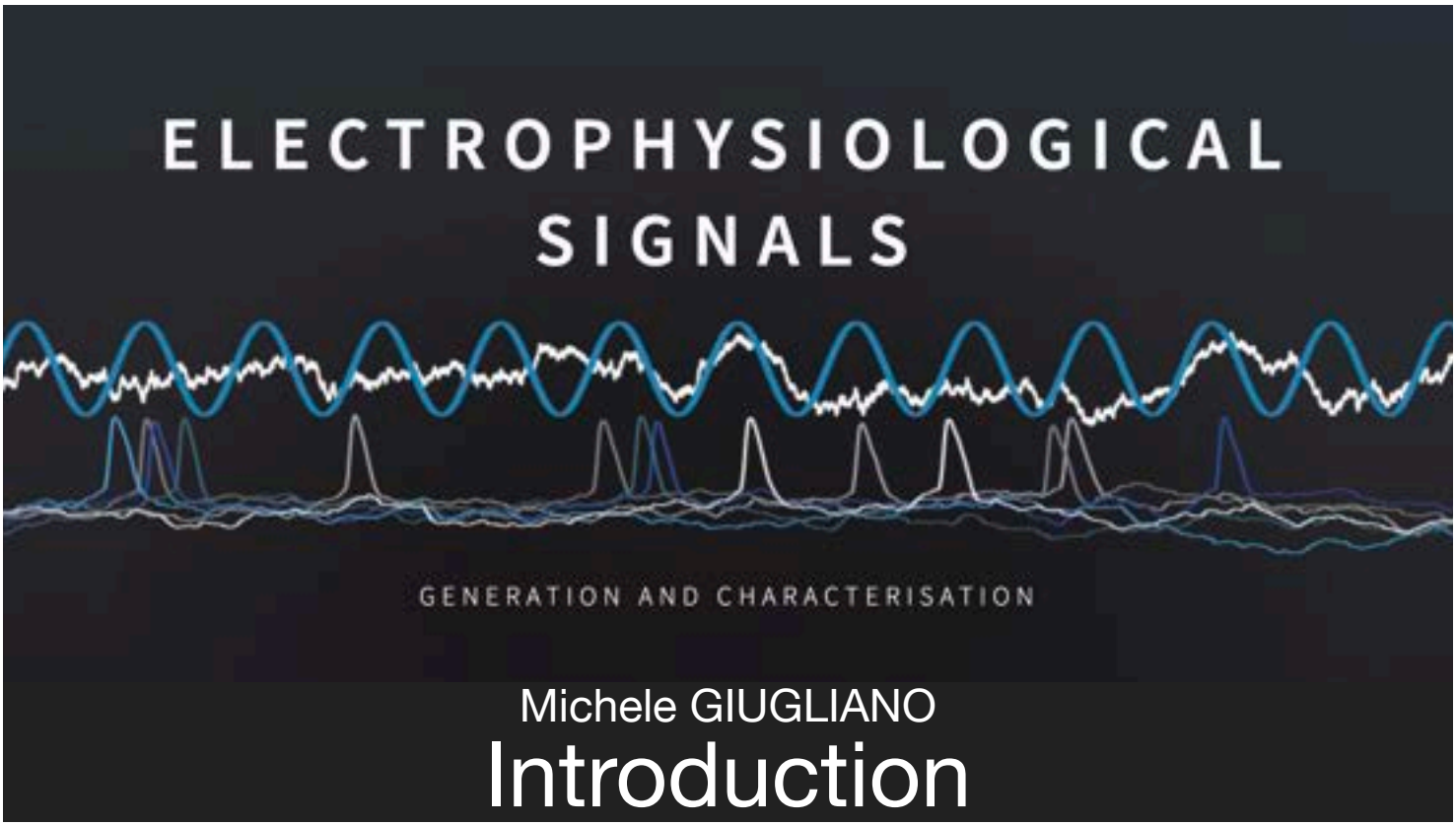


Michele GIUGLIANO

Introduction

ATTENDANCE TRACKING - **code ??????**

(for statistical purposes only)

Download for iPhone

Download for Android

https://www.unimore.it/it/servizi/unimore-app

Instant messaging

Announcements, Q&A for all !

This course's module has its website

...and GitHub *repo*.

