Neuroprosthetic-based assistive solutions for sensorimotor impairments

Christine Azevedo
INRIA - Université de Montpellier

Neuroprosthetics

Electronic medical devices interfacing with the nervous system to compensate for the failure of an organ or a function

Source: www.inserm.fr/c-est-quoi/transmission-de-pensee-cest-quoi-une-neuroprothese

Neuroprosthetics

Electronic medical devices interfacing with the nervous system to compensate for the failure of an organ or a function

Electrodes placed in contact with nerve tissue to

- **record**

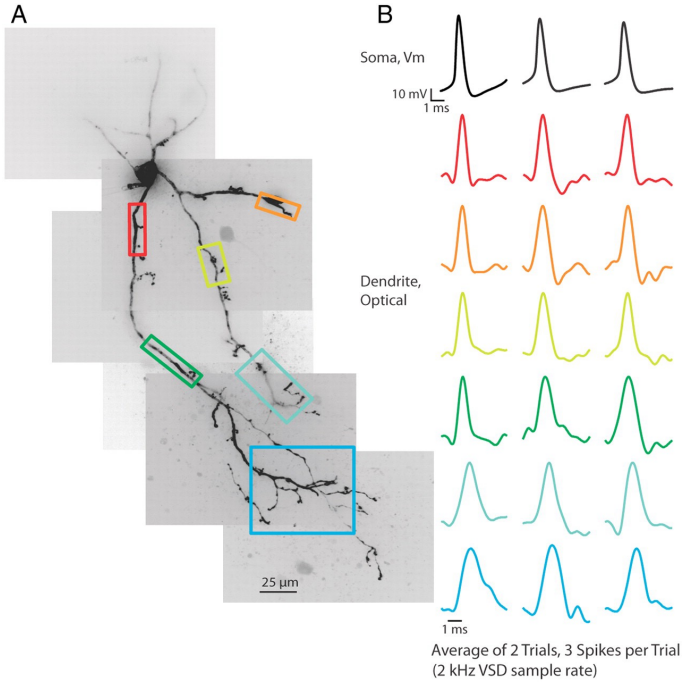
- **stimulate** (active electrodes)

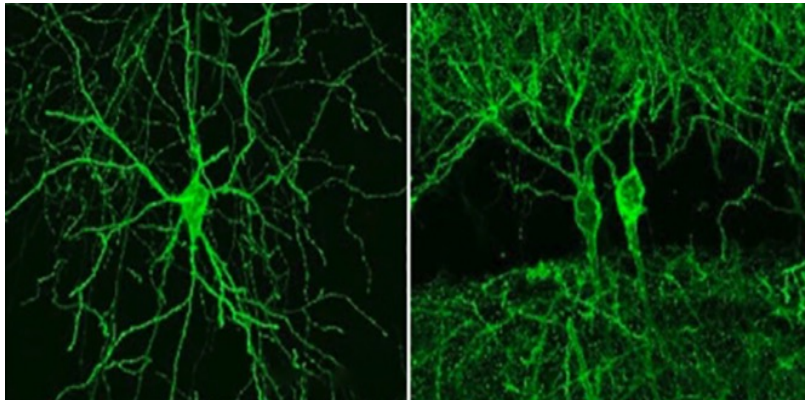
the activity of neurons involved in the targeted function (hearing, vision, motor skills...).

Source : www.inserm.fr/c-est-quoi/transmission-de-pensee-cest-quoi-une-neuroprothese

Nerve Electrical Activity

Information Transmission





© BU/MIT research team

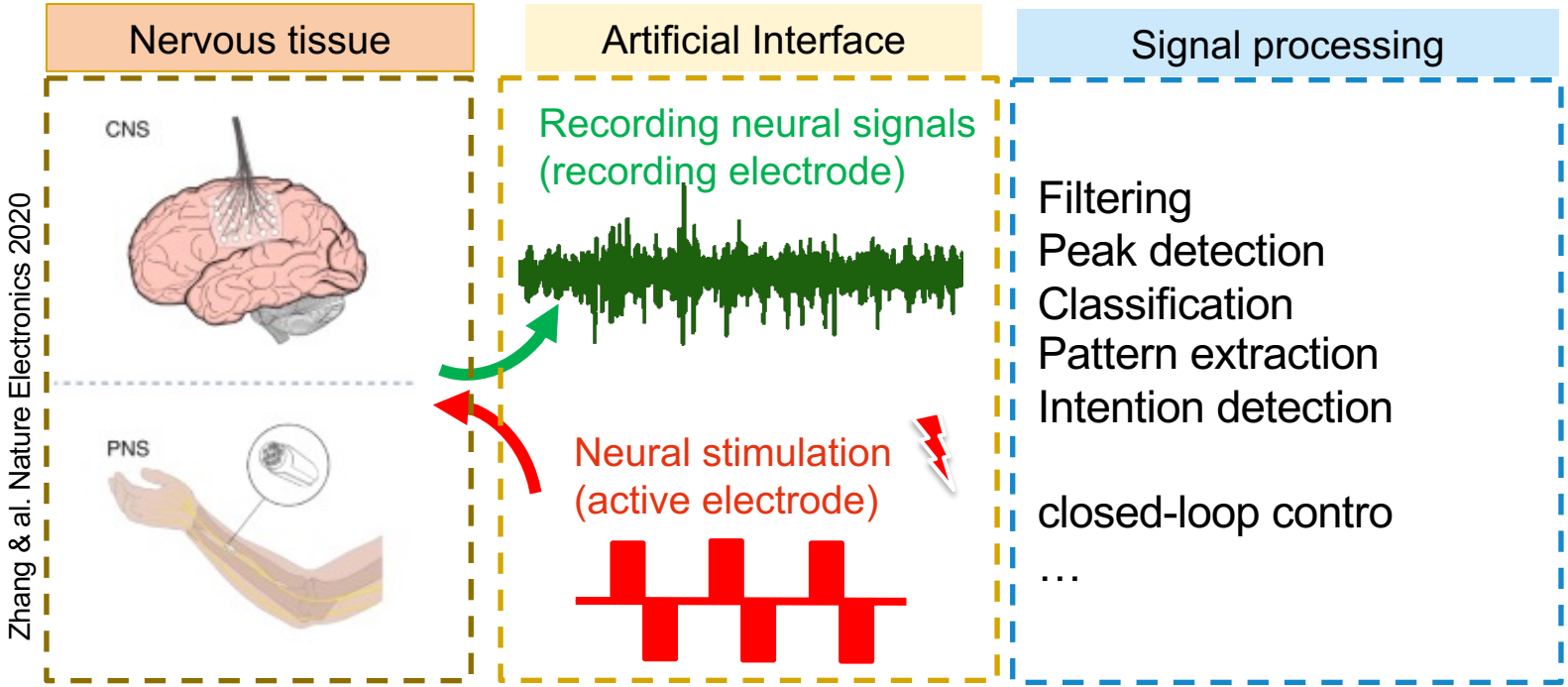
Neuron: chemical and **electrical** transmission of information.

