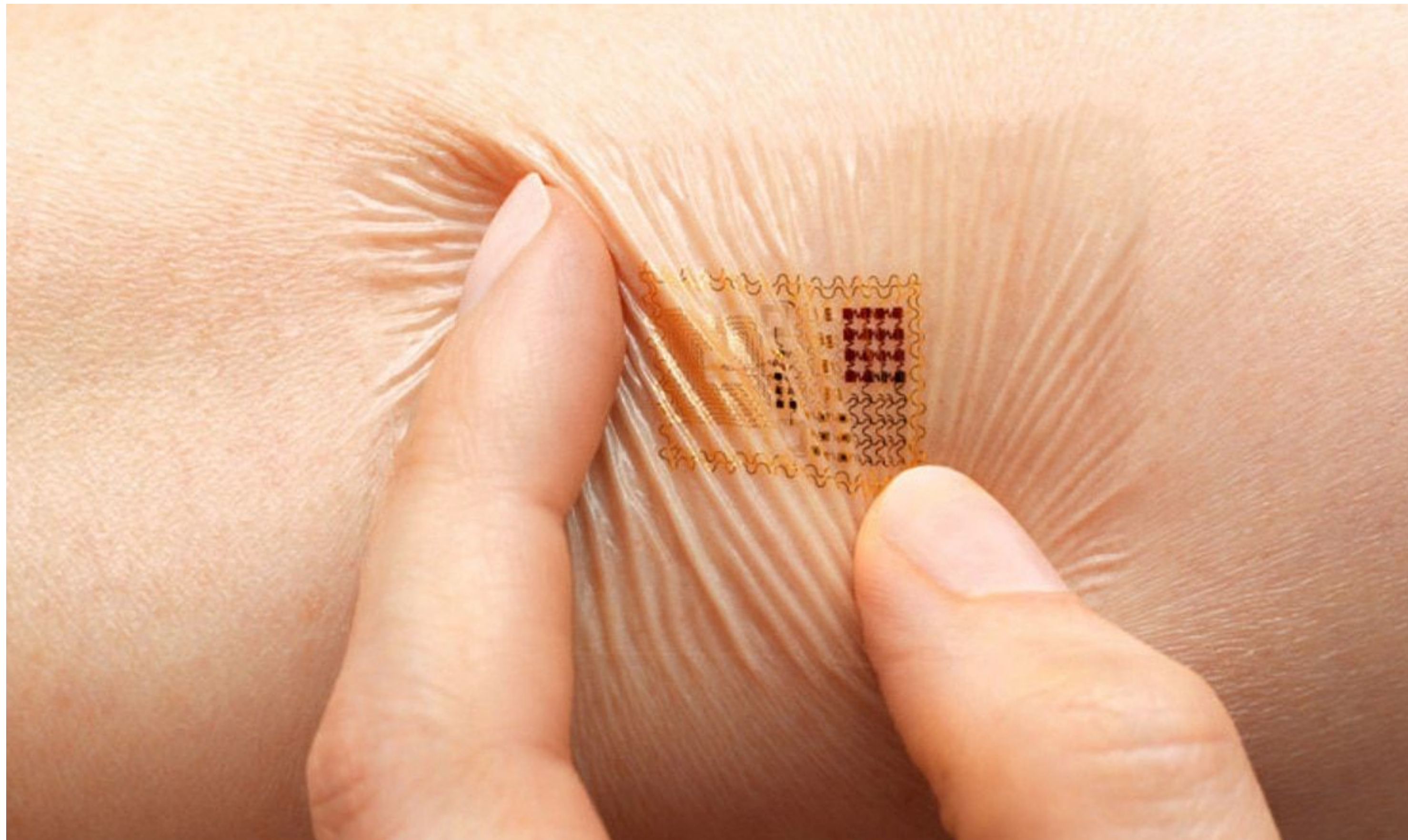
**Biotechnology has also  
gone low-profile and wireless!**





**Brain-body-machine interfaces:** Baker et al., "Continuous Detection and Decoding of Dexterous Finger Flexions With Implantable MyoElectric Sensors," *IEEE TNSRE* 18(4):424-32, 2010.





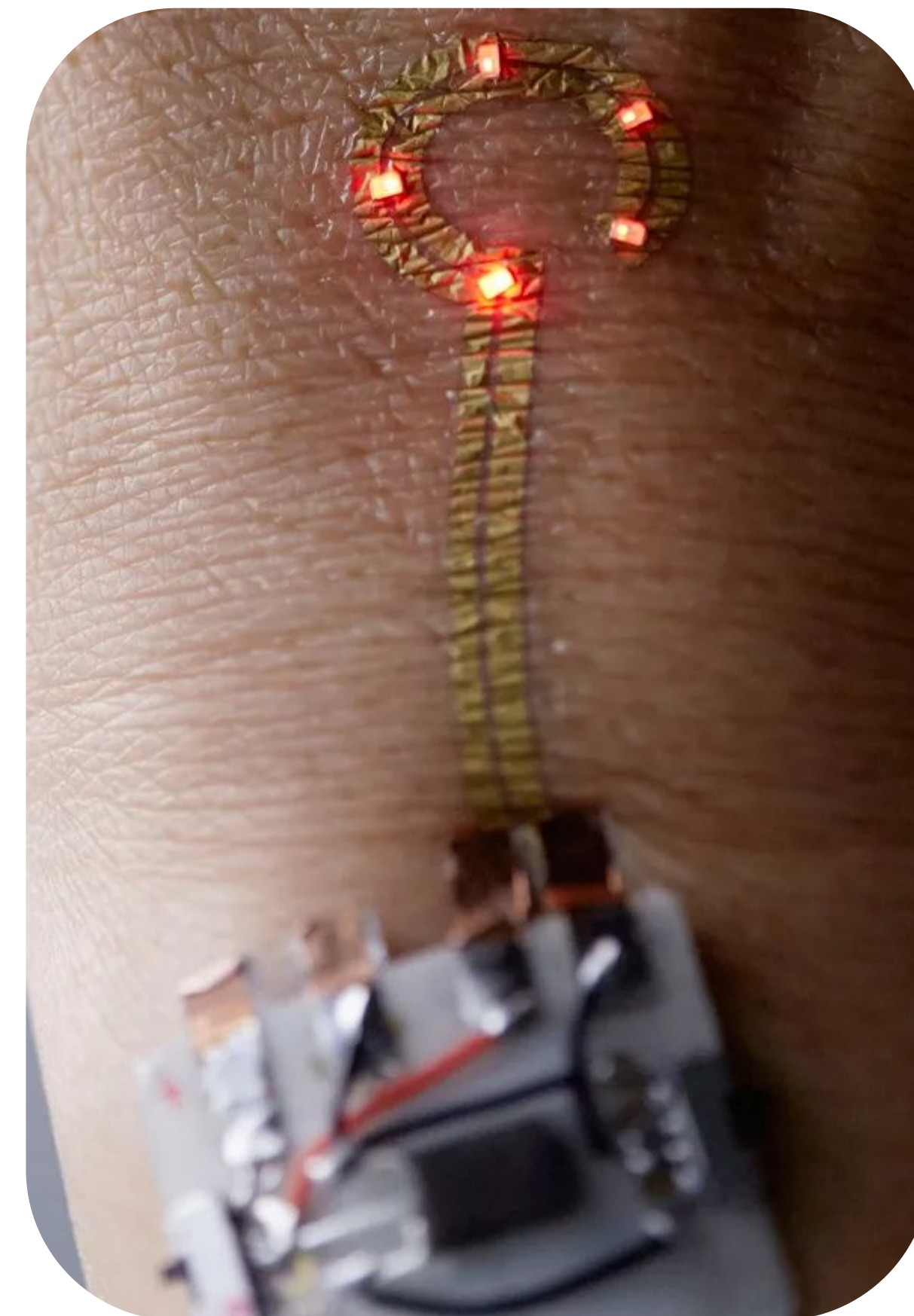
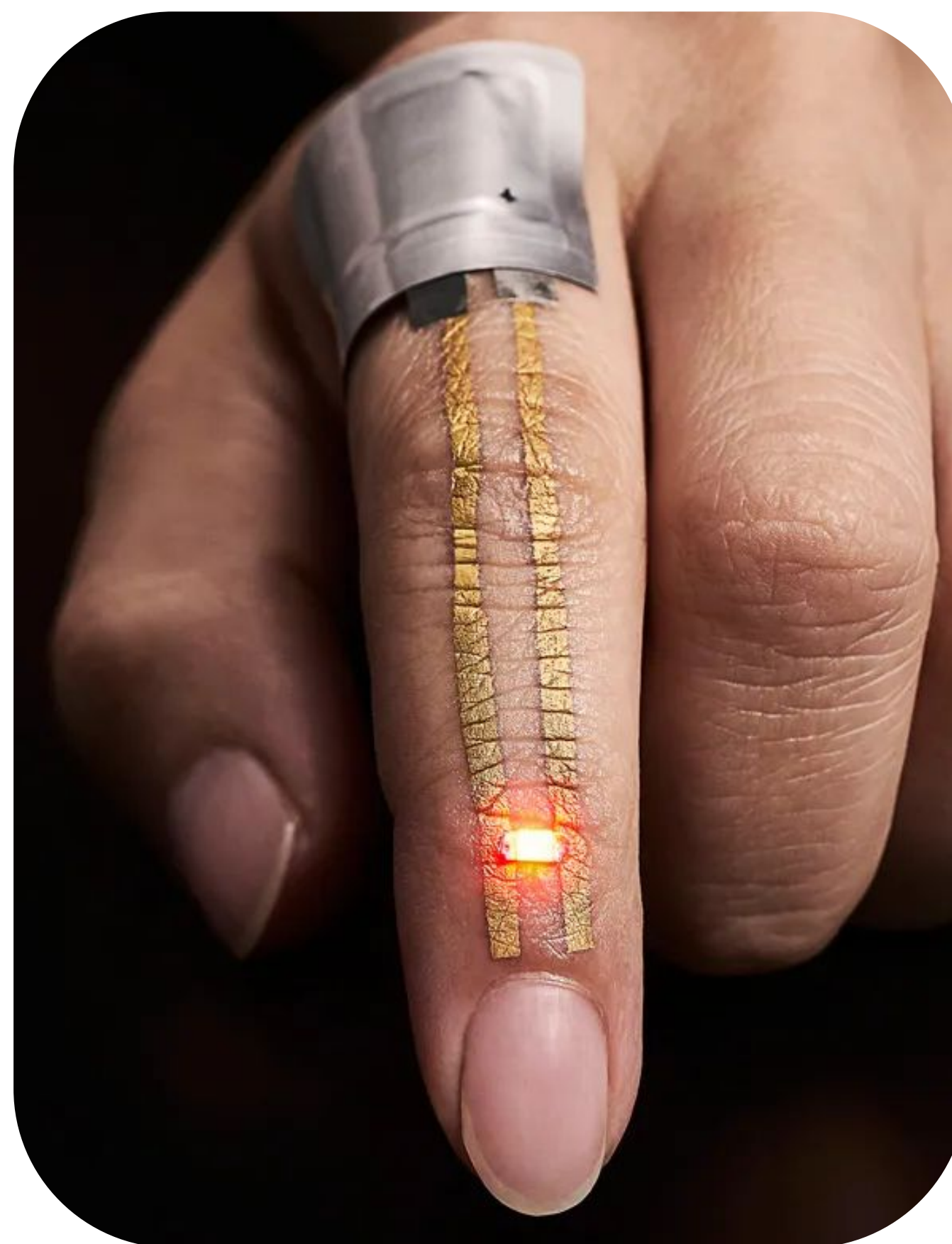
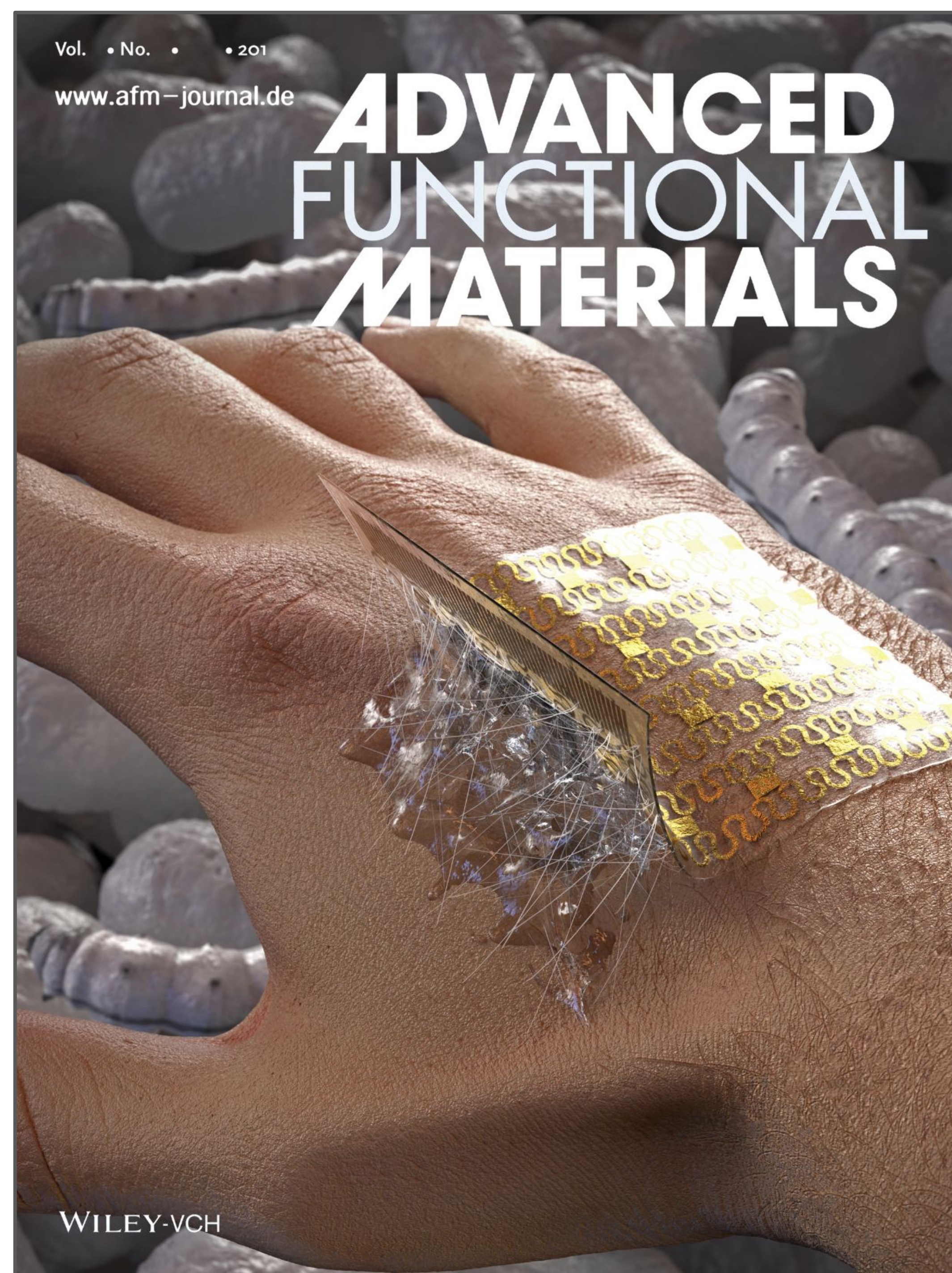
Tian, L., Zimmerman, B., Akhtar, A. et al. **Large-area MRI-compatible epidermal electronic interfaces for prosthetic control and cognitive monitoring.** Nat Biomed Eng 3, 194–205 (2019).