Organisation and Practicalities

- Slides + chalk/board
- **Interactive!** I can't read your mind (yet)
- I do NOT mind *stupid* questions (really!)
- Demos & hands-on exercises (python, ...)
- Evaluation: oral exam (20 min, informal)
  (or mini-projects for super interested students)

Organisation and Practicalities

- **videotaping** will NOT be made available to all
- **hand-outs**: available online in advance (website)
- **attendance** tracking: statistical purposes only
- **hands-on** skills: in a web browser (or installing sw on your laptop... if really interested - **ask**)
- **prerequisites**: math (**ask**), computer proficiency (**ask**), physiology (**ask**), neurobiology (**ask**)

Organisation and Practicalities

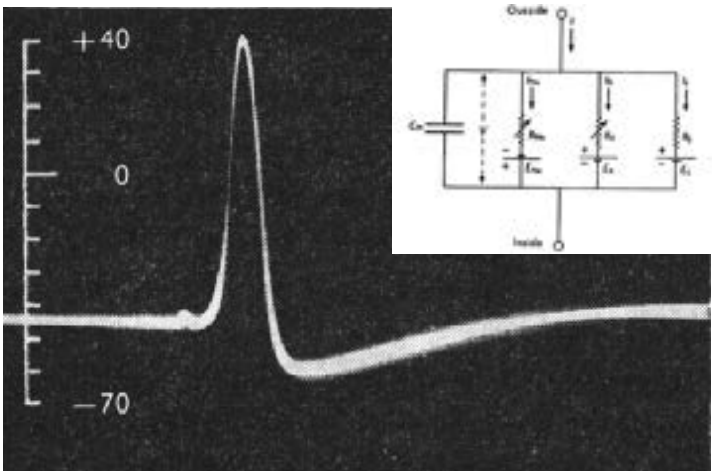
- https://youtu.be/GeQAZt4iEgQ

Google Colaboratory

jupyter

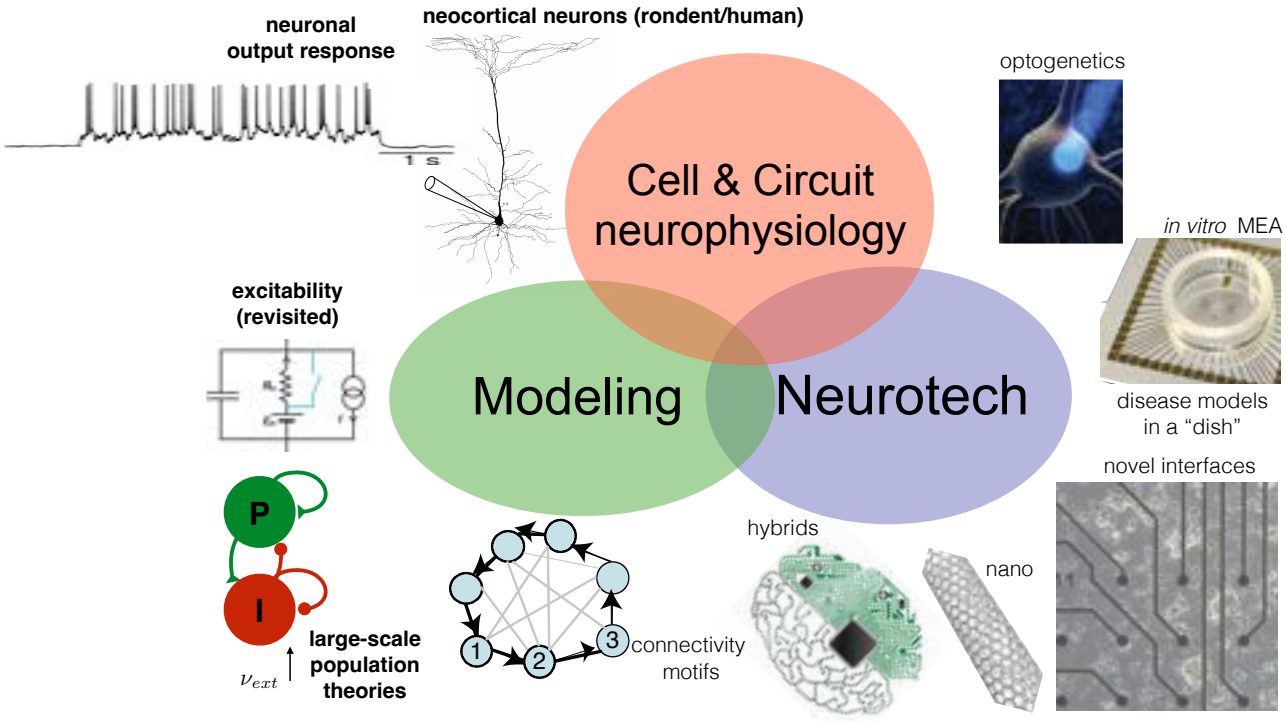
- https://github.com/jupyterlab/jupyterlab-desktop