Electrical signals (action potentials) conveyed along the cell membrane.

Casale & McCormick Journal of Neuroscience 2011

Neuroprothetics

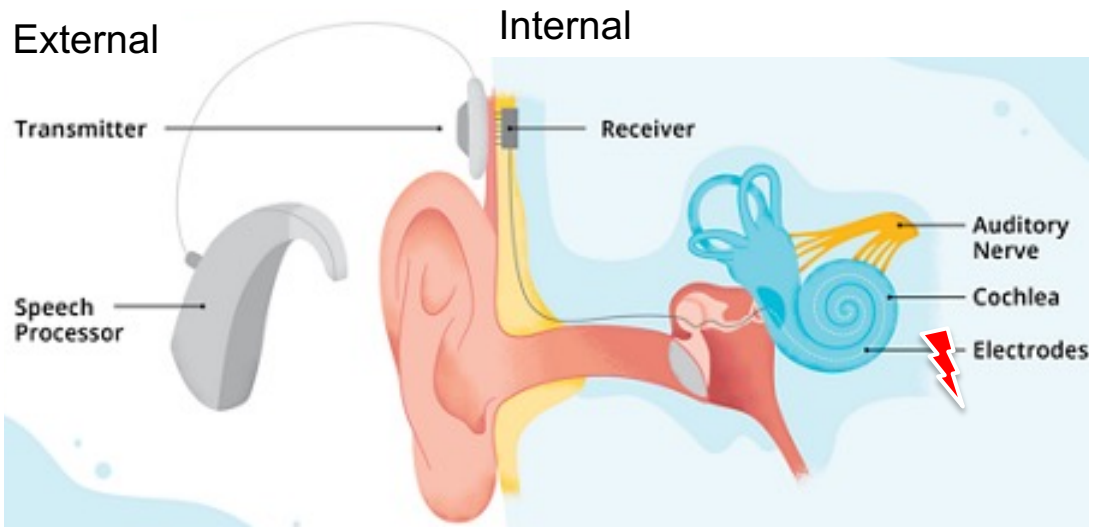
RECORD VS STIMULATE



Neuroprosthesis for Restoring Sensory Functions

EXAMPLE - COCHLEAR IMPLANT

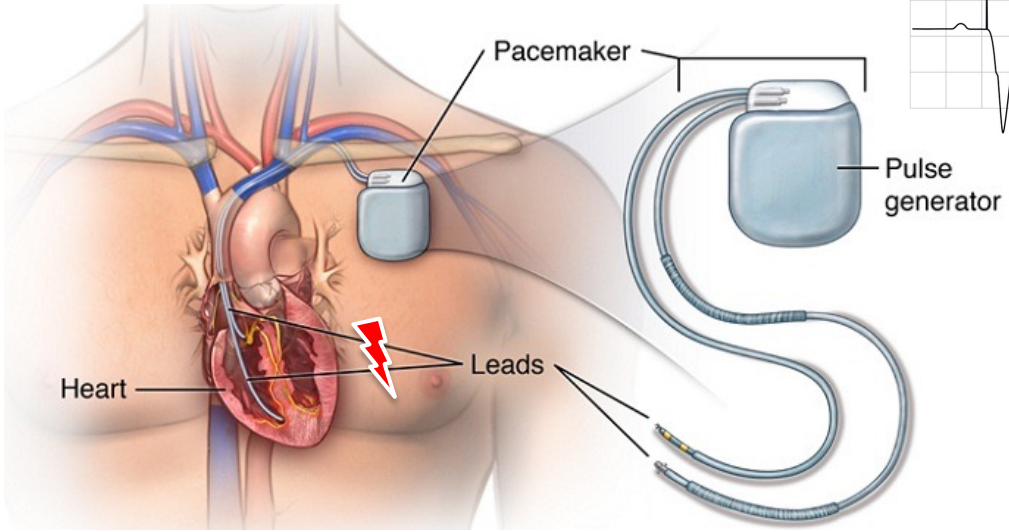
Source: together.stjude.org

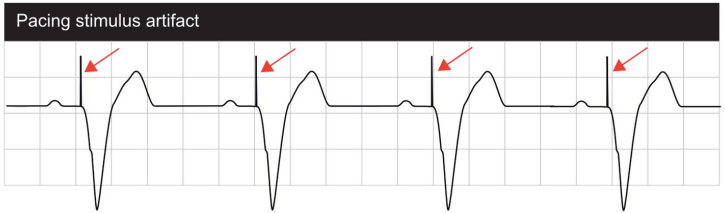


Environmental sounds are captured by a microphone and encoded to be converted into electrical impulses to stimulate the auditory nerve fibers.