<https://doi-org.login.ezproxy.library.ualberta.ca/10.1038/s41551-019-0347-x>

**Epidermal Electronics** (2011) Dae-Hyeong Kim, Nanshu Lu, Rui Ma, Yun-Soung Kim, Rak-Hwan Kim, Shuodao Wang, Jian Wu, Sang Min Won, Hu Tao, Ahmad Islam, Ki Jun Yu, Tae-il Kim, Raed Chowdhury, Ming Ying, Lizhi Xu, Ming Li, Hyun-Joong Chung, Hohyun Keum, Martin McCormick, Ping Liu, Yong-Wei Zhang, Fiorenzo G. Omenetto, Yonggang Huang, Todd Coleman, and John A. Rogers Science, 333 (6044), • DOI: 10.1126/science.1206157



# ADVANCED FUNCTIONAL MATERIALS



<https://spectrum.ieee.org/skin-displays-will-give-wearables-their-independence>

<https://doi.org/10.1002/adfm.201870250>





**Meanwhile, at the  
University of Tokyo ...**

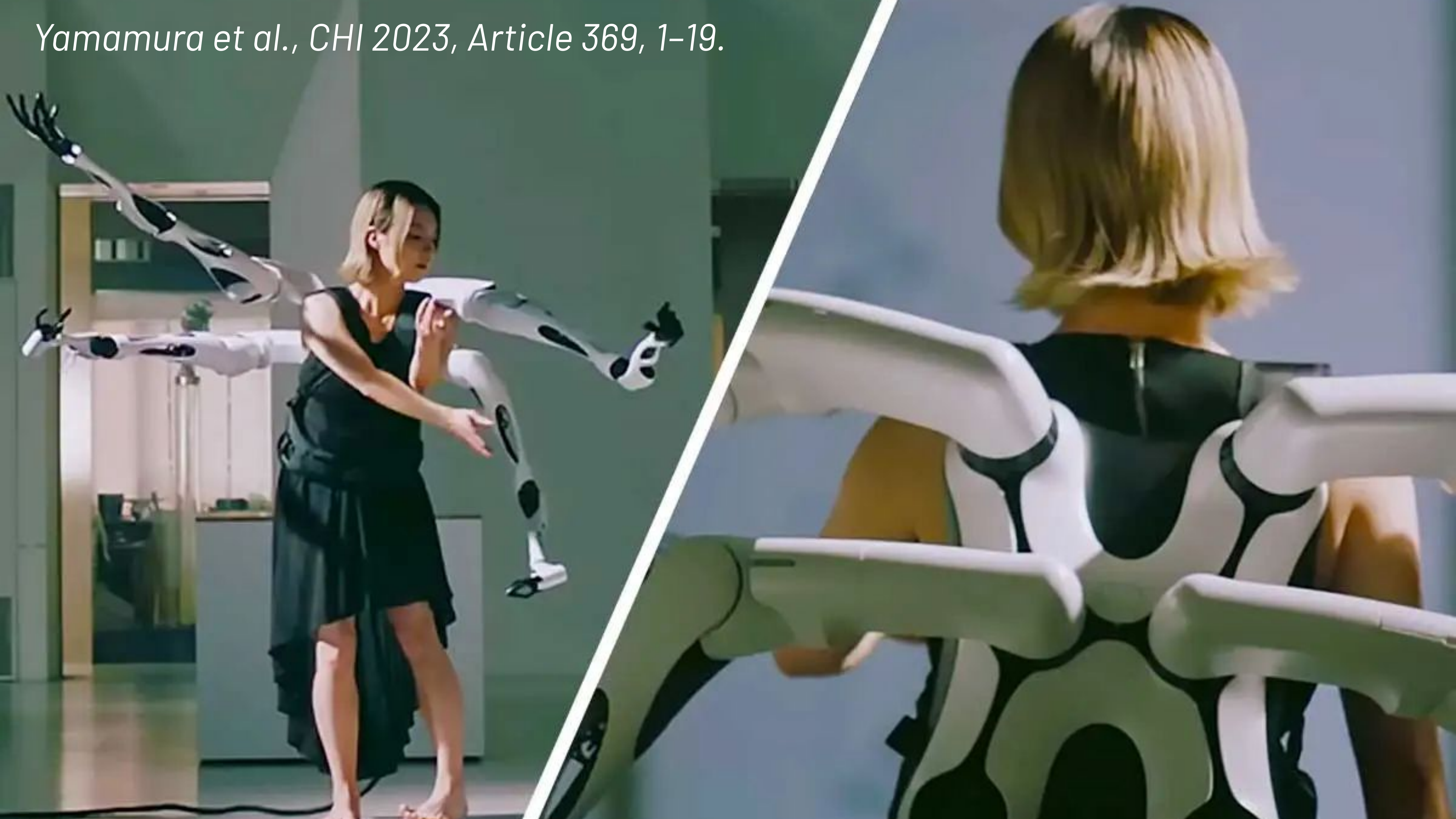




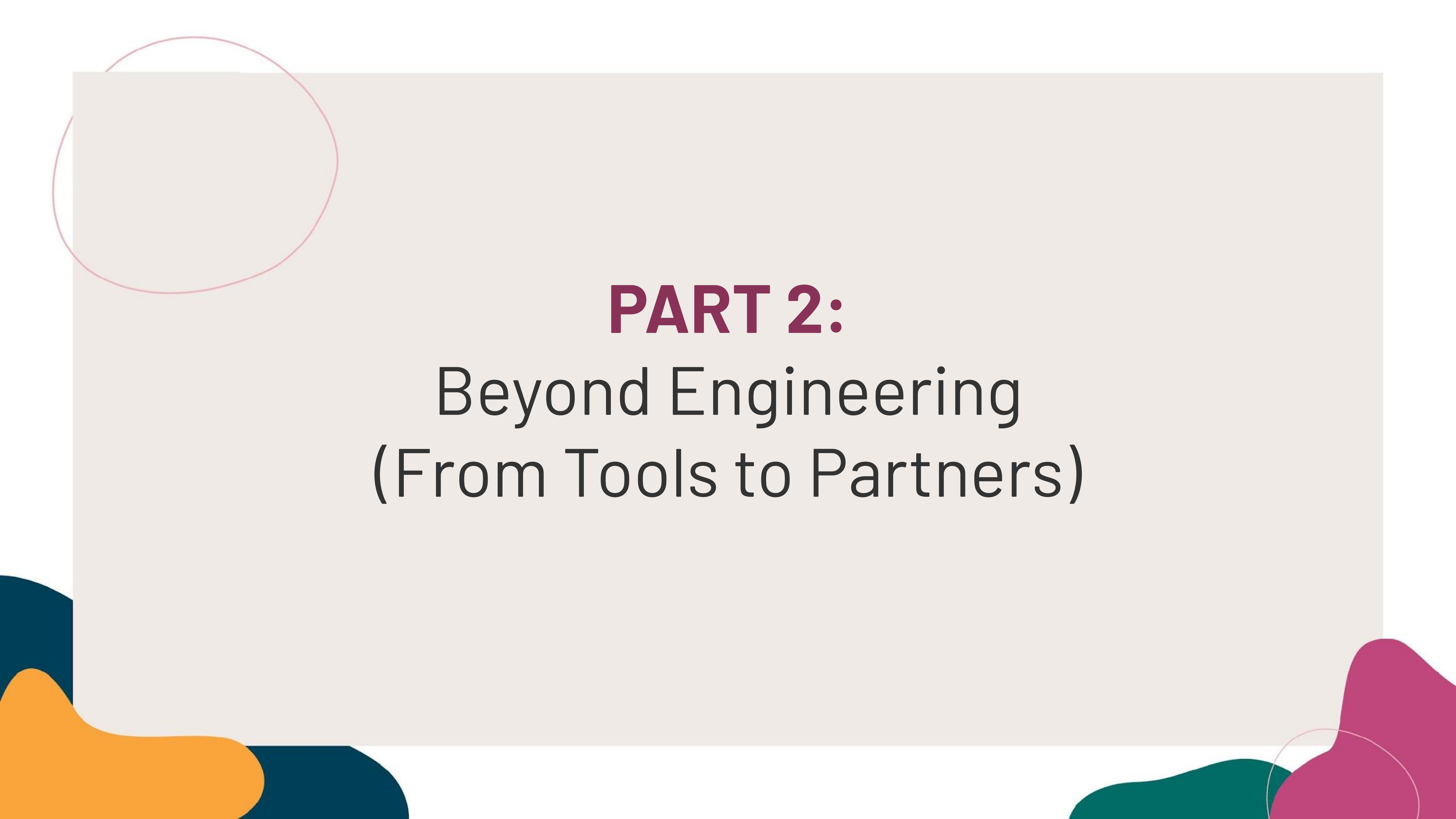
自在肢

JIZAI ARMS





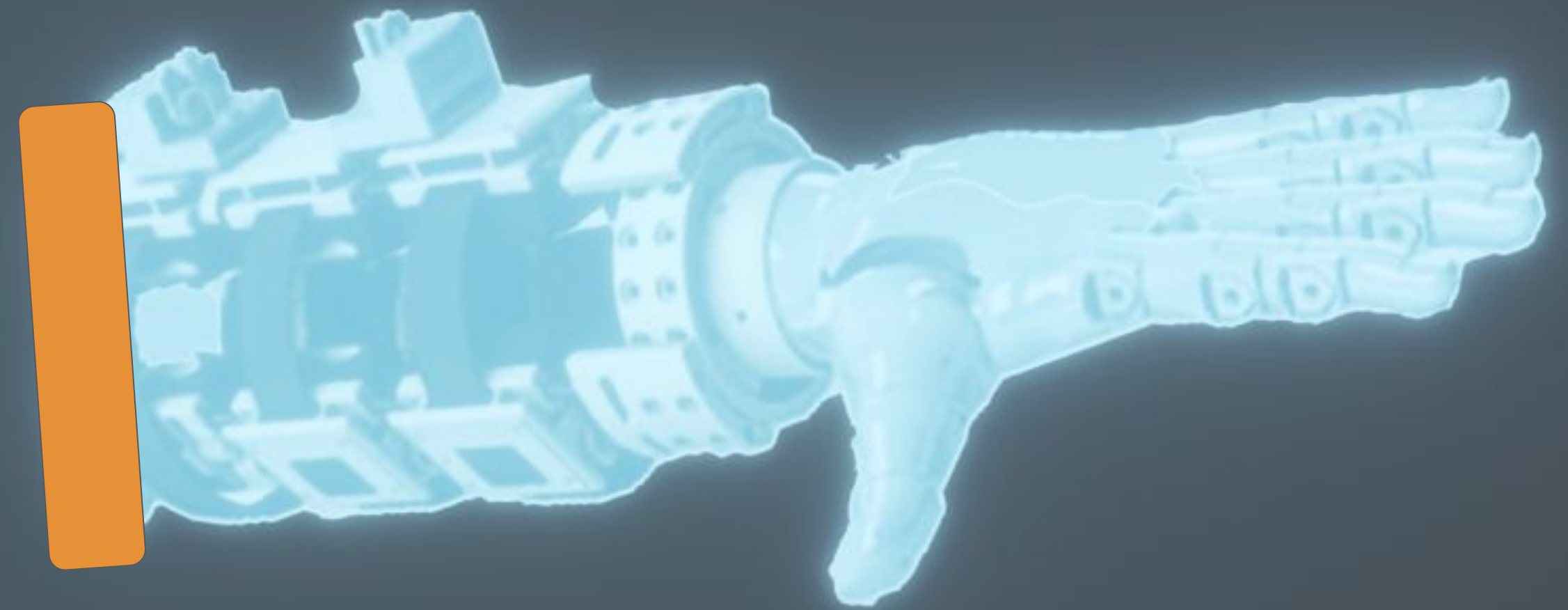
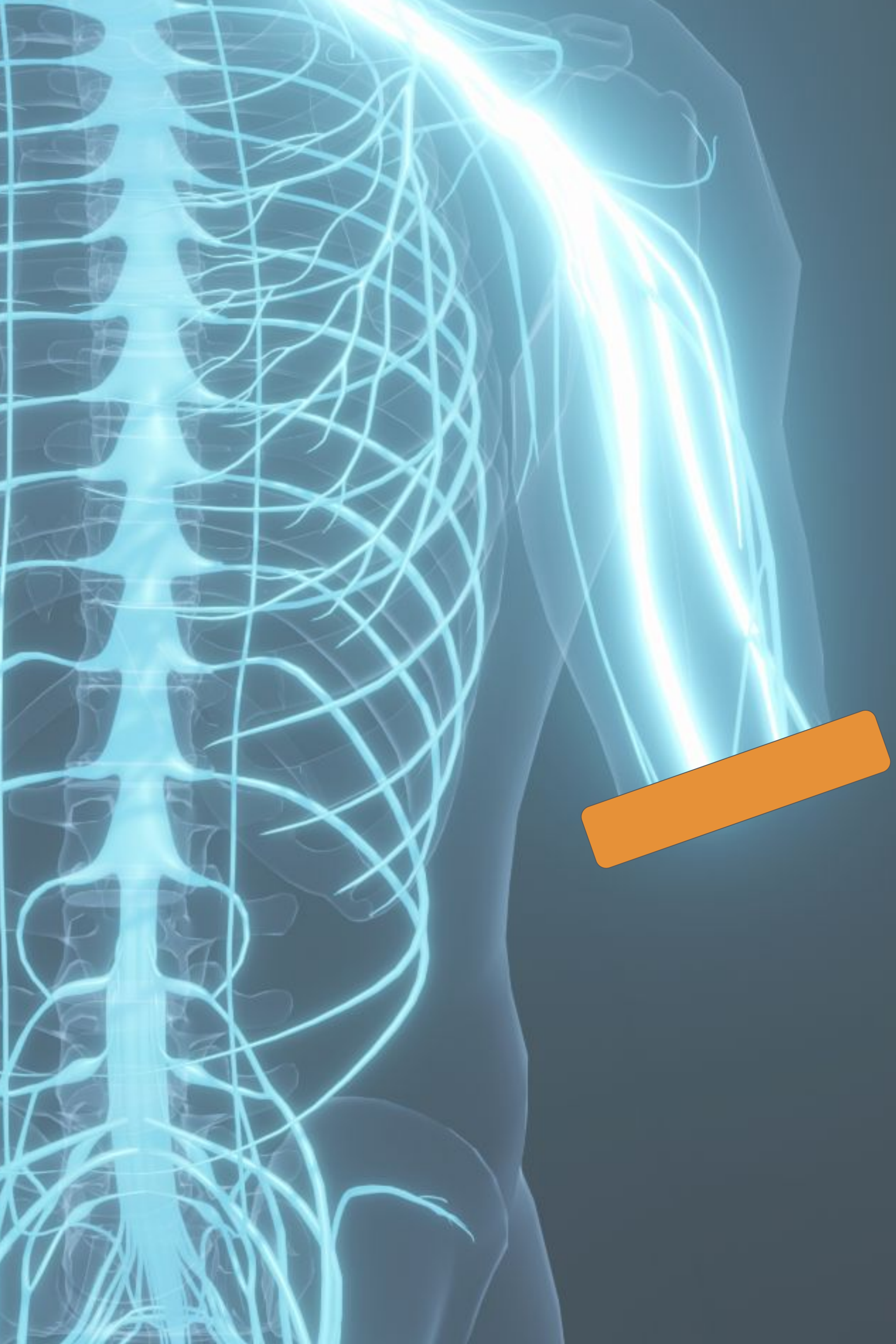