1997:	Laurea (5 years) in **Electronic/Biomedical Engineering**	(Genova)
2001:	PhD in **Bioengineering** and Computational Neuroscience	(Milano)
2001:	Postdoc in **Cellular Neurophysiology**	(Bern)
2005:	Group Leader in **Microcircuit Neurophysiology**	(Lausanne)
2008:	Prof. of **Neuroscience**	(Antwerpen)
2019:	Prof. of **Physiology**	(Trieste)
2024:	Prof. of **Bioengineering**	(Modena)



$$\frac{dV}{dt} = -\frac{1}{C_M}\{\bar{g}_K n^4 (V - V_K) + \bar{g}_{Na} m^3 h (V - V_{Na}) + \bar{g}_l (V - V_l)\}$$

Background and (my) perspective



UNIMORE Caffè SCIENZA
Insolite chiacchiere da bar

www.caffescienza.unimore.it

01/10/2024, 19.00 – 20.30 (tonight!)

Quanto va veloce il pensiero

(**M. Giugliano**) ***Caffè Concerto*** *di Modena (Piazza Grande, 26)*

Study Material (chapters from)

- Halnes et al., (2024) Electric Brain Signals - Cambridge Univ. Press

- Weiss TF (1996) Cellular Biophysics 1-2, MIT Press
- Bear MF, Connors B, Paradiso MA (2006) Neuroscience [..] (ch. 1-4)
- Kandel et al. (2012) Principles of Neural Science, 5th ed., McGraw Hill
- Alberts et al. (2009) Essential Cell Biology, 3rd ed., Garland Science

- Primer on “Brain Facts” (see parts 1-2, 4)
- (few) pages from Longstaff, 2007 (neurons, diversity, CNS)
- “Eye, Brain, and Vision” book by D. **Hubel** (ch. 1-5)

(BIOLOGICAL) SIGNALS

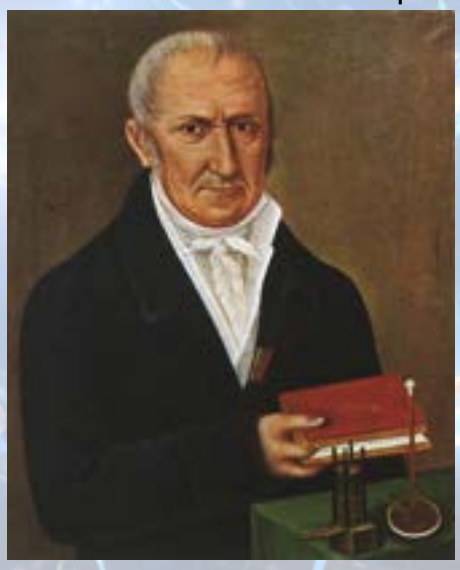
- A "***signal***" is physical variable (or observable), subject to **variations**.
- Variations may be (e.g.) through time **t**, through space **x,y,z**,….
- It is represented as a scalar/vector *function* of **indep.** variable(s).
- Examples of (known) functions: f(**t**) = $sin(2\pi\ 0.1\ \mathbf{t})$ g(**x**,**y**) = $e^{(\mathbf{x}+\mathbf{y})}$
- It is represented as a collection of data points, one (more) for each value of the independent variable(s).

- *scalar*: EMG (1d), mono music (1d), b/w photo (2d), b/w video (3d), MRI (3d), fMRI (4d)
- *vector*: velocity of a fly (4d —> 3d), stereo music (1d —> 2d), color of a RGB photo (2d —> 3d)

(BIOLOGICAL) ELECTROPHYSIOLOGICAL SIGNALS

"Animal Electricity" or …conventional Electrical phenomena??