Neuroprothetics for restoring muscular contractions

EXAMPLE – PACEMAKER



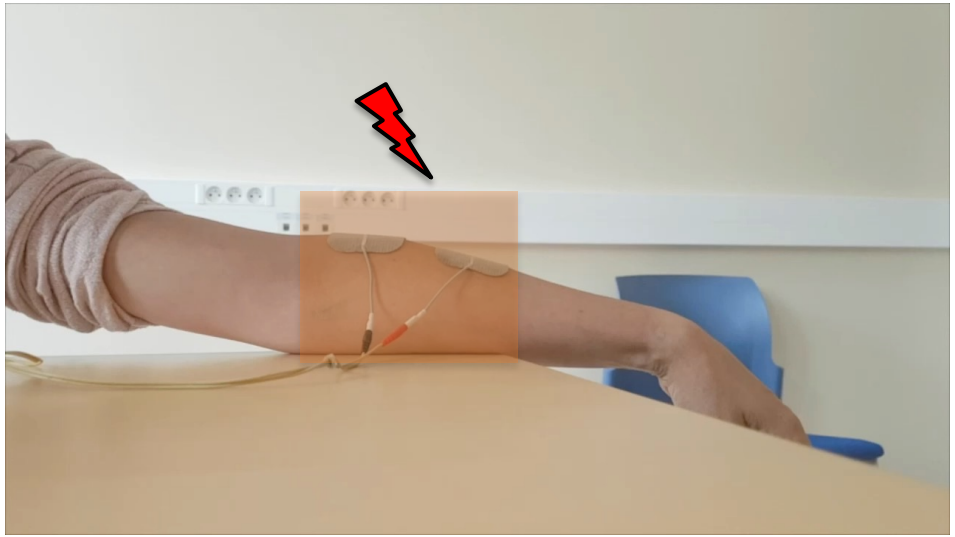


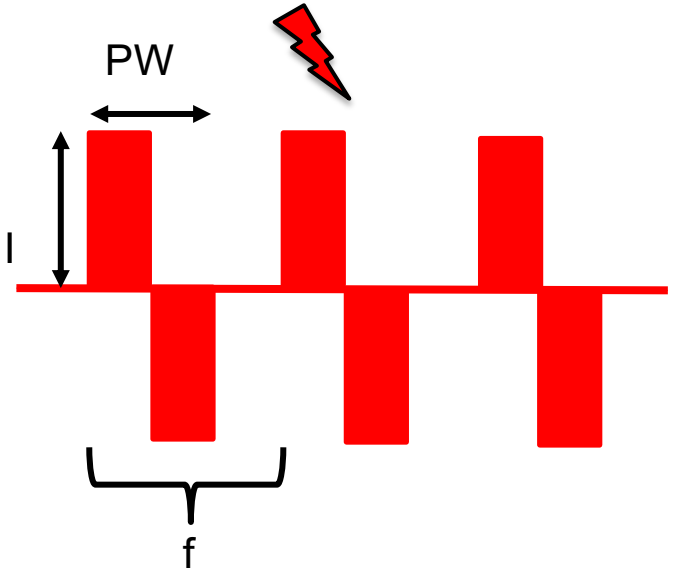
Electrical impulses to control the triggering of heart muscle contractions

Source: www.medicarespots.com

Functional Electrical Stimulation

ARTIFICIALLY TRIGGER A NATURAL CONTRACTION





Contraction of an isolated muscle

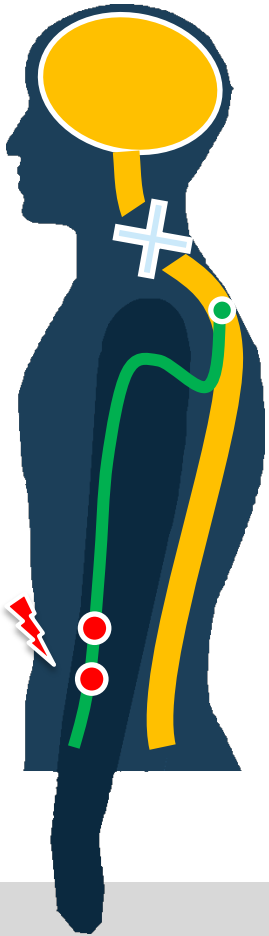
Coordinated contractions of different muscles to restore a function

Functional Electrical Stimulation

ACTIVATE THE MUSCLES OF PARALYZED LIMBS

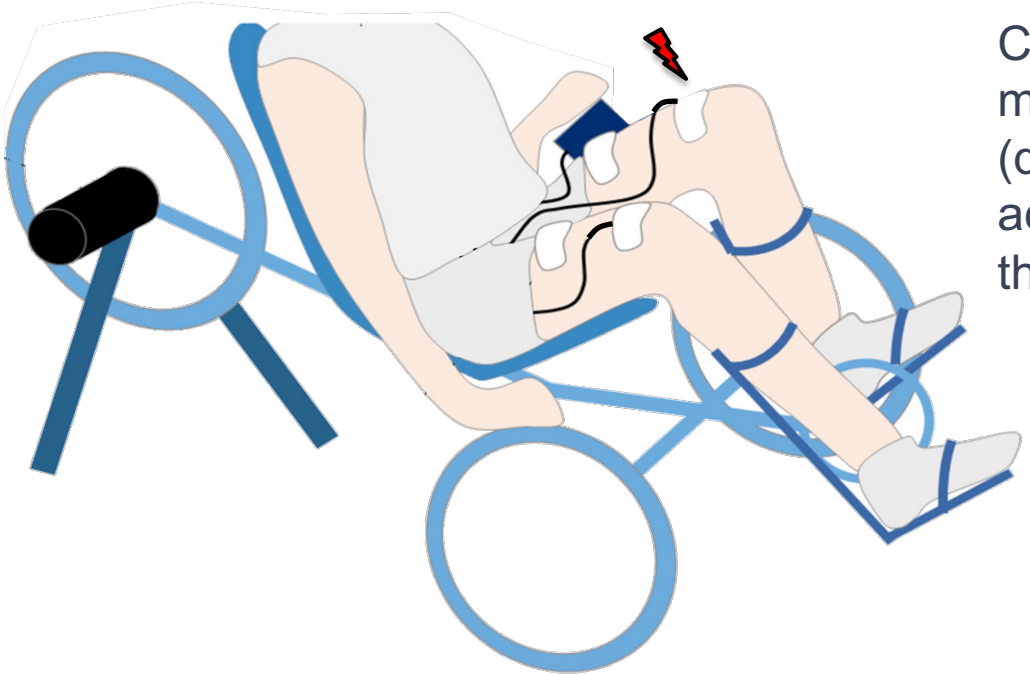
Restore **functions**:

- grasping
- posture and walking
- bladder emptying…

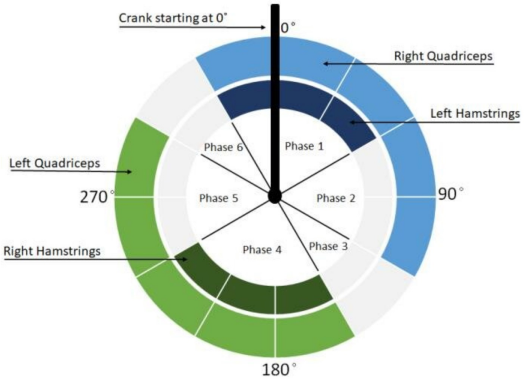


Activation of the muscles of paralyzed lower limbs

EXAMPLE: RESTORATION OF PEDALING MOVEMENTS



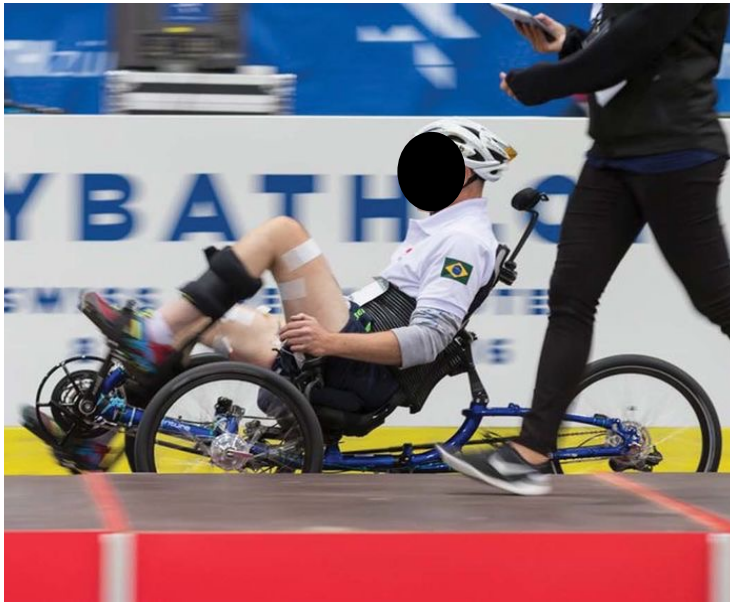
Coordinated activation of the muscles of both legs (quadriceps/hamstrings) according to the progression of the pedaling cycle



Former associate team with UnB - CACAO

Activation of the muscles of paralyzed lower limbs

EXAMPLE: RESTORATION OF PEDALING MOVEMENTS



Challenges: adapted training, coordination of contractions, movement optimization, reduction of early fatigue

Participation in CYBATHLON event

http://freewheels.inria.fr

Activation of the muscles of paralyzed lower limbs

EXAMPLE: RESTORATION OF PEDALING MOVEMENTS

Xavier (T4 AIS A) 2020

Ongoing work on musculoskelatal modelling and optimal control
(see presentation of F Bailly tomorrow)

Associate team with UFMG - GOIABA

USSAP
Union Sanitaire et Sociale pour l'Accompagnement et la Prévention

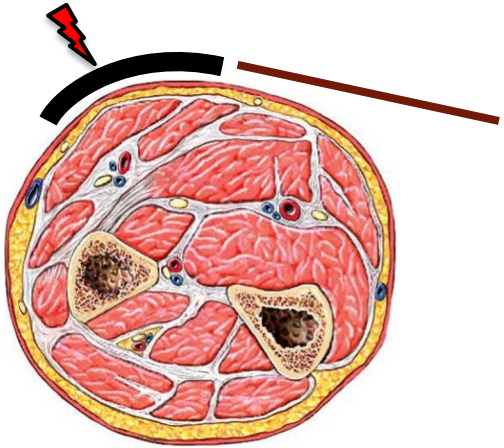
Activation of the muscles of paralyzed upper limbs

STIMULATION VIA SURFACE ELECTRODES

Participant with quadriplegia

Activation of the muscles of paralyzed upper limbs

STIMULATION VIA SURFACE ELECTRODES

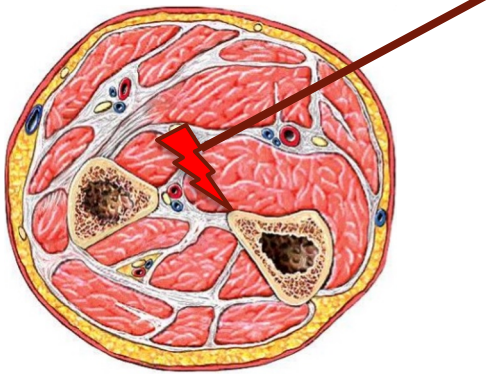


Surface electrodes: low selectivity, tedious positioning, skin movements…

Numerous, thin, and sometimes deep muscles

Activation of the muscles of paralyzed upper limbs

STIMULATION VIA IMPLANTED MUSCLE ELECTRODES



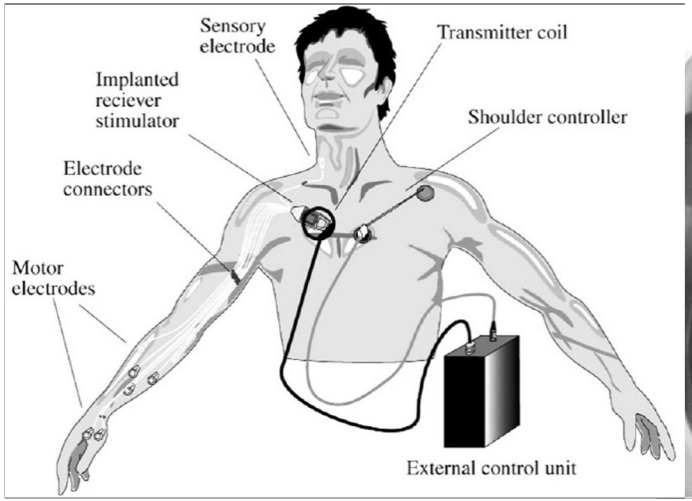
Implanted electrodes:

- epimysial
- intramuscular

Activation of the muscles of paralyzed upper limbs

STIMULATION VIA IMPLANTED MUSCLE ELECTRODES

FREEHAND (Neurocontrol, USA) - 1997



© Cleveland Center

Kilgore et al. (1997)

8 to 12 epymisial and intramuscular electrodes

surgery 6h

300 patients implanted worldwide (7 in France)

Activation of the muscles of paralyzed upper limbs

STIMULATION VIA IMPLANTED MUSCLE ELECTRODES

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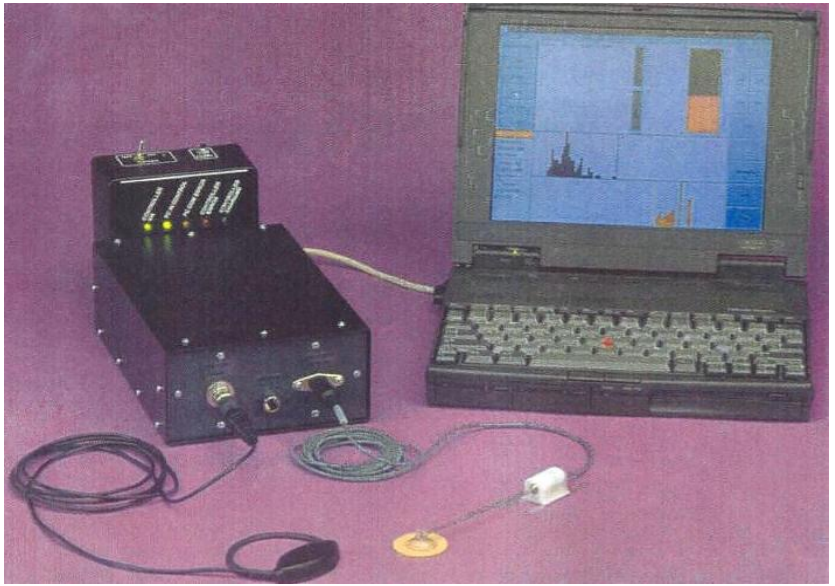
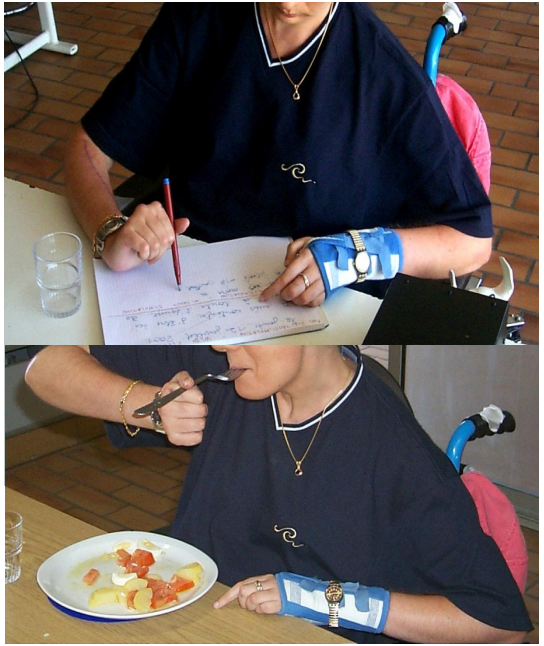


With courtesy of Dr Charles Fattal

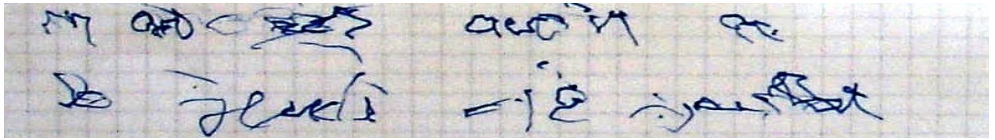
Activation of the muscles of paralyzed upper limbs

STIMULATION VIA IMPLANTED MUSCLE ELECTRODES

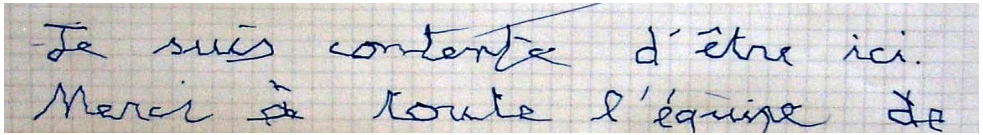
Système FREEHAND (Neurocontrol, USA) **– comercialized until 2001**



sans stimulation



avec stimulation



With courtesy of Dr Charles Fattal

Activation of the muscles of paralyzed upper limbs

STIMULATION VIA IMPLANTED NEURAL ELECTRODES

AI-HAND project – Neural approach

Ai-Hand

Funded by the European Union

Inria REHAZENTER LUXEMBOURG universität freiburg

neurinnov

USSAP

CorTec Thinking ahead

Clinique Saint Jean Sud de France

For more details: https://www.aihand.eu

Activation of the muscles of paralyzed upper limbs

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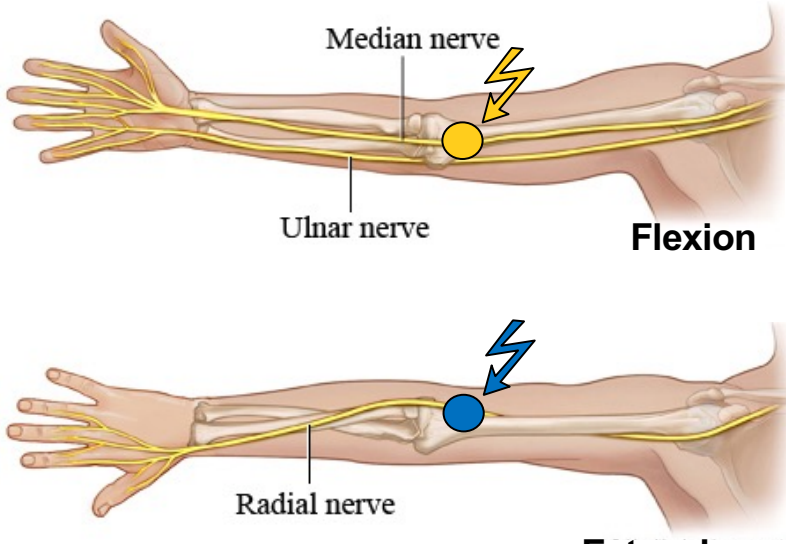