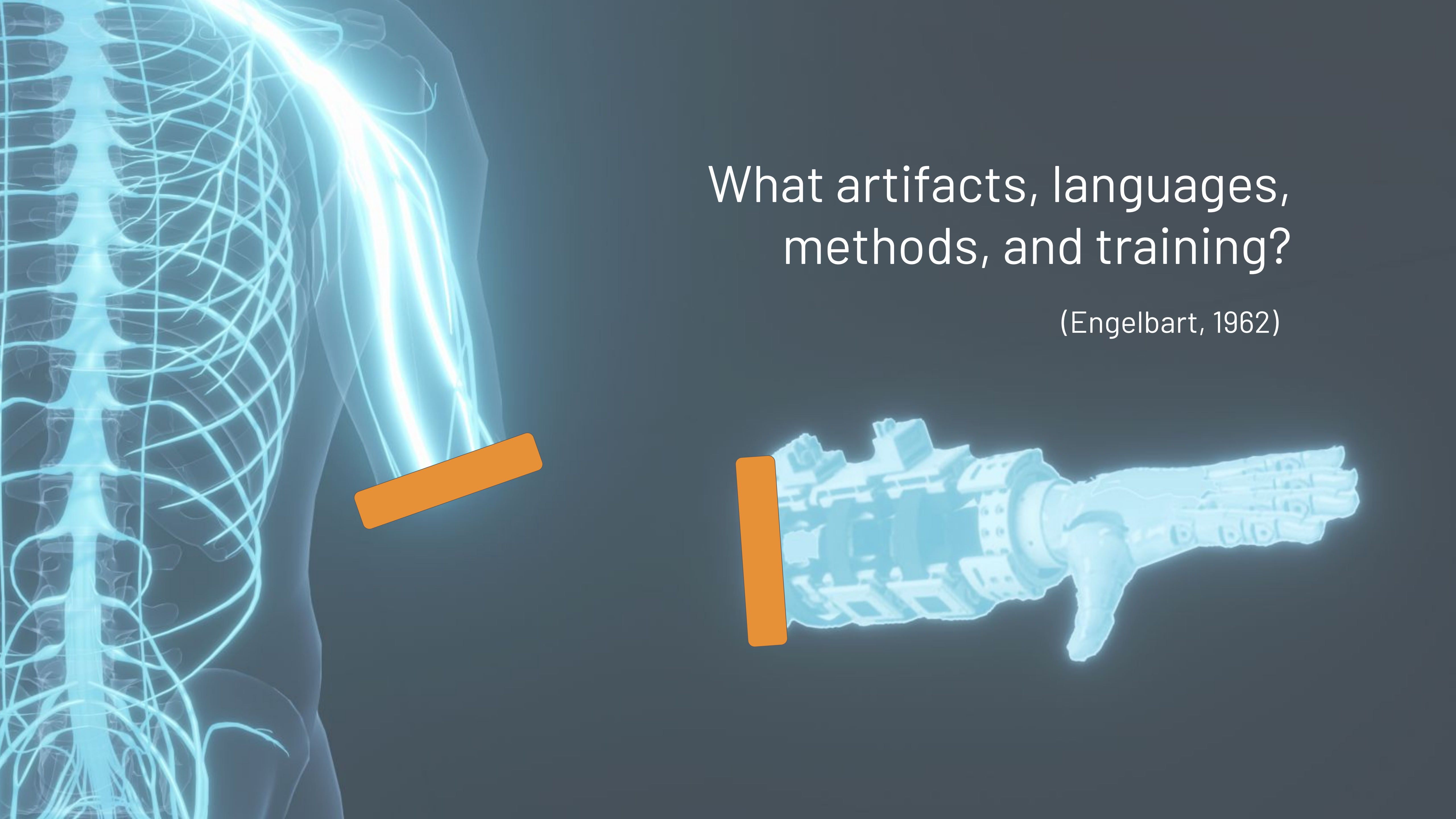
**PART 2:**  
Beyond Engineering  
(From Tools to Partners)



What are the things that connect  
the person and the machine?





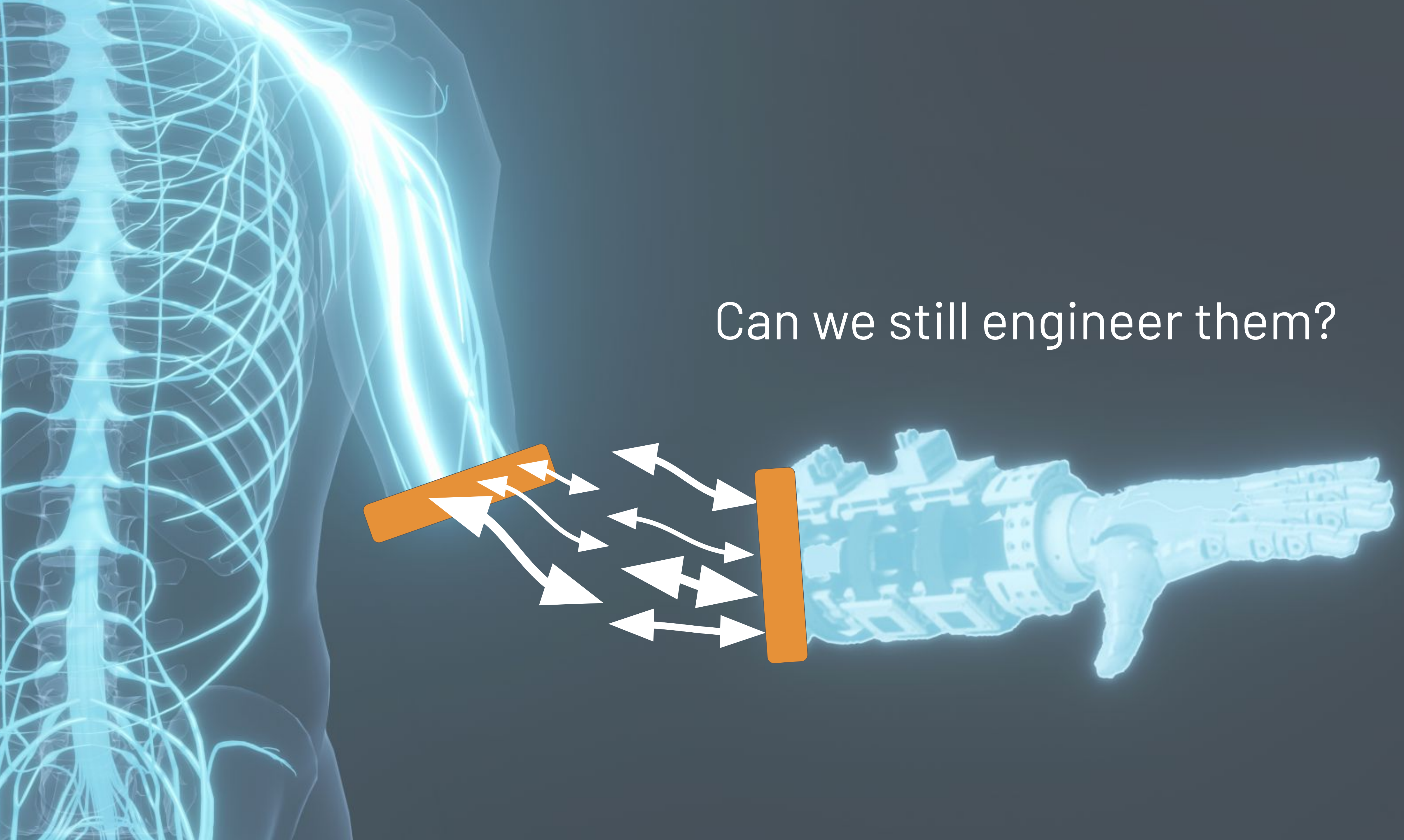


What artifacts, languages,  
methods, and training?

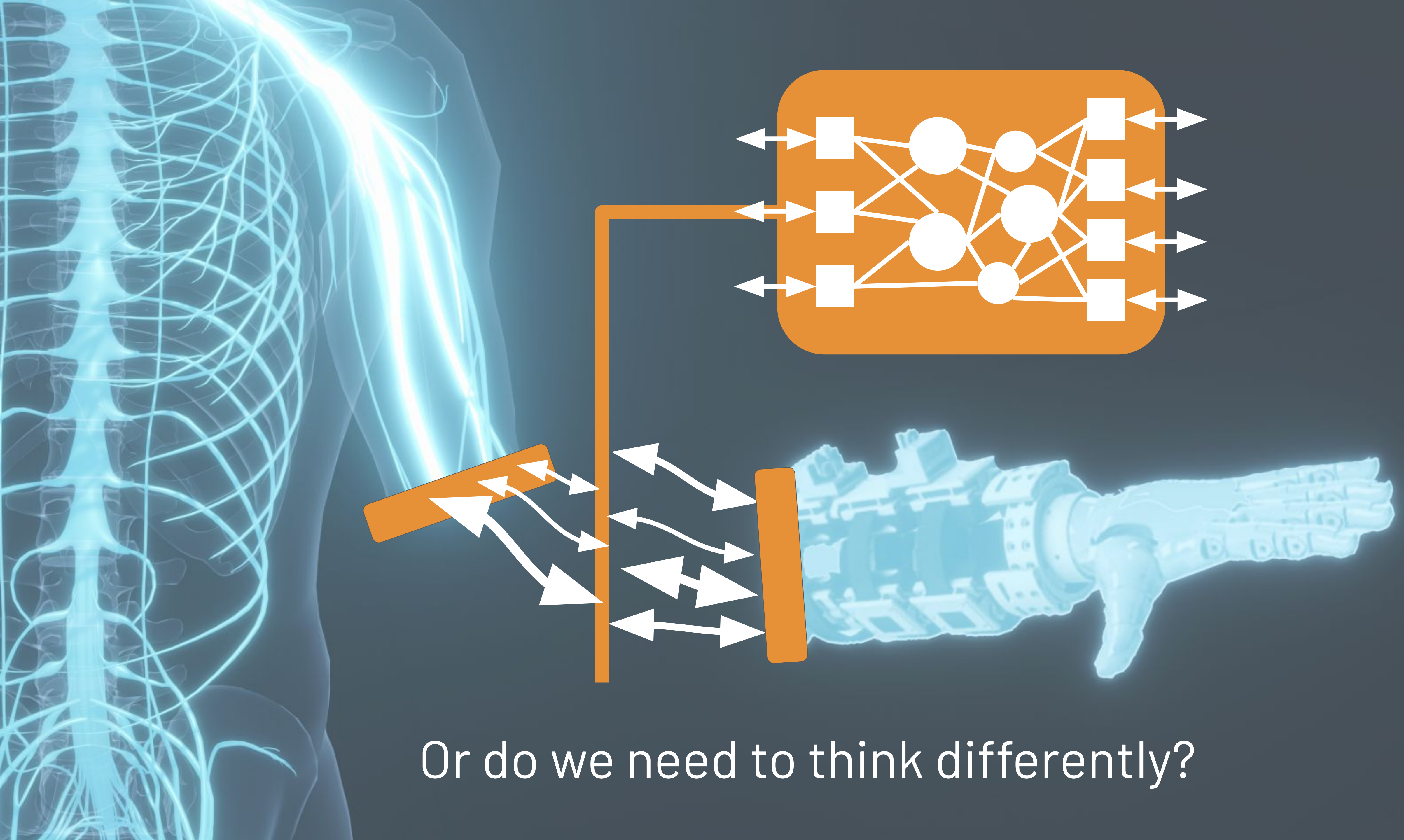
(Engelbart, 1962)



Can we still engineer them?

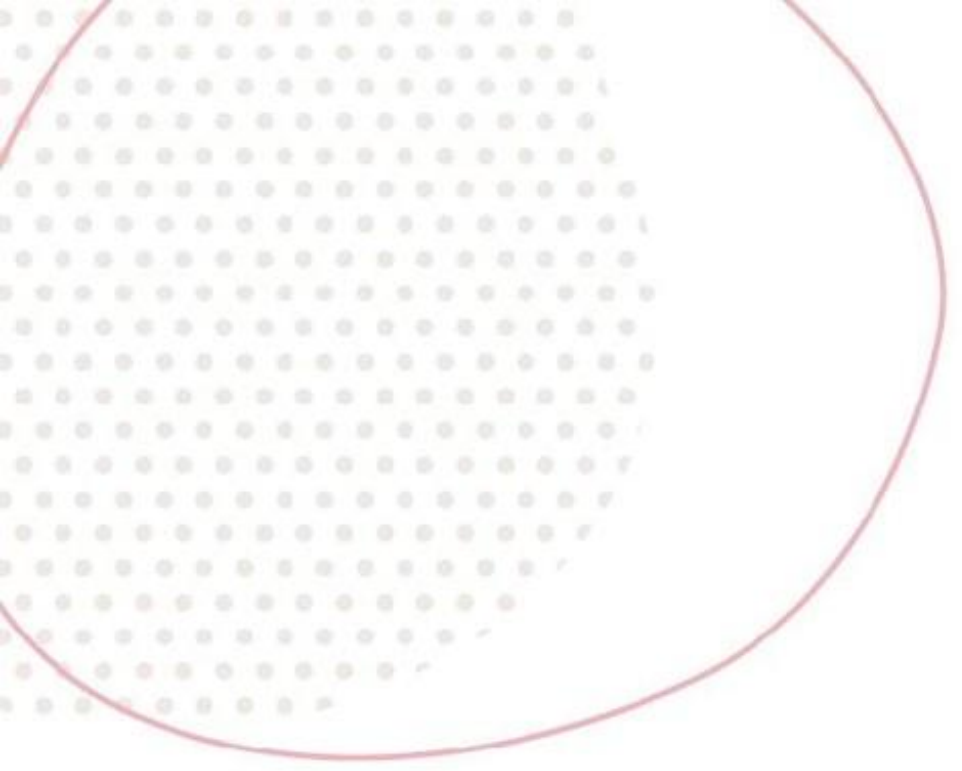




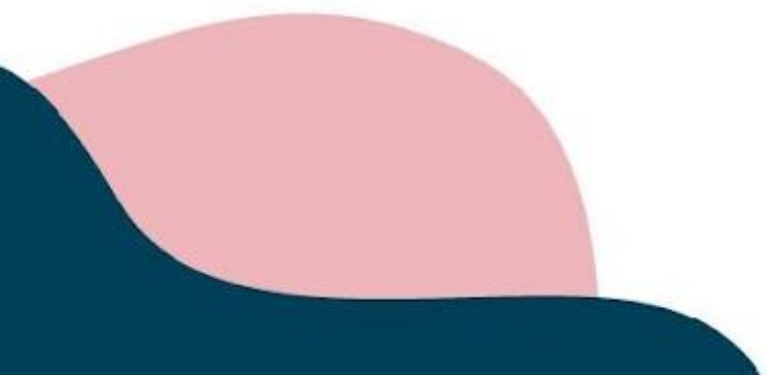


Or do we need to think differently?