Luigi GALVANI
(1737-1798)



Alessandro VOLTA
(1745-1827)

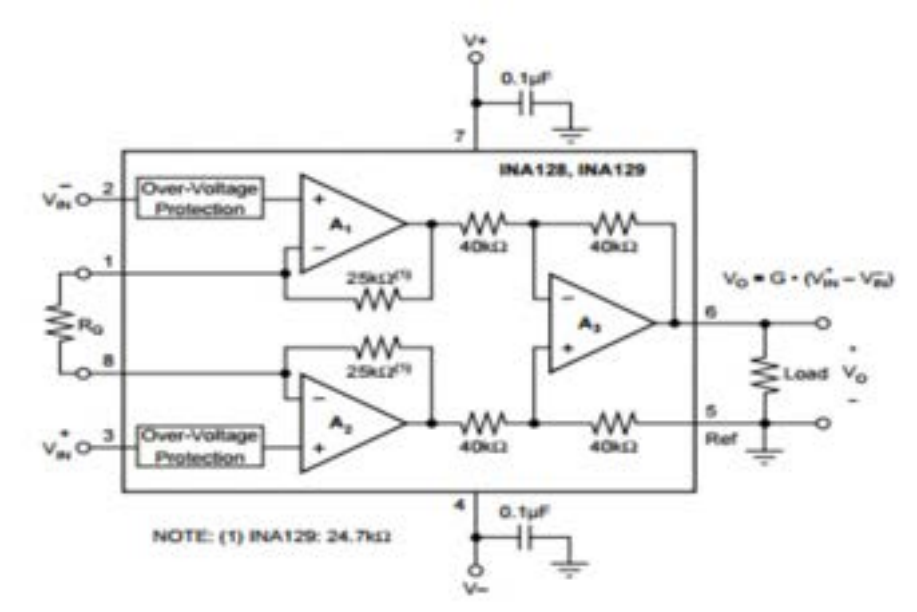
“Animal Electricity” or …conventional Electrical phenomena??

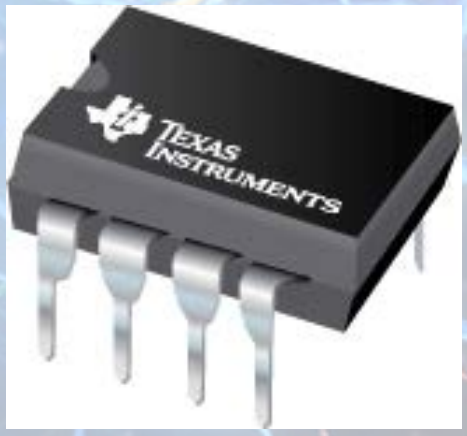
Luigi GALVANI
(1737-1798)

Alessandro VOLTA
(1745-1827)

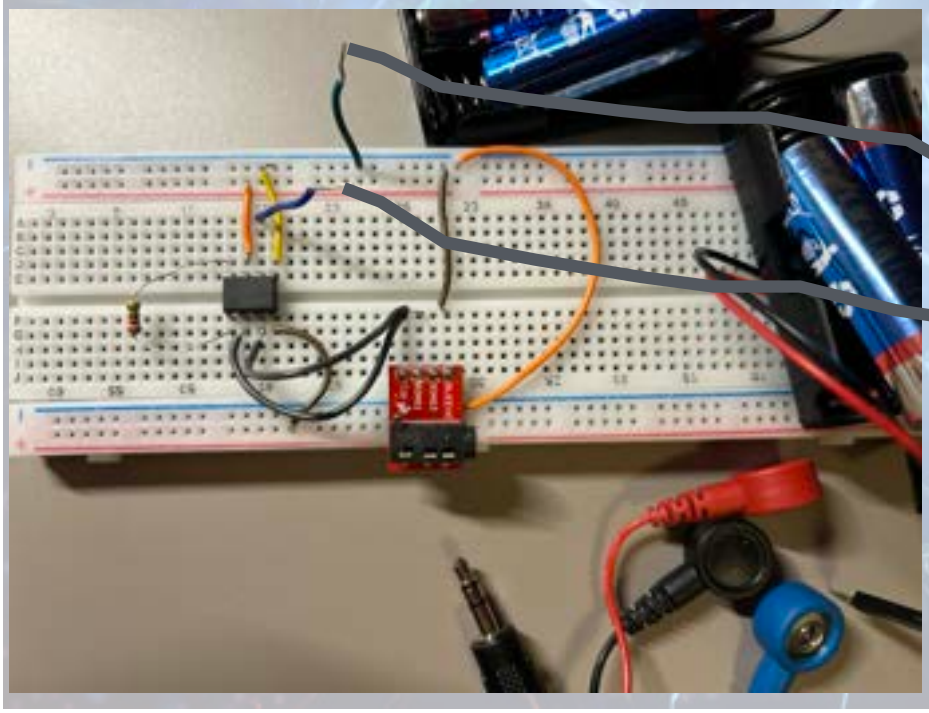
- *connecting* nerves to muscles leads to spasms
- contacting different metals creates an electric field
- passing current through frog leg, it contracts

Is Michele GIUGLIANO like… a frog??!??