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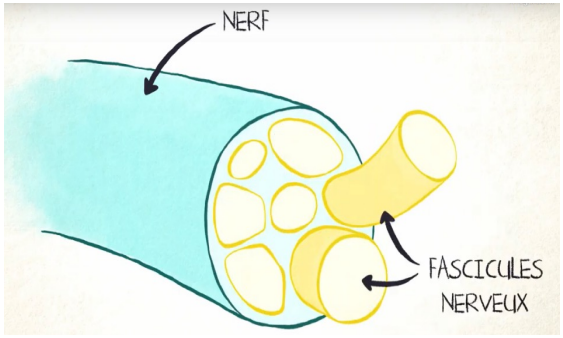

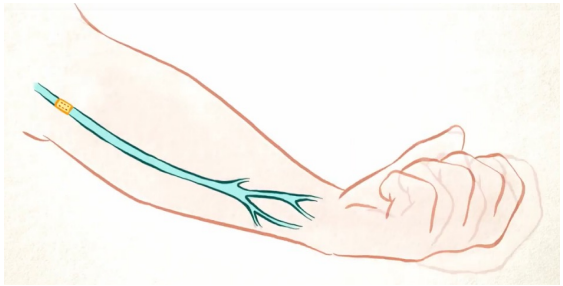

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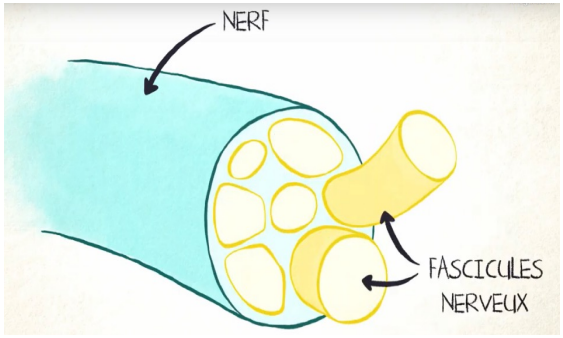

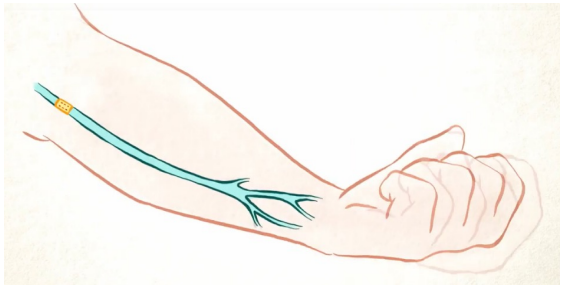

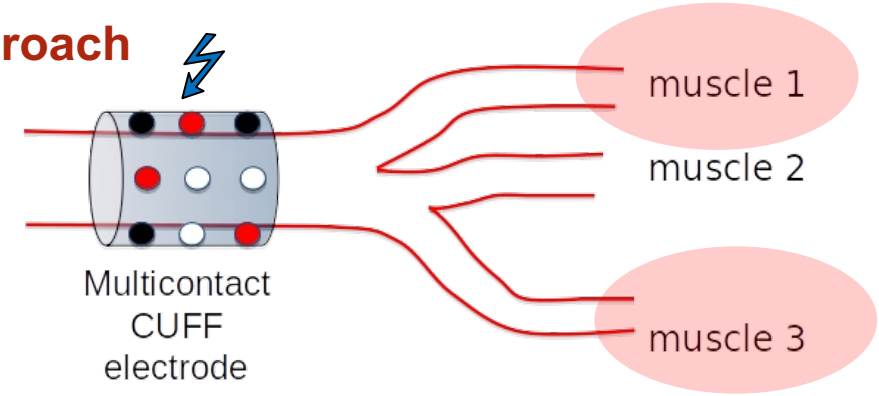

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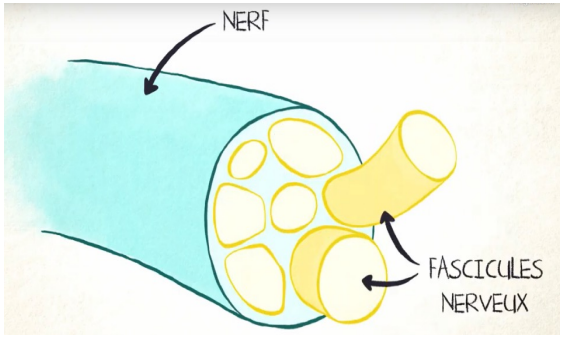
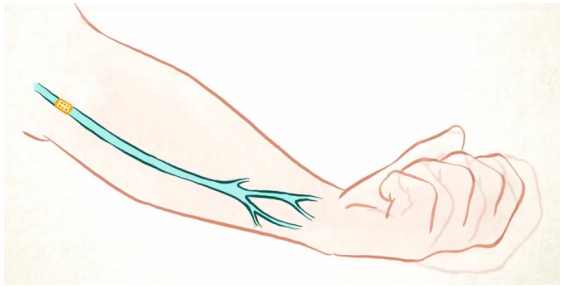
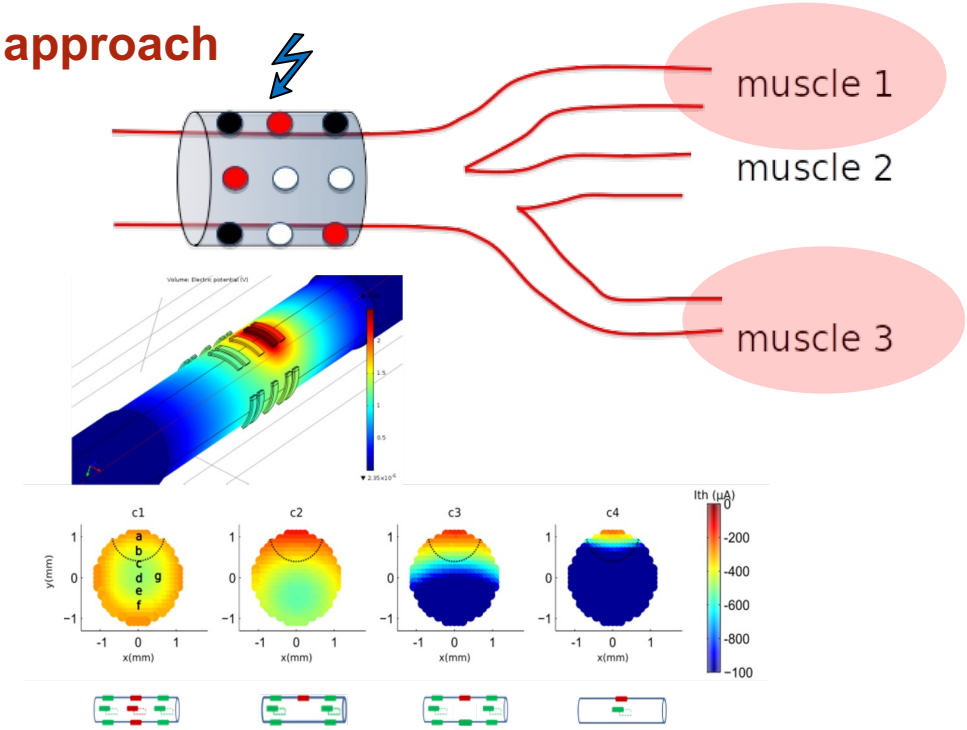