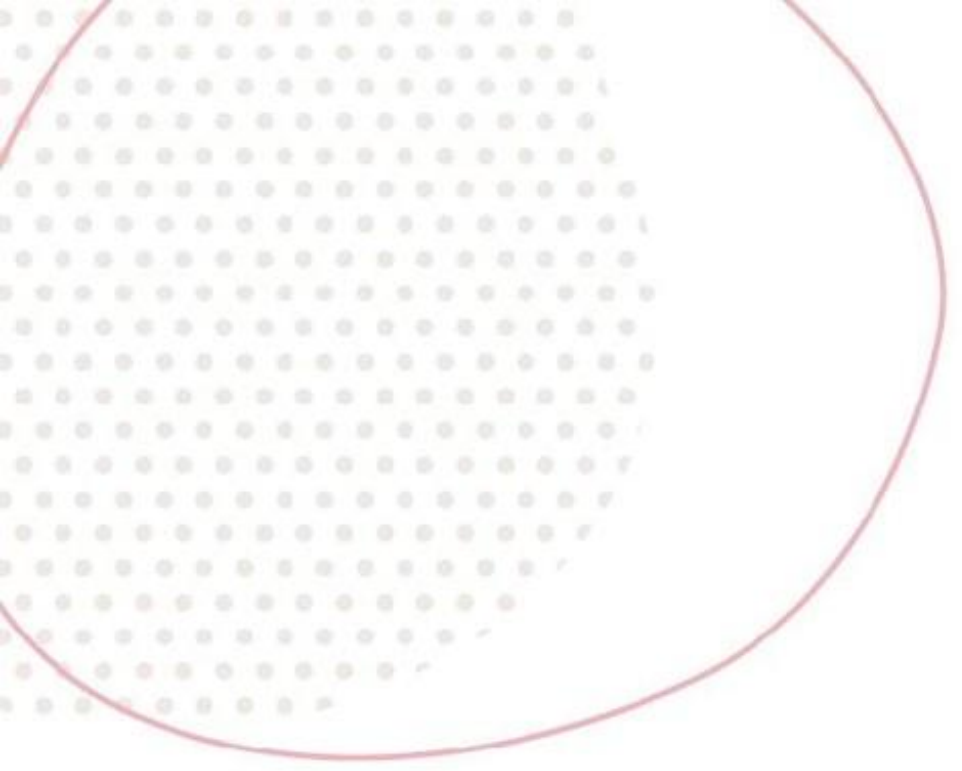




# View 1

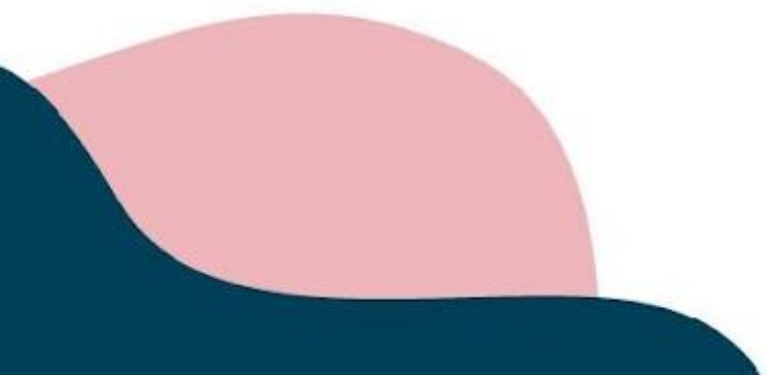




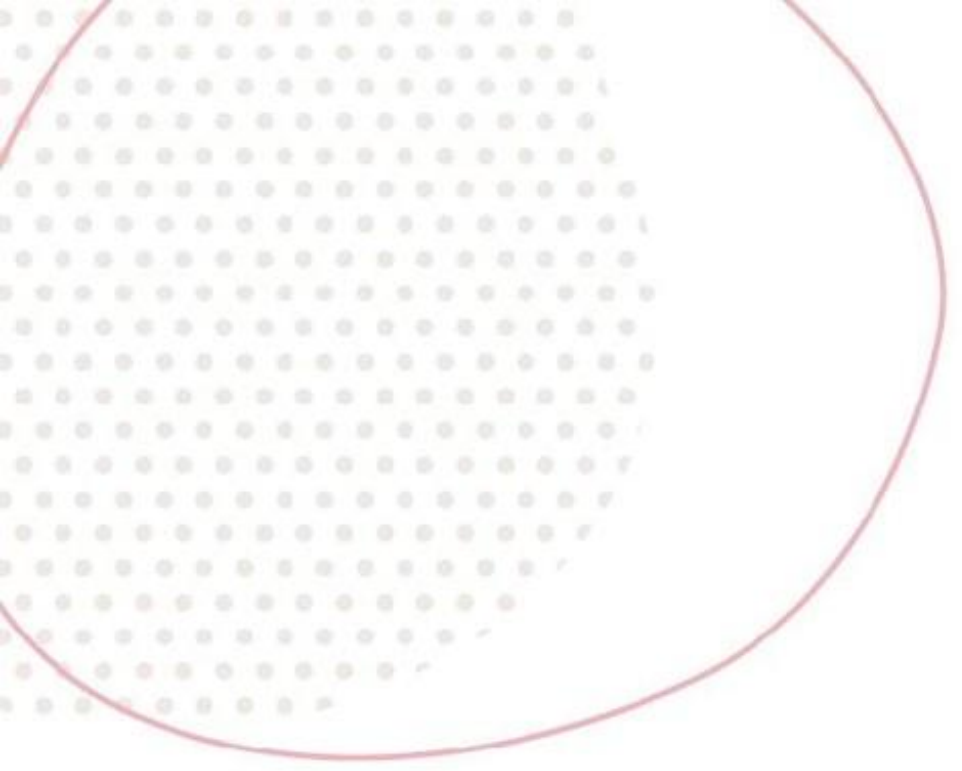


# **View 1**

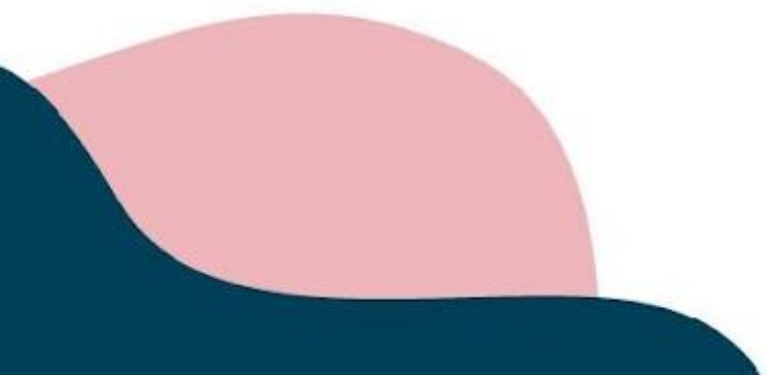
## Dolphin Training



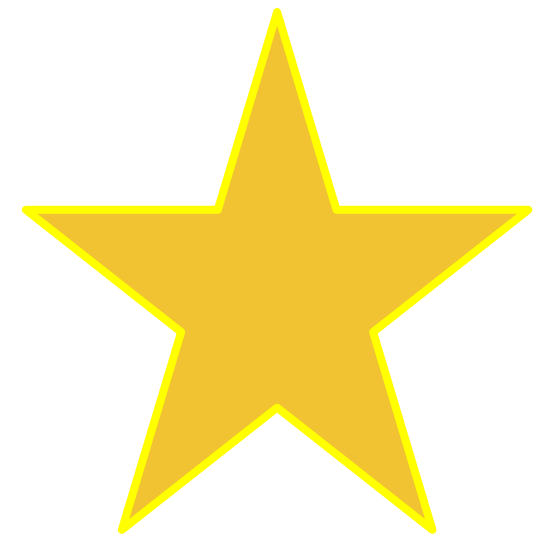
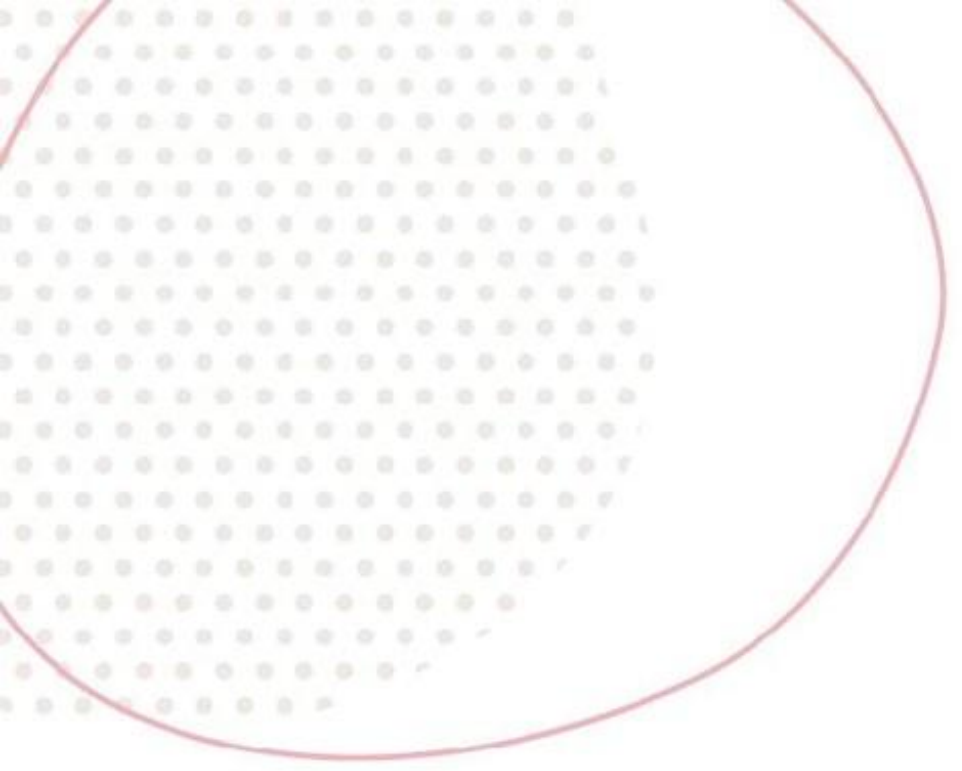




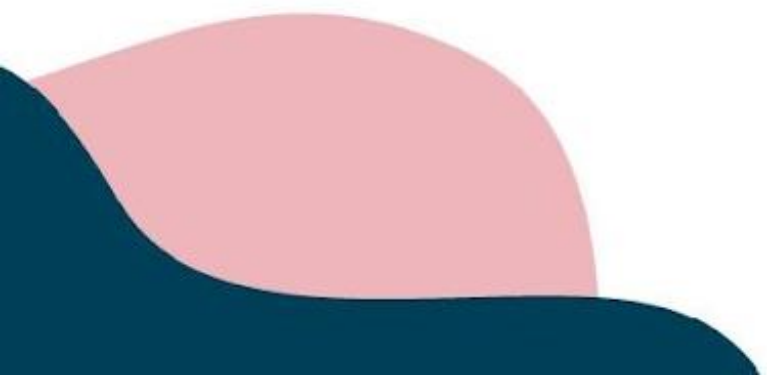
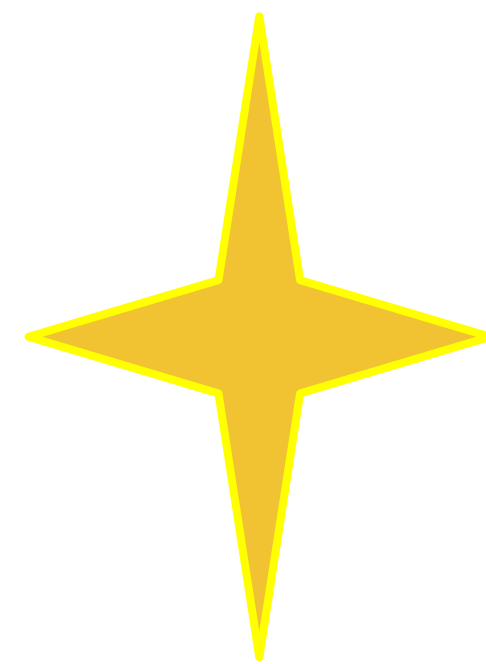
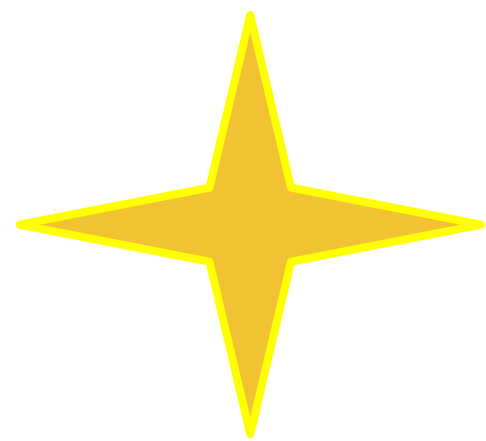
**View 1**  
Dolphin Training  
Wait, what?



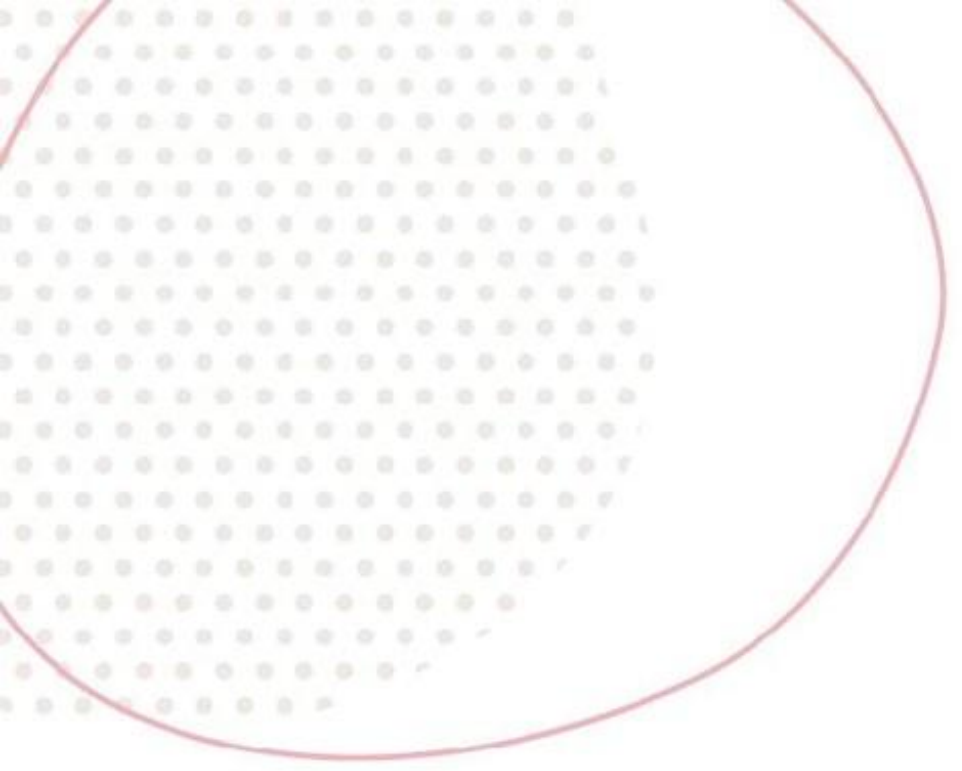




audience  
participation  
time!

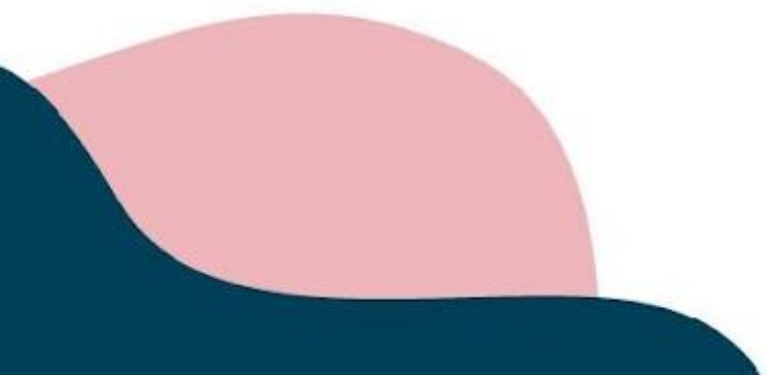




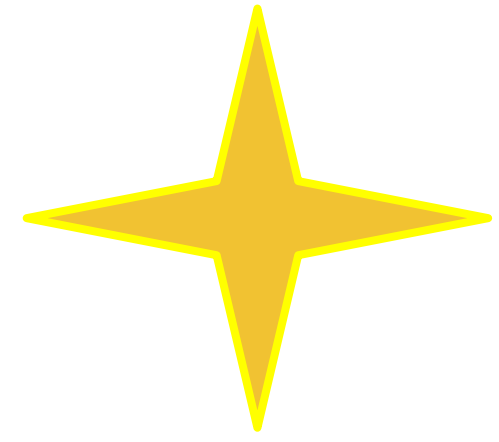
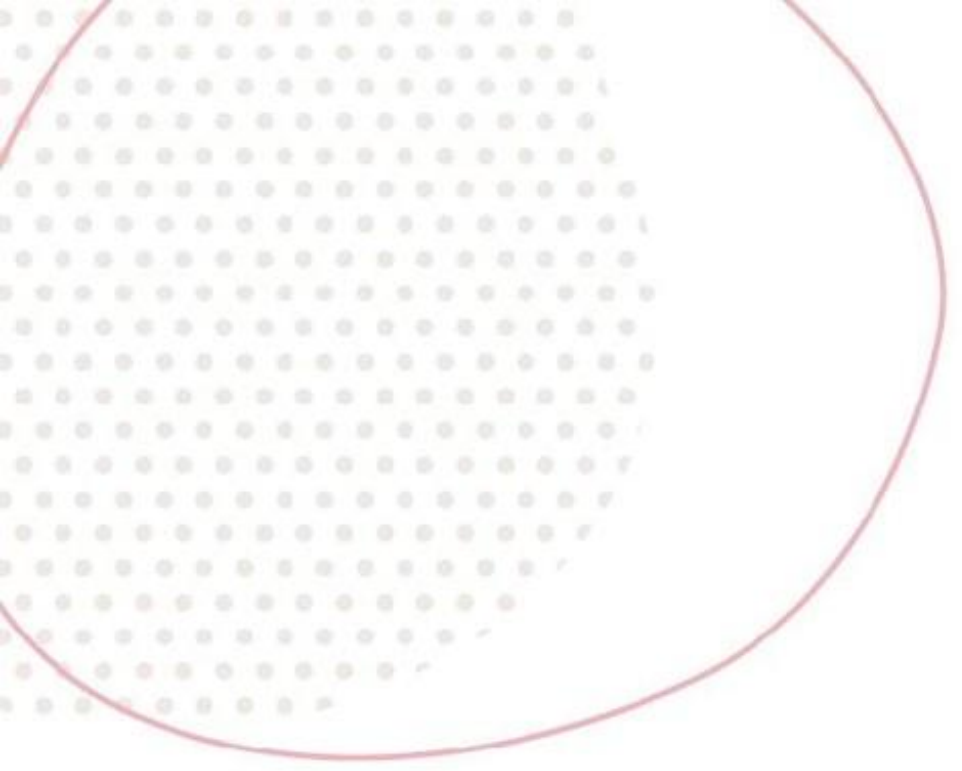


# View 2

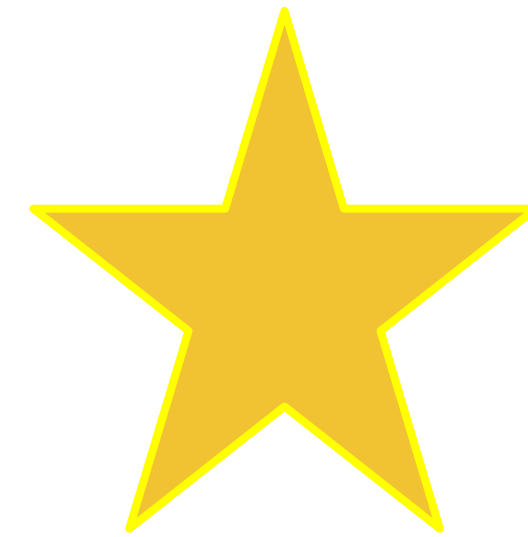
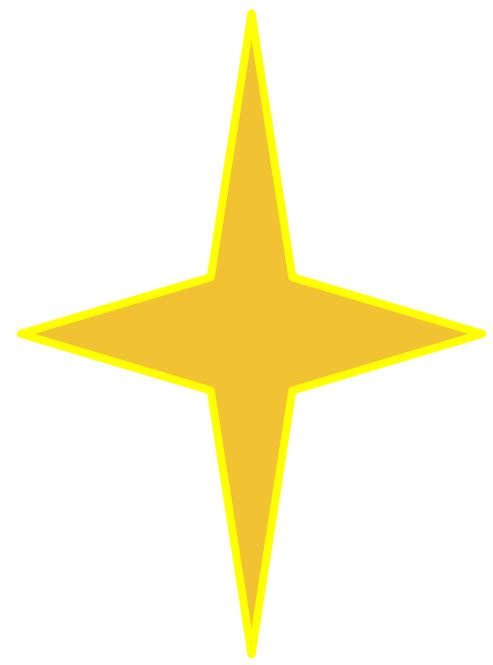
## Wrystlebot



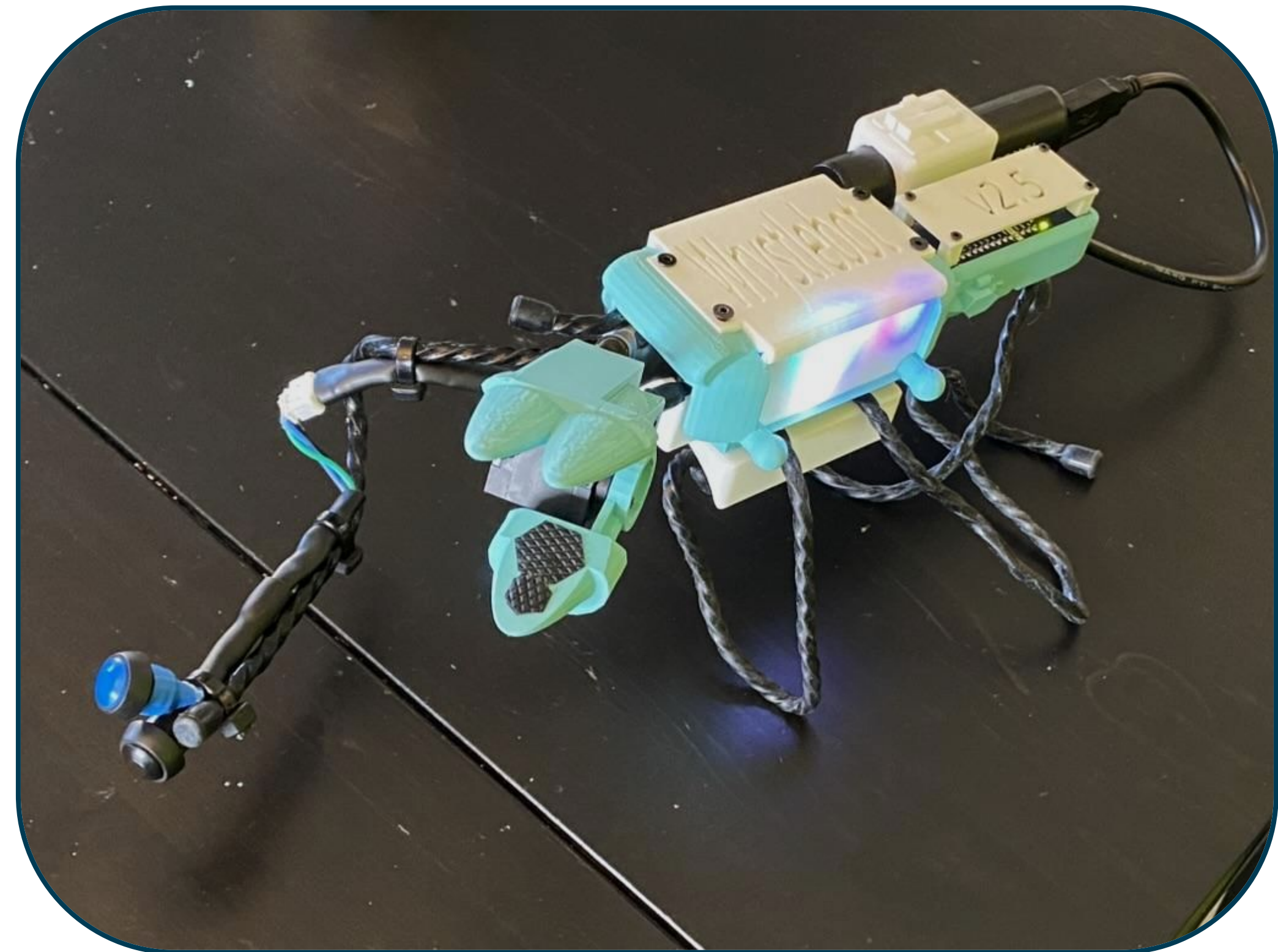
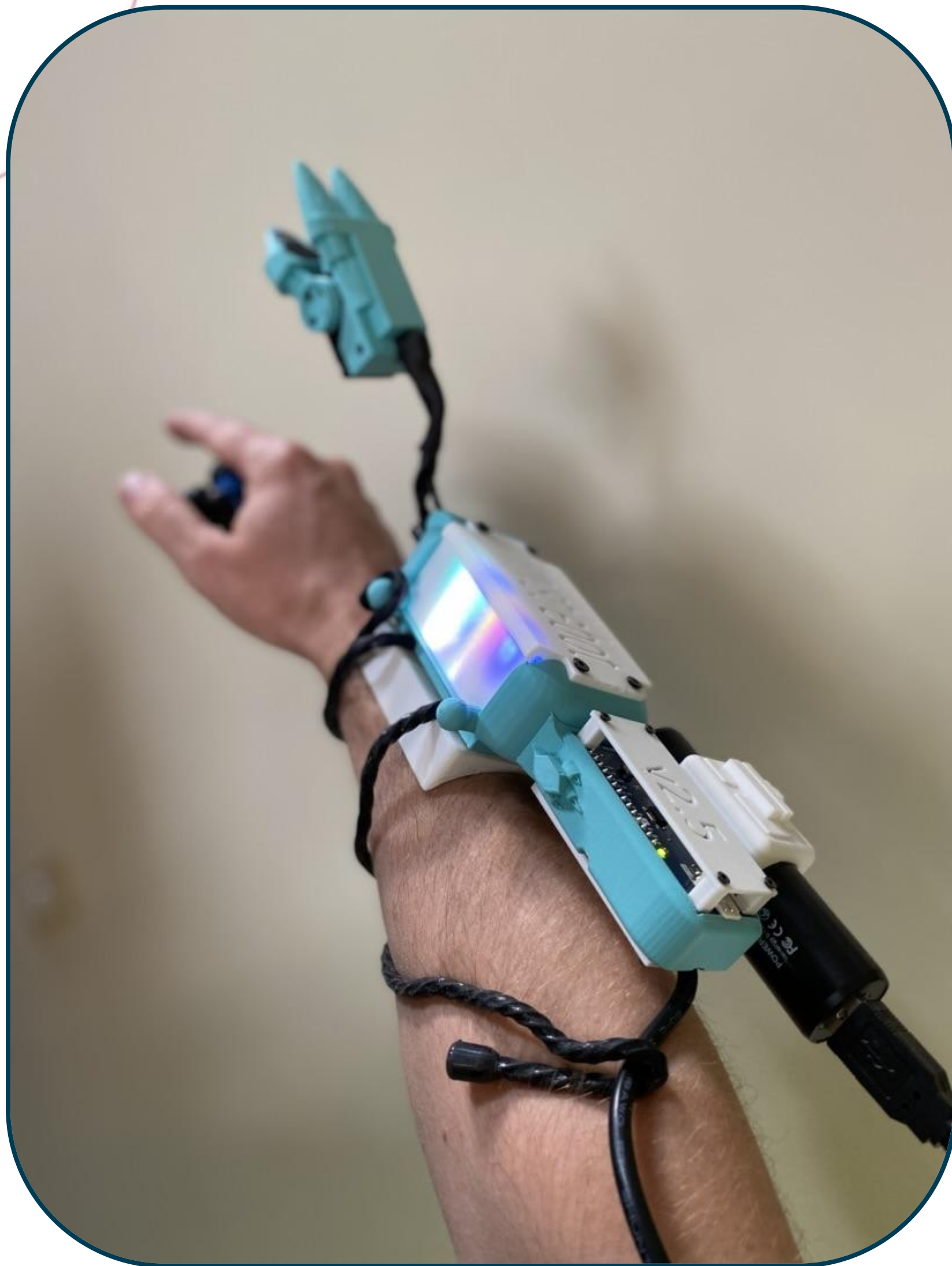




*live  
demo  
time!*







## **Wrystlebot v2.5**

P. Pilarski & R. Pilarski






**Instead of engineering ... training?**





## **PART 3:**

# Progress on the Home Front (University of Alberta)







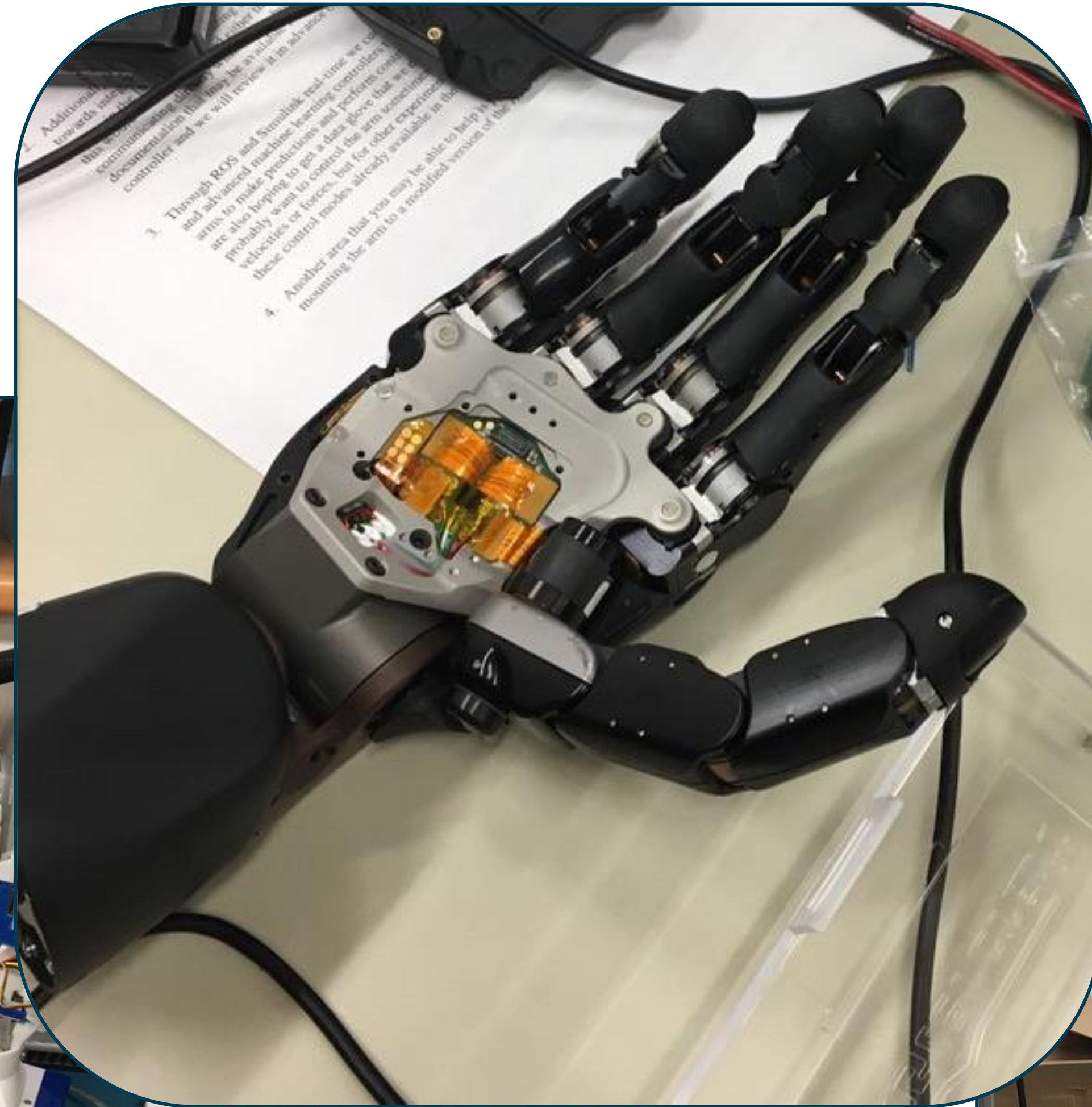
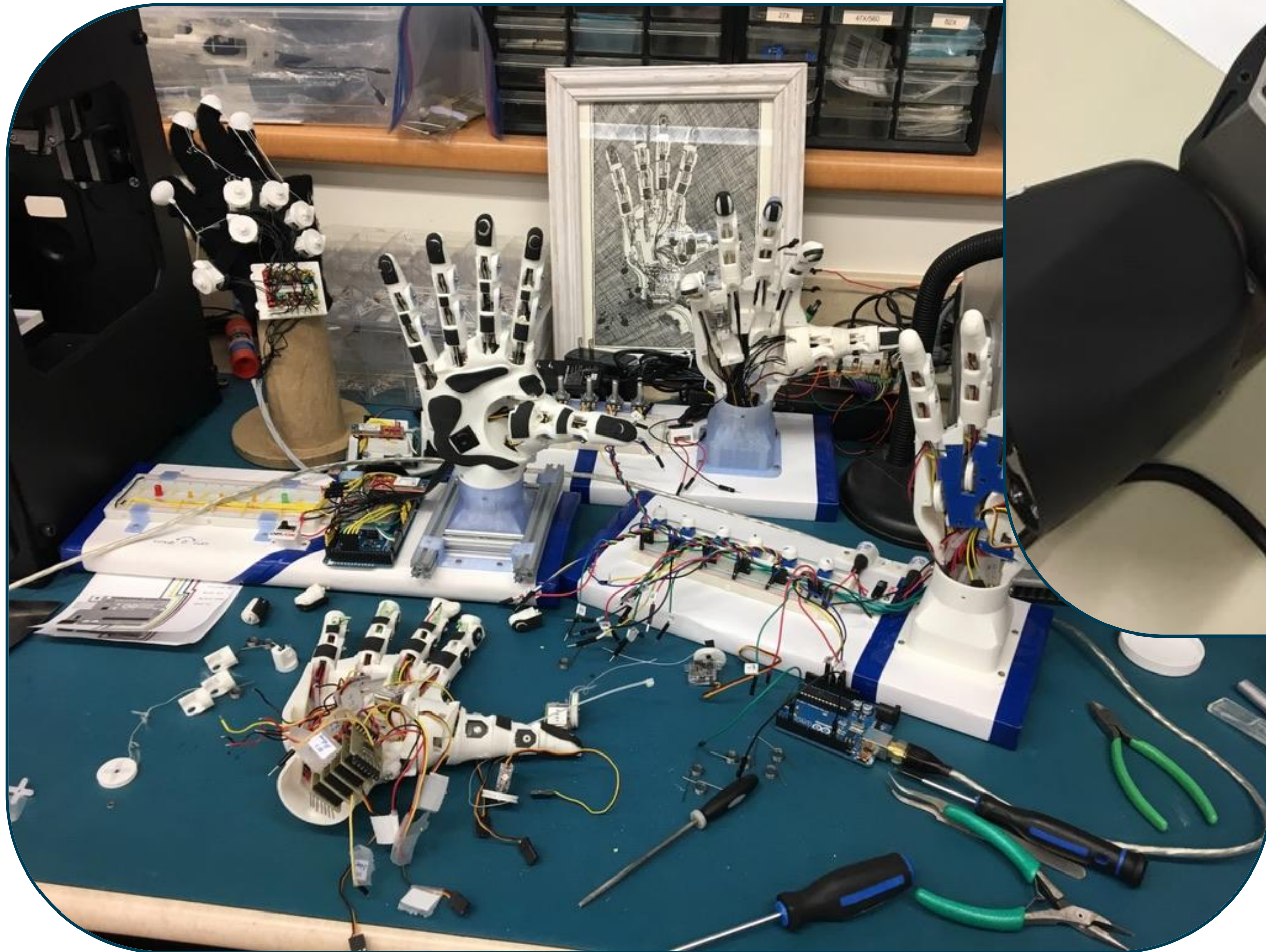
# BLINC



# SMART NETWORK

Sensory  
Motor  
Adaptive  
Rehabilitation  
Technology













## **The Bento Arm and the HANDi Hand**

<http://blincdev.ca>



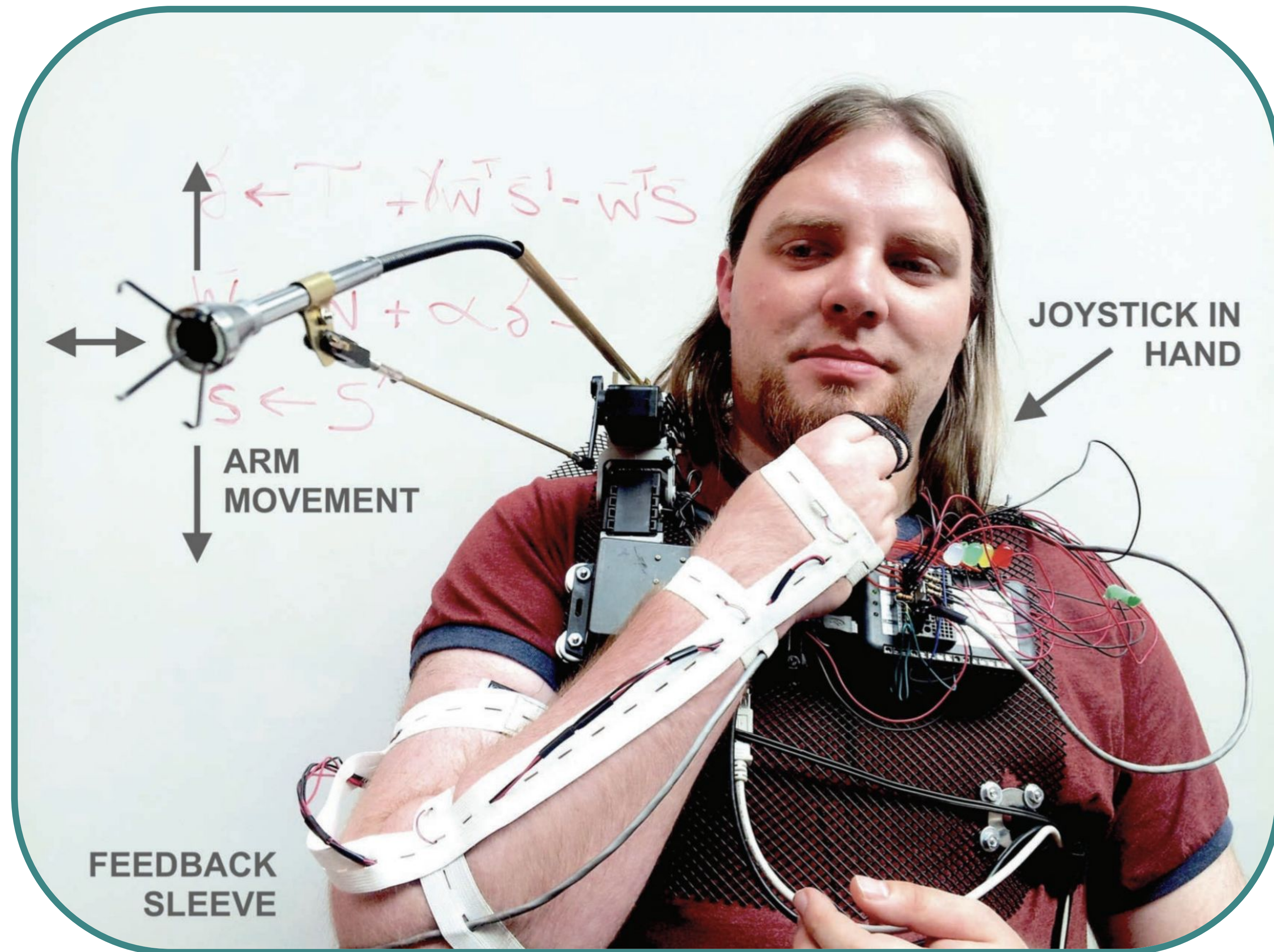


To quote *Dr. Horrible's Sing-Along Blog*:  
"We [also] do the weird stuff"

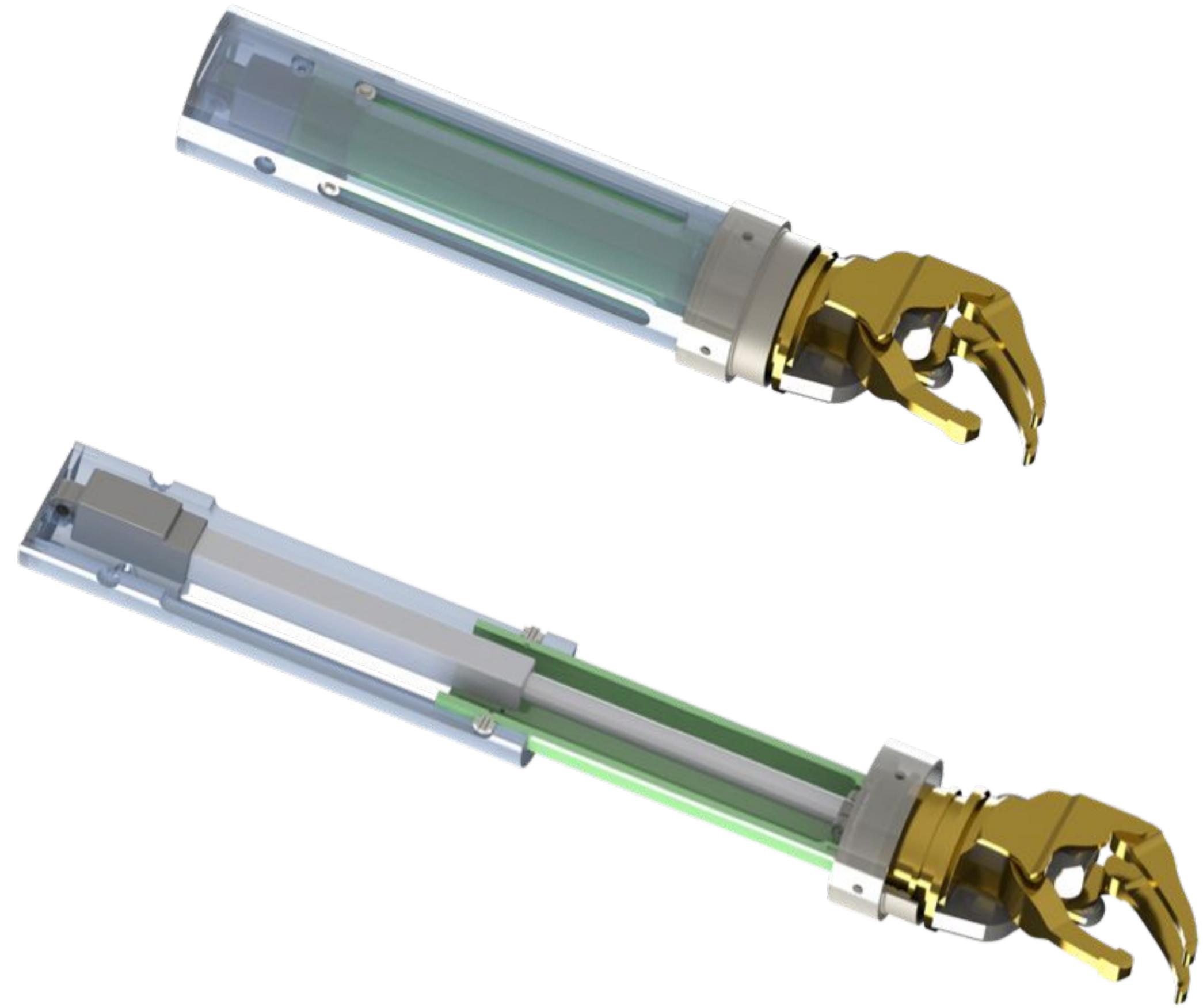




**The XRM**  
Parker *et al.*,  
*arXiv* 2014.







**Extendable Forearm Prosthesis**  
(a.k.a. the "Go-Go-Gadget Wrist")

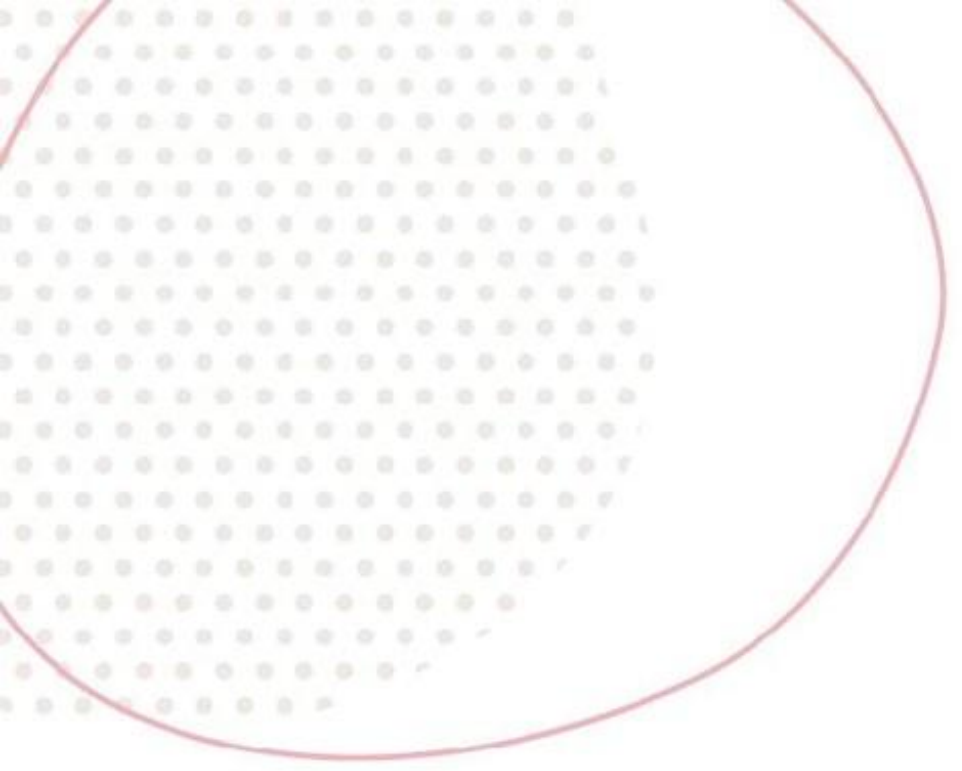


# Bonsai World Forge

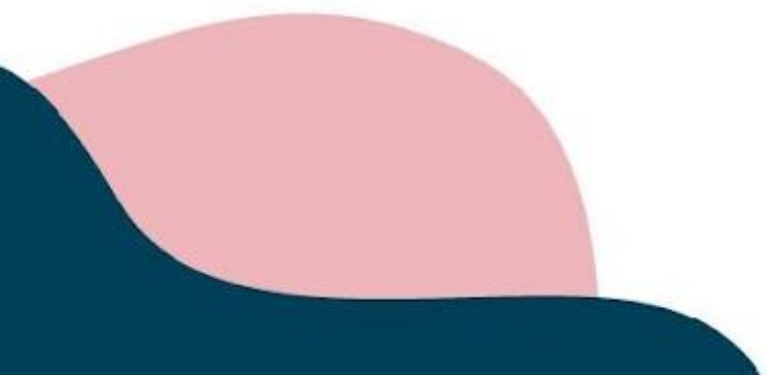
<https://github.com/pilarski/BonsaiWorldForge>



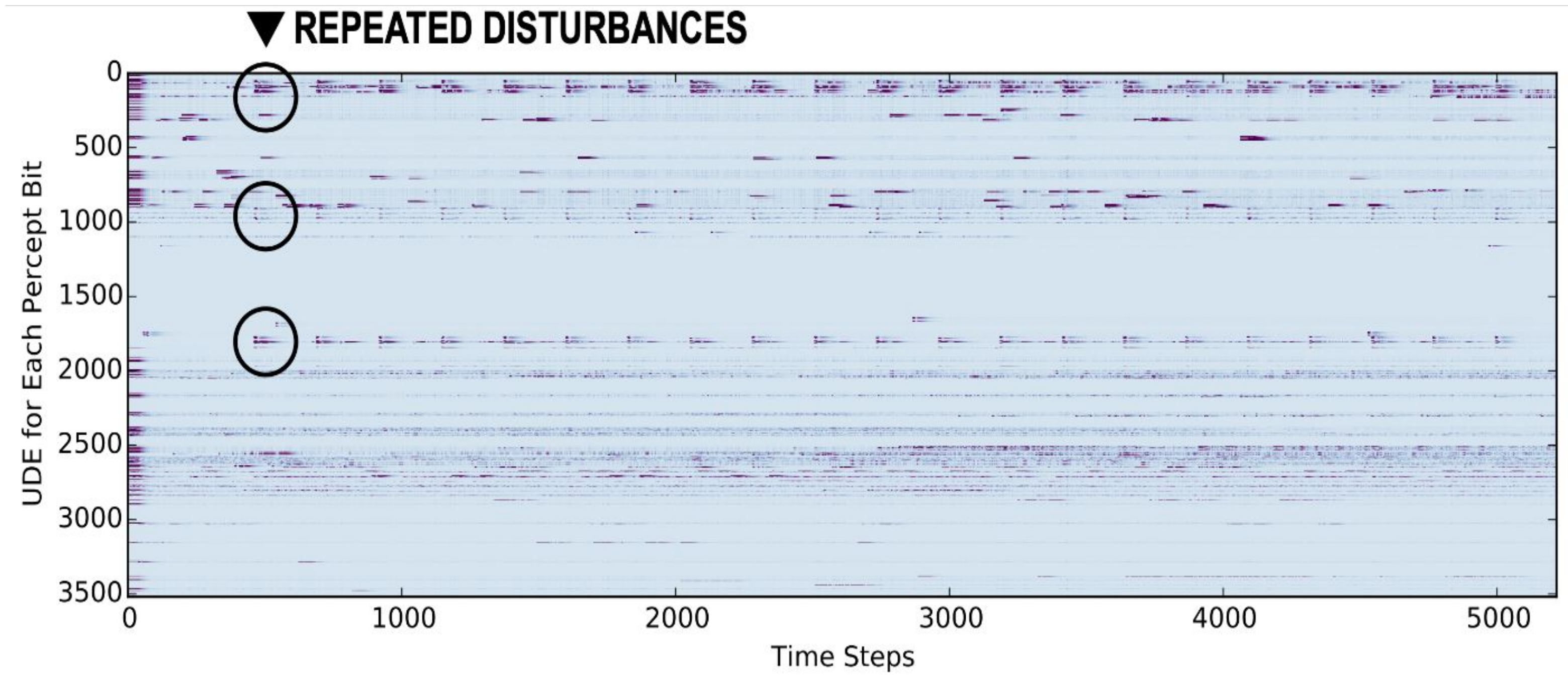
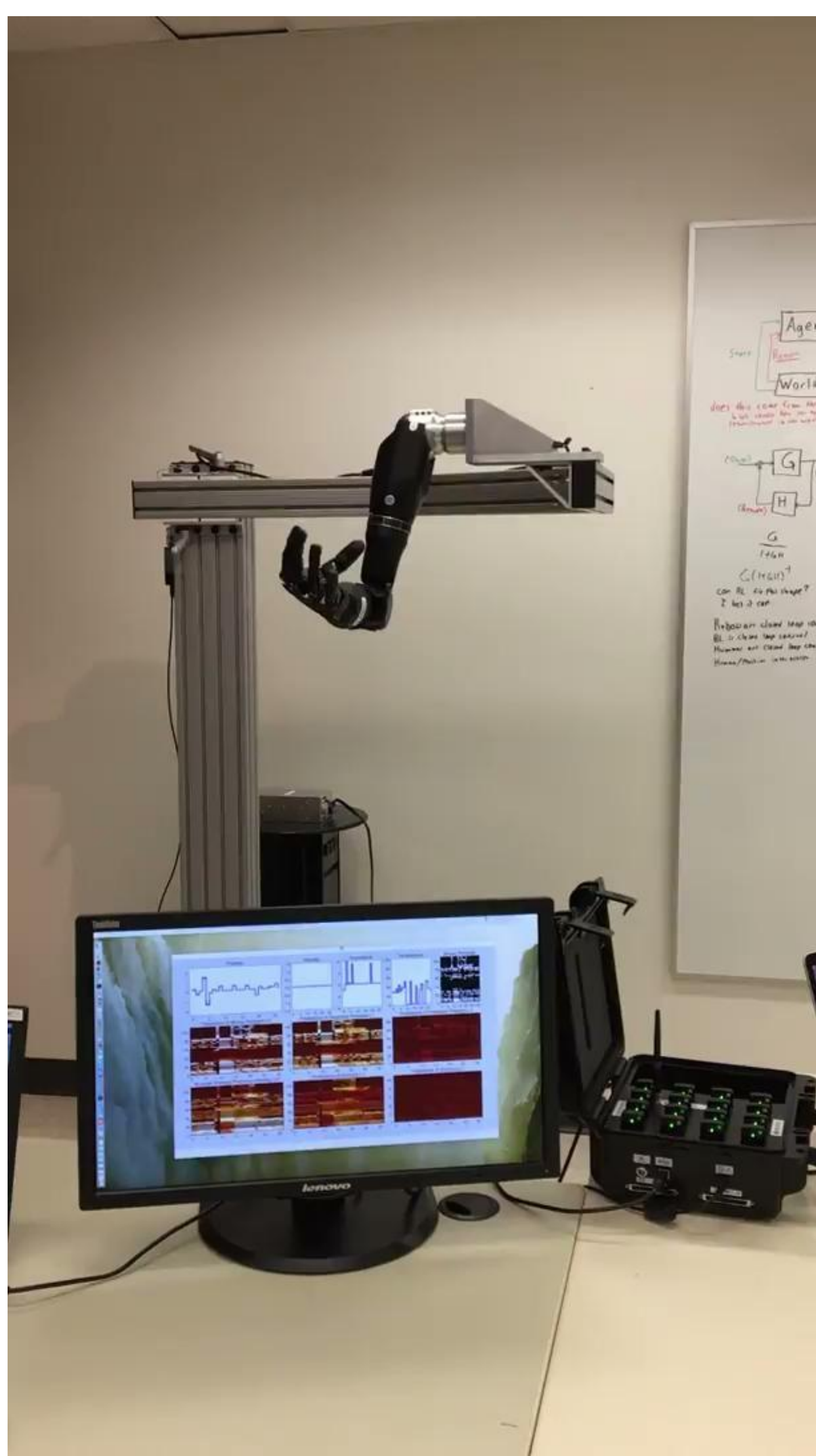




# **Training body parts, the easy (and hard) ways ...**







Günther *et al.*, Proc. AAAI Fall Symposium, 2018.

Günther *et al.*, Frontiers in Robotics and AI, vol. 7, no. 34, 2020.





## Adaptive Switching

Edwards et al., *MEC*, 2014

Edwards et al., *Prosthetics Orthotics Int.*, 2016



# Artificial Intelligence, On Board

Williams *et al.*, "Recurrent Convolutional Neural Networks as an Approach to Position-Aware Myoelectric Prosthesis Control," *IEEE TBME*, 2022.

Video courtesy:  
Amii / Chris Onciul



# Reinforcement Learning from Demonstration

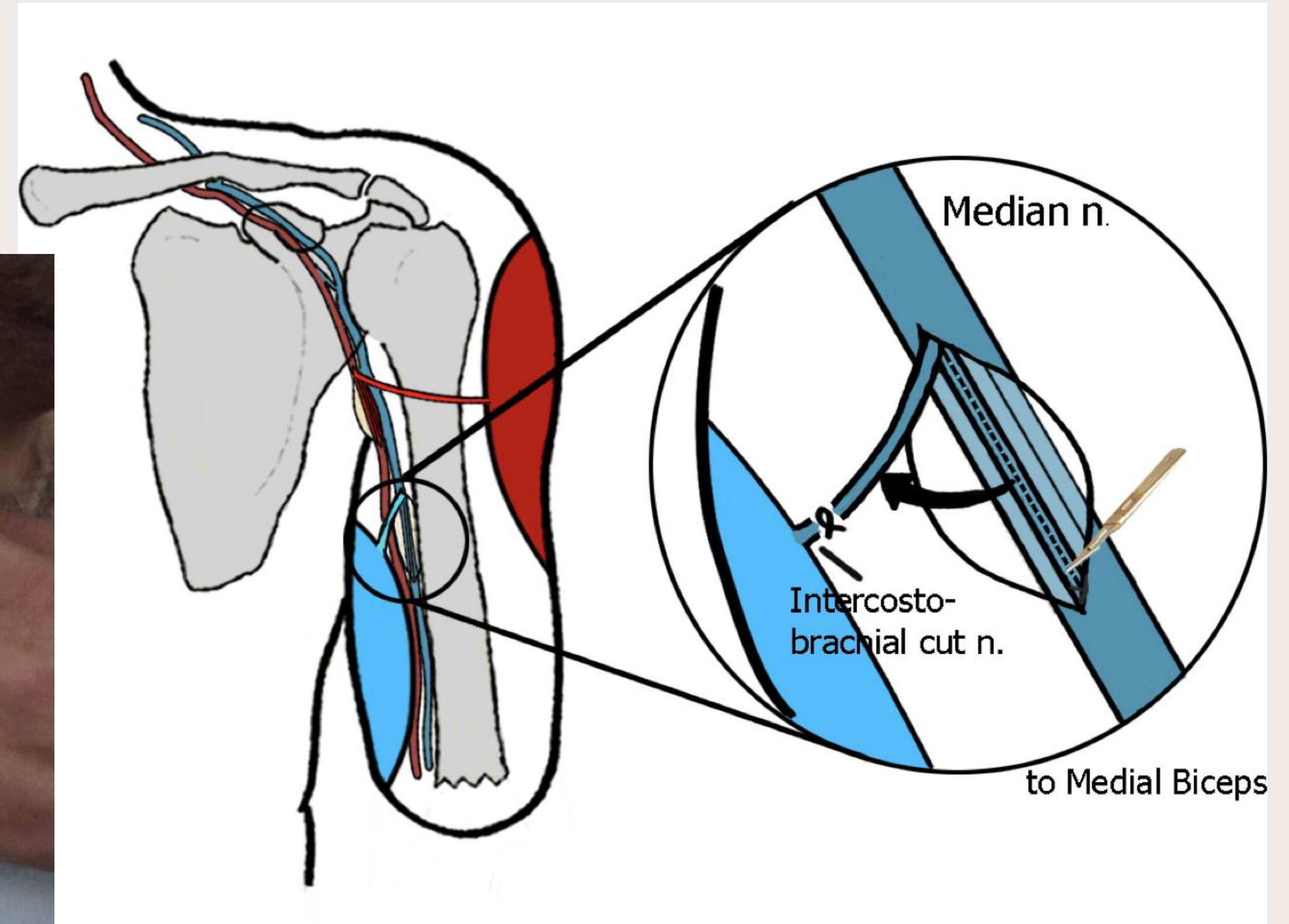






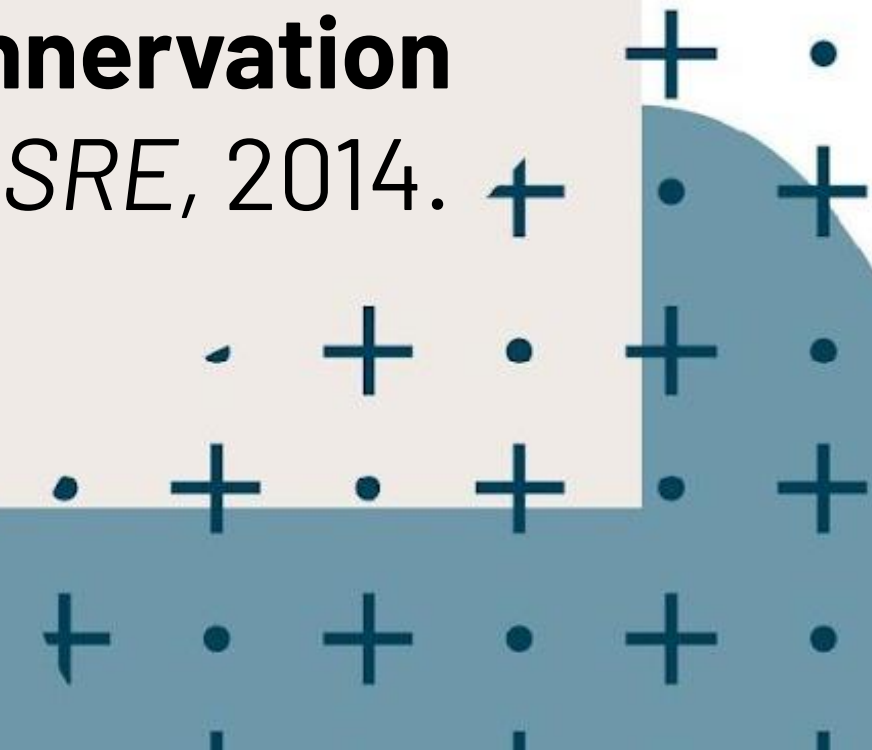
**Changing the body to change the  
machine to change the body ...**





## Targeted Motor and Sensory Reinnervation

Hebert *et al.*, *IEEE-TNSRE*, 2014.





Object Grasping Task  
July 5th, 2012

**Targeted muscle  
reinnervation  
(TMR)**



**Targeted sensory  
reinnervation  
(TSR)**

also using continual machine learning  
to streamline limb control



# David's Story



David's  
Story



<https://www.youtube.com/watch?v=NheJKcYwkNg>

Post-surgery Osseointegration  
Rehabilitation conducted at the  
Glenrose Rehabilitation Hospital

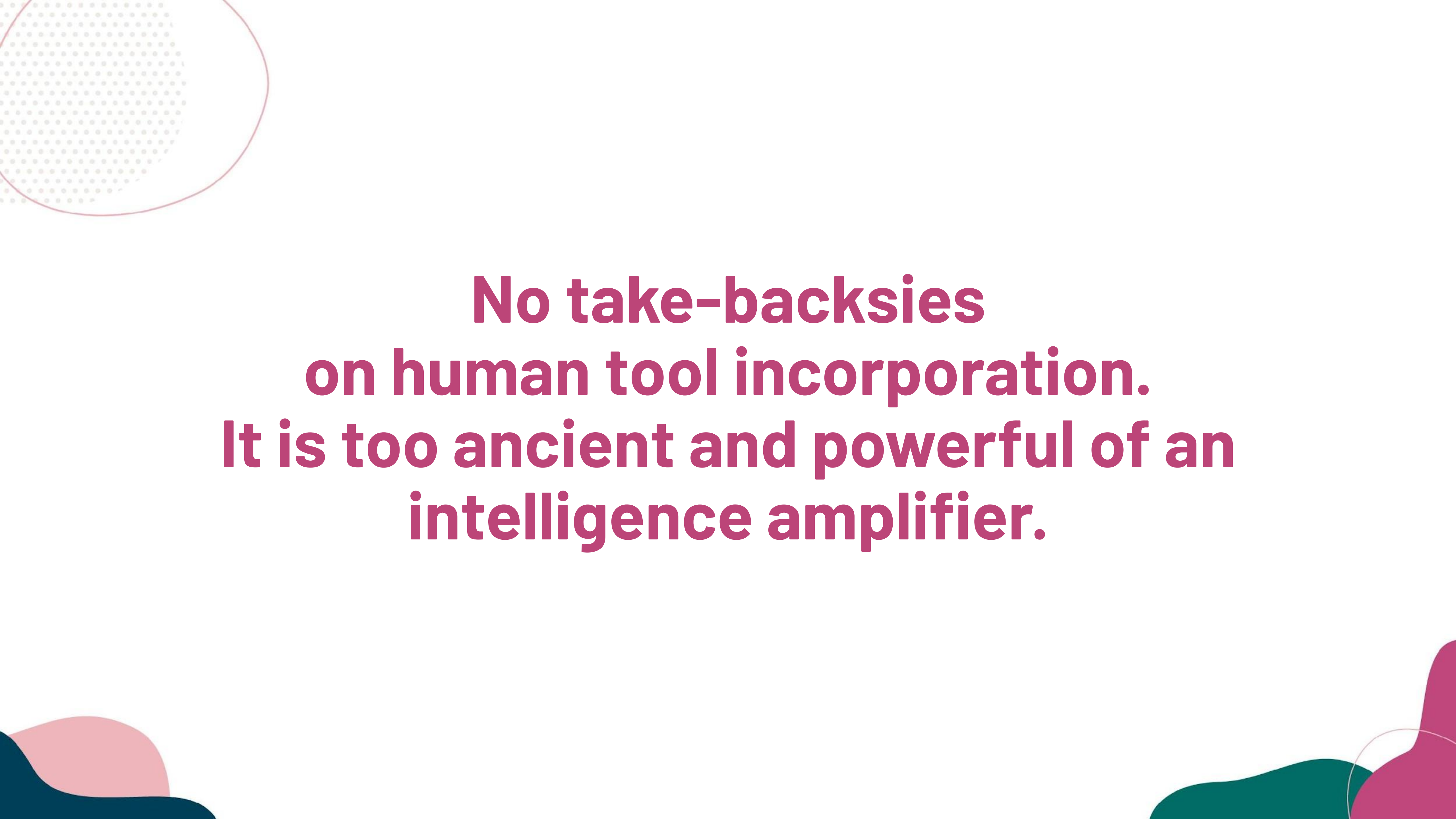




# **CLOSING THOUGHTS:**

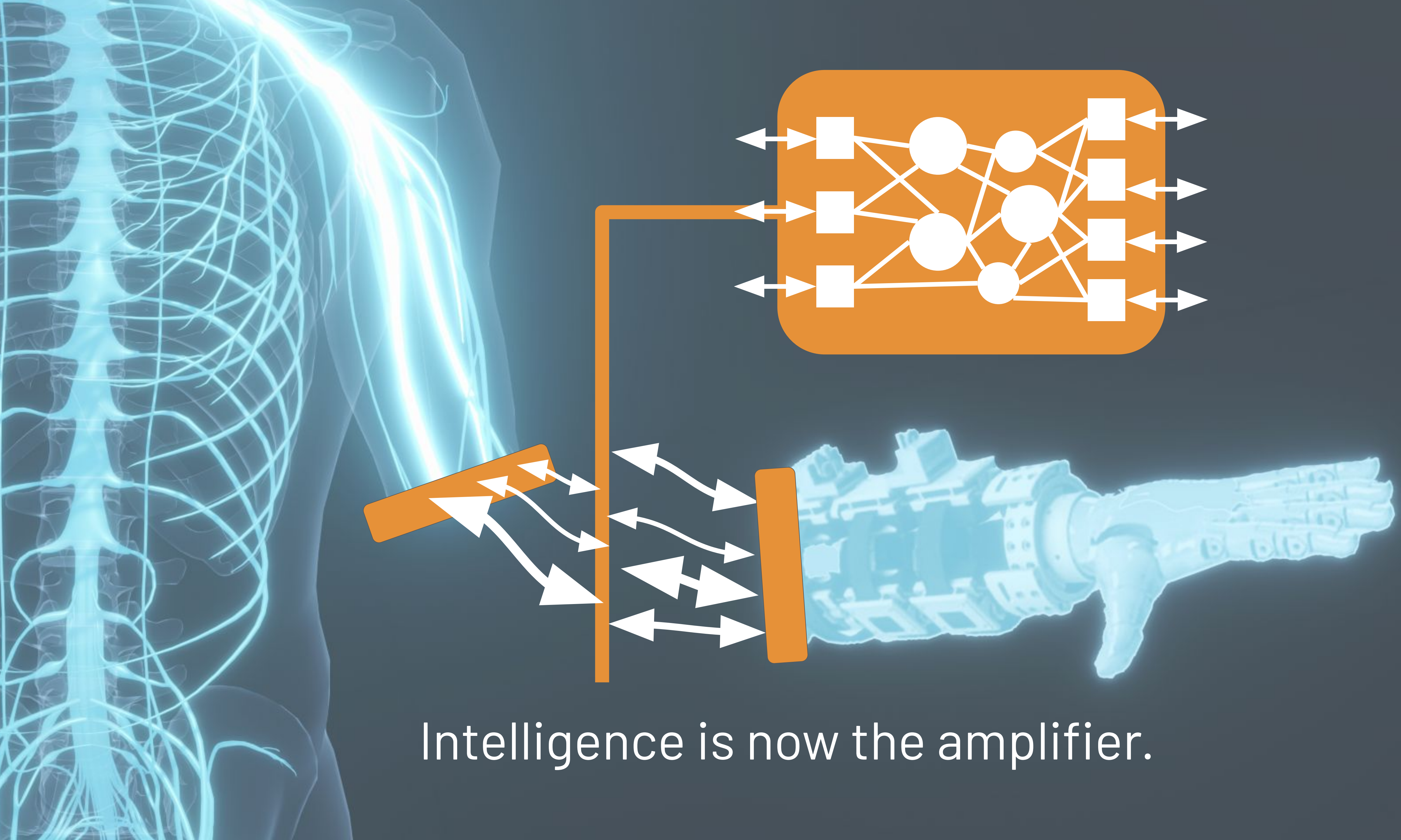
You are already  
becoming bionic





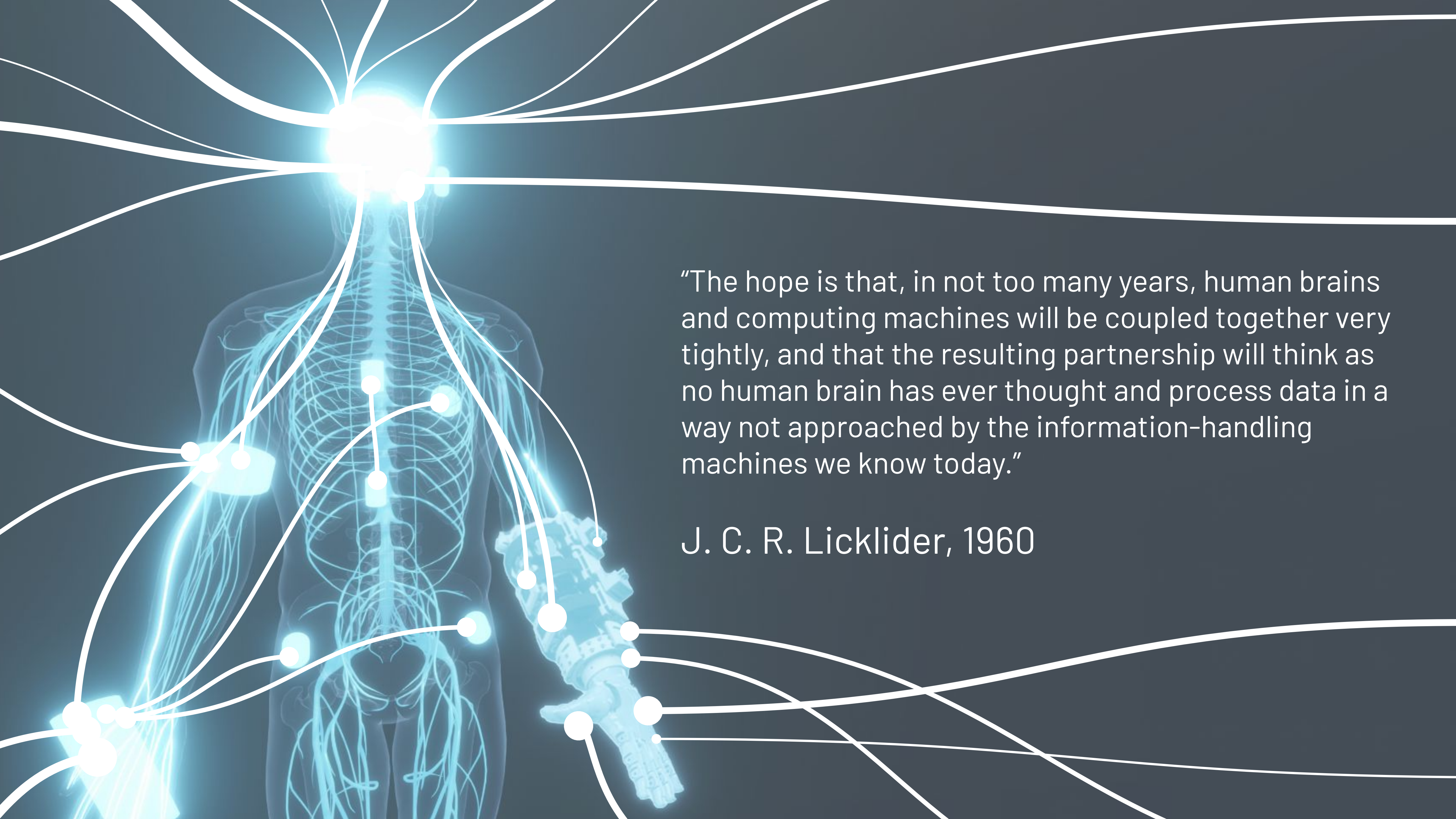
**No take-backsies  
on human tool incorporation.  
It is too ancient and powerful of an  
intelligence amplifier.**





Intelligence is now the amplifier.

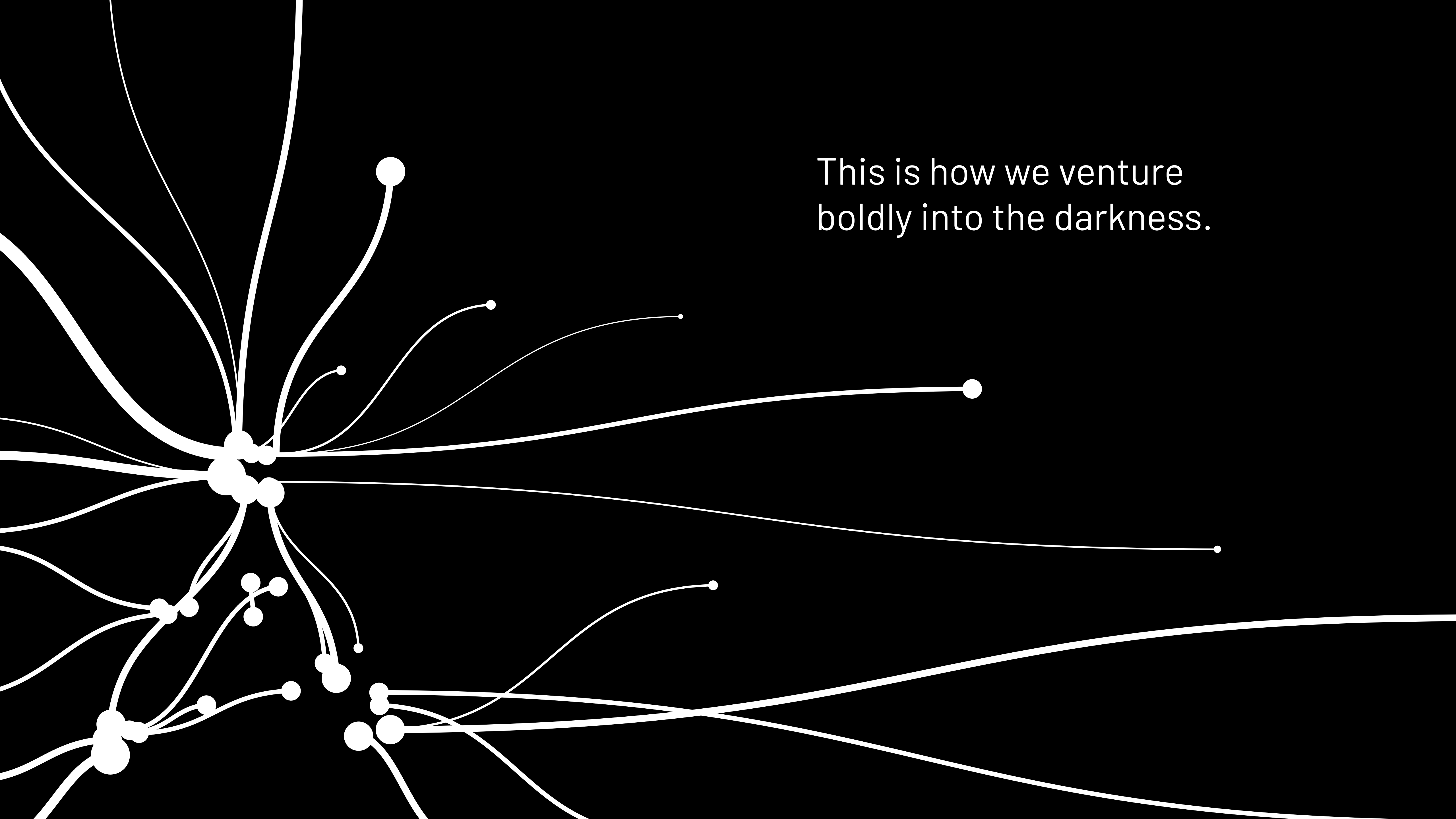




"The hope is that, in not too many years, human brains and computing machines will be coupled together very tightly, and that the resulting partnership will think as no human brain has ever thought and process data in a way not approached by the information-handling machines we know today."

J. C. R. Licklider, 1960

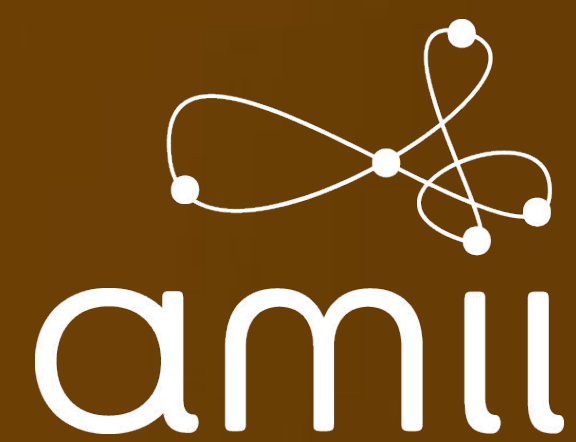
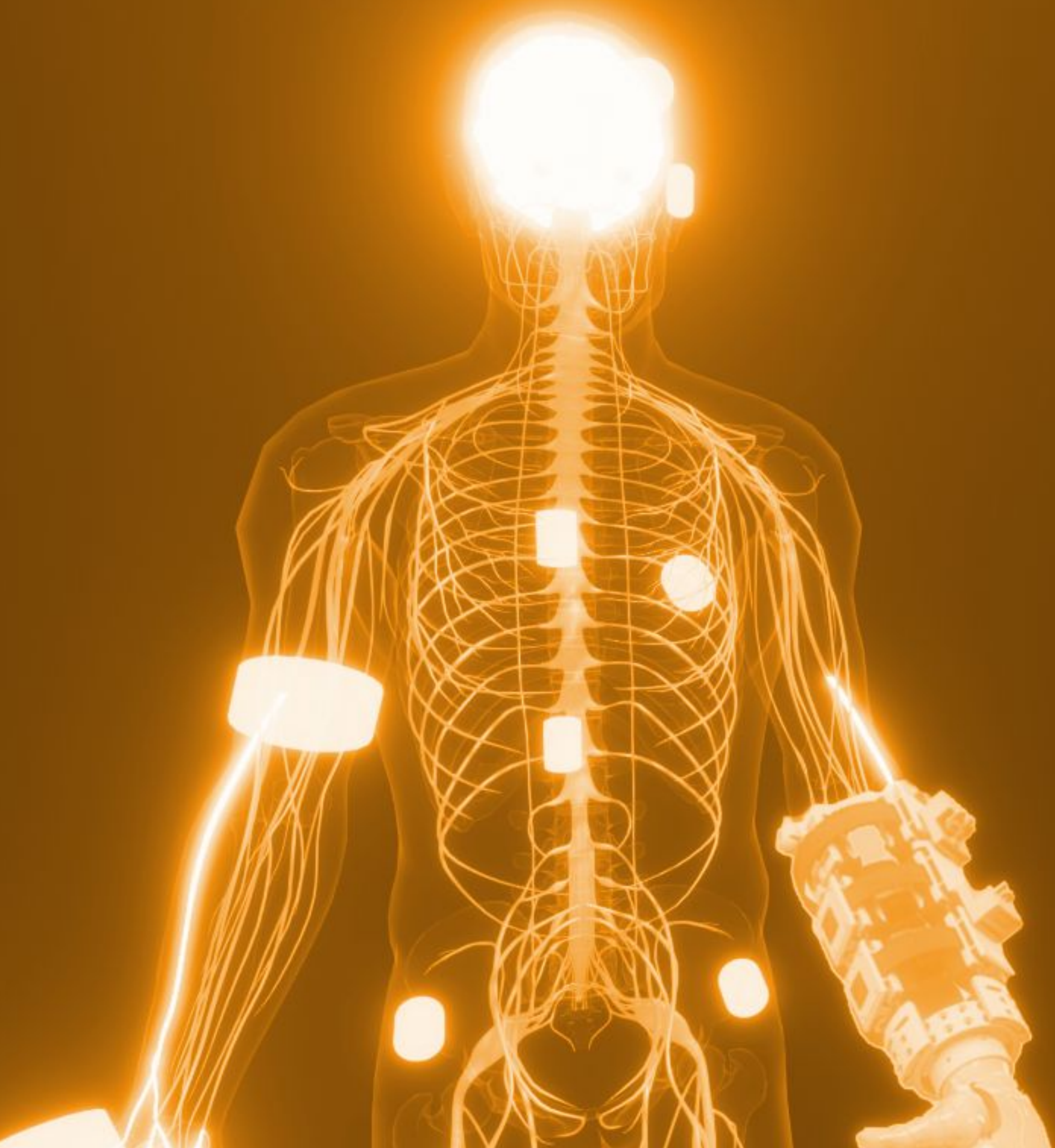


The image features a complex network of white lines and dots on a black background. The lines radiate from a central point on the left, branching out in various directions. Some lines are thick and curve downwards, while others are thin and extend horizontally to the right. Small white circles of varying sizes are placed at various points along the lines, suggesting nodes or connections in a network. The overall effect is that of a neural network or a data visualization.

This is how we venture  
boldly into the darkness.



**Thank you  
for being here!**



**UNIVERSITY  
OF ALBERTA**