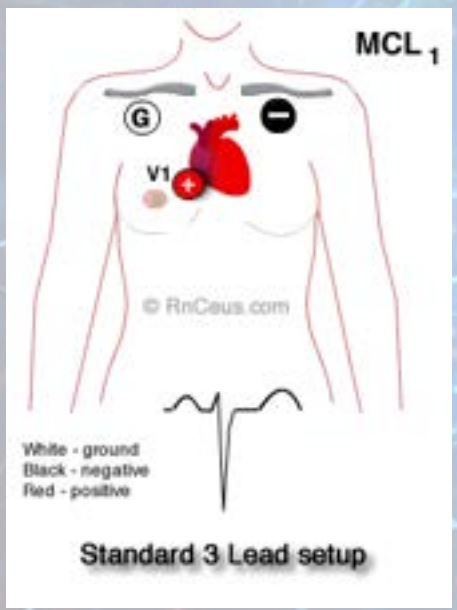
Is Michele GIUGLIANO like… a frog??!??

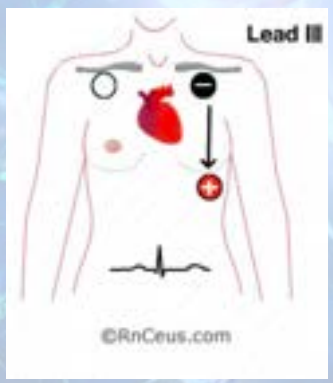


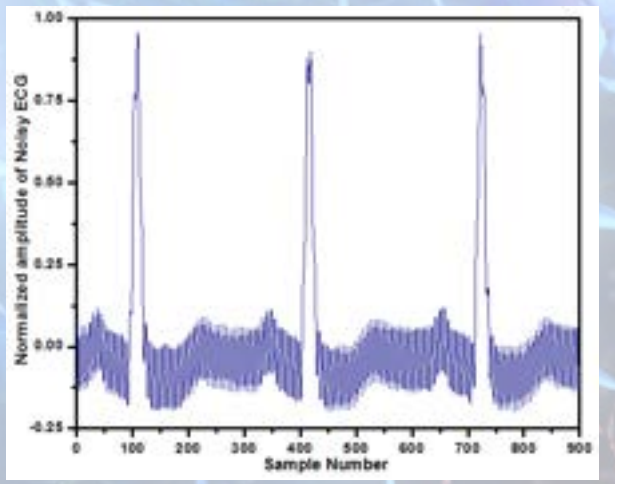
Is Michele GIUGLIANO like… a frog??!??

DEMO TIME!

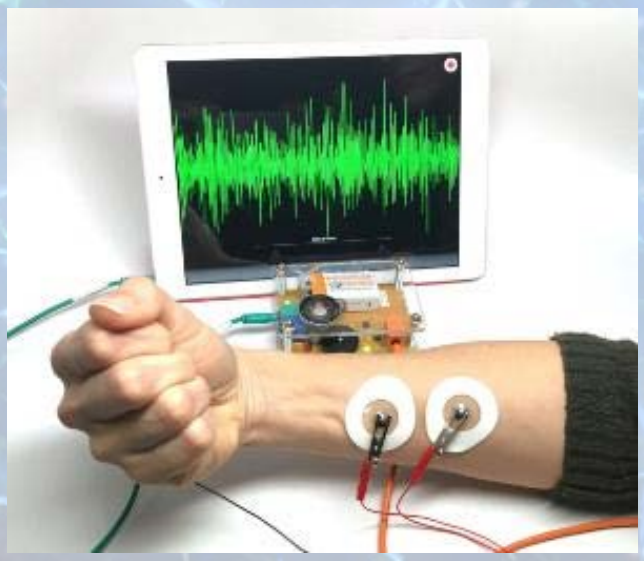
EKG - noise - signals polarity







Motor units - Electromyography



BIOLOGICAL SIGNALS: why bother??!

Basic research

Fundamental understanding of the brain, heart, pancreas, muscles…

Understanding (and treating!) dysfunctions

Epilepsy, schizophrenia, Parkinson's, Motor neuron diseases, Multiple Sclerosis, Alzheimer, Blindness, etc. …diabetes, arhythma, etc.

Neuroprostheses, Neuromodulators, …Electroceutics

Retina