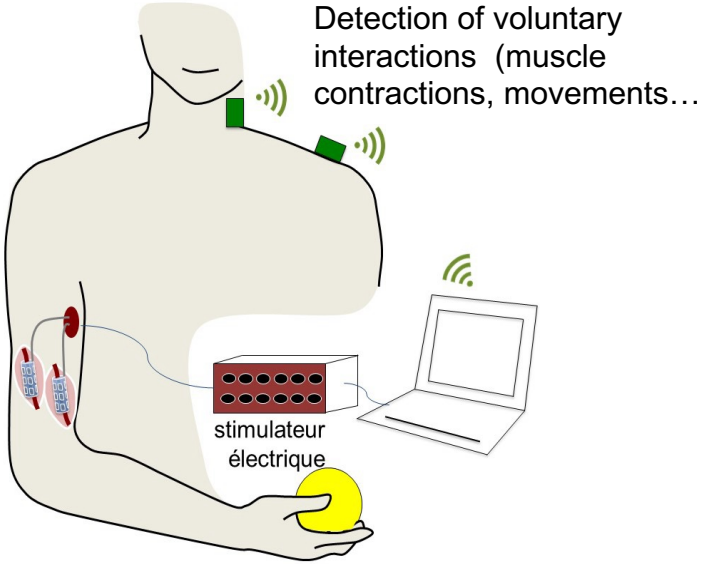


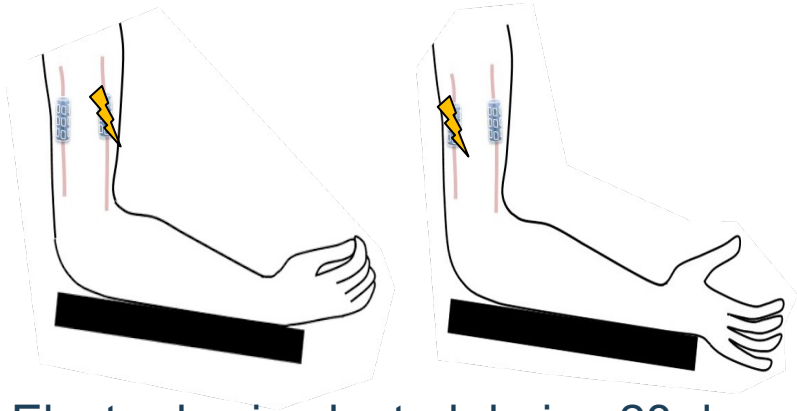


Activation of the muscles of paralyzed upper limbs

STIMULATION VIA IMPLANTED NEURAL ELECTRODES

Validation of the approach on 4 participants with complete tetraplegia

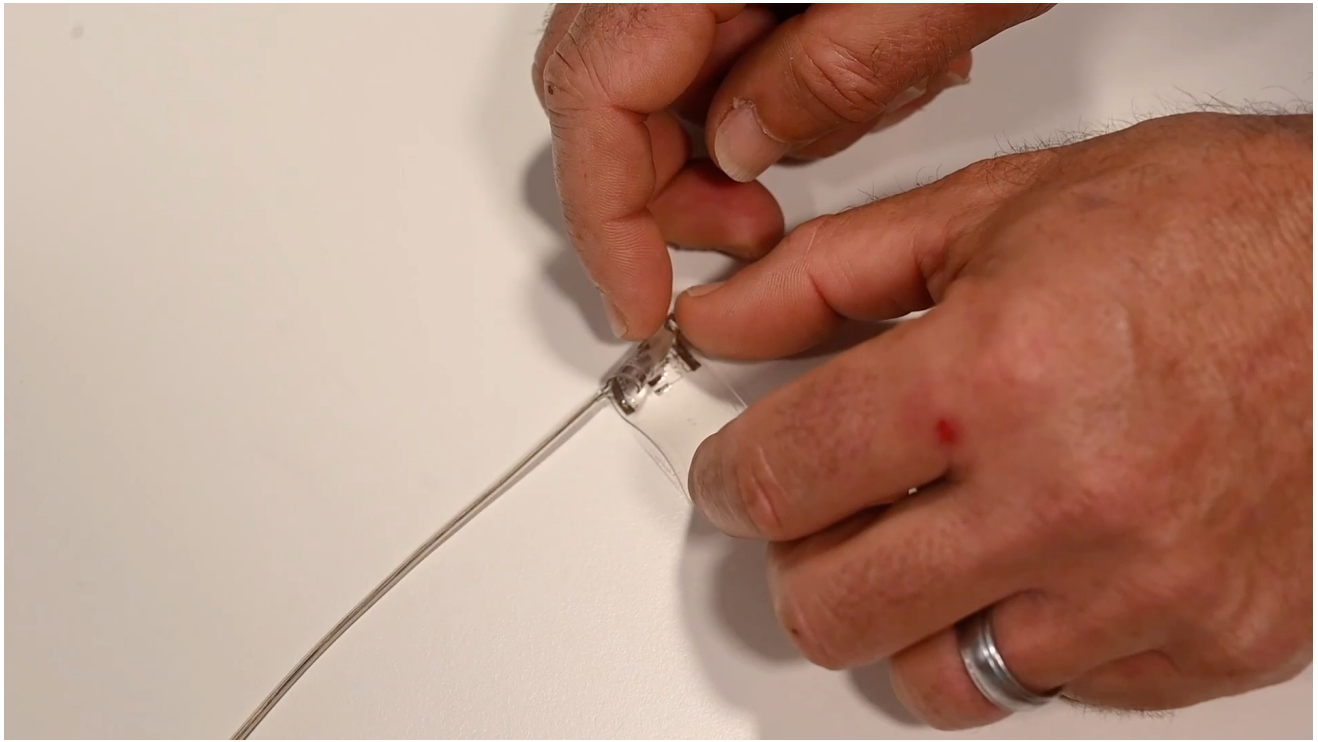




Electrodes implanted during 28 days

Activation of the muscles of paralyzed upper limbs

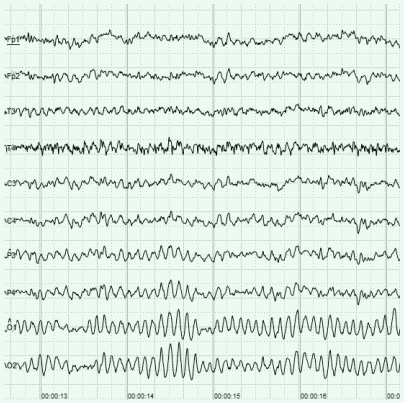
STIMULATION VIA IMPLANTED NEURAL ELECTRODES



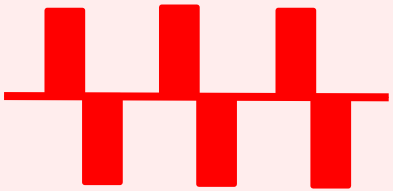
FIM study
planned for 2026

Neuroprosthetics: electronic medical devices interfacing with the nervous system to compensate for the failure of an organ or function

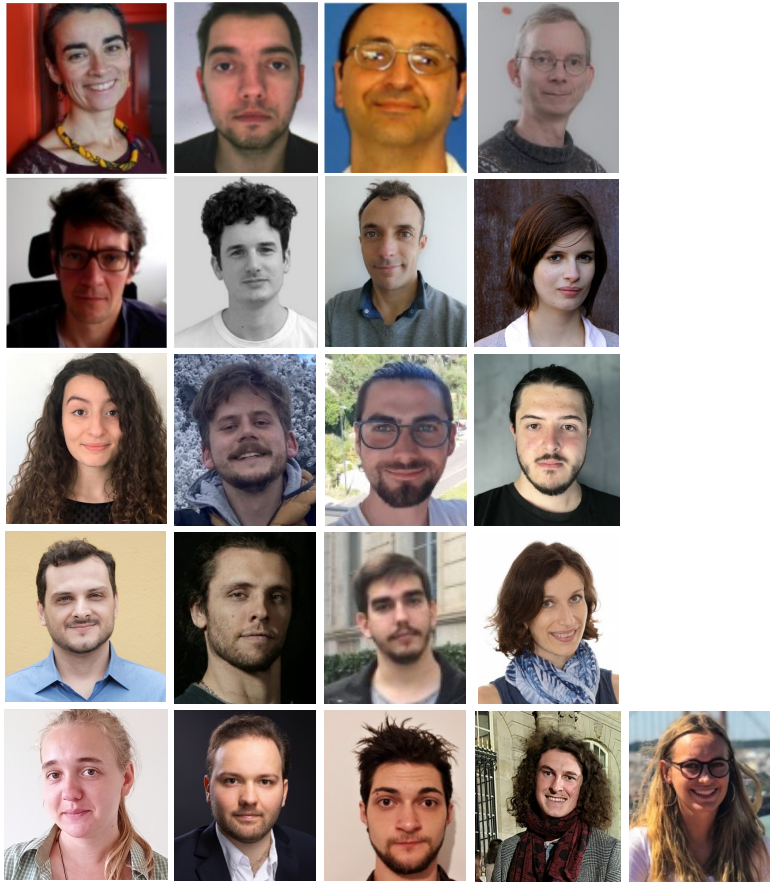
recording



Activation



Signal processing



A team's work

Contact:
christine.azevedo@inria.fr

C Azevedo, L William, L Fonseca, A Hiairrassary, D Andreu, A Geffrier, J Teissier, C Fattal, D Guiraud **Activating effective functional hand movements in individuals with complete tetraplegia through neural stimulation** Scientific Reports 2022

C Fattal, J Teissier, A Geffrier, L Fonseca, L William, D Andreu, D Guiraud, C Azevedo **Restoring Hand Functions in People with Tetraplegia through Multi-Contact, Fascicular, and Auto-Pilot Stimulation: A Proof-of-Concept Demonstration** J Neurotrauma 2022

C Fattal, M Schmoll, R Le Guillou, B Raoult, A Frey, R Carlier, C Azevedo ***Benefits of 1-Yr Home* Training With Functional Electrical Stimulation Cycling in Paraplegia During COVID-19 Crisis** Am J Phys Med Rehabil 2021

W Tigra, M Dali, L William, C Fattal, A Gélis, JL Divoux, B Coulet, J Teissier, D Guiraud, C Azevedo **Selective neural electrical stimulation restores hand and forearm movements in individuals with complete tetraplegia** J Neuroeng Rehabil 2020

C Fattal, B Sijobert, A Daubigney, B Lucas, C Azevedo **Feasibility of training with FES-assisted cycling: Psychological, physical and physiological consideration** Annals of Physical and Rehabilitation Medicine 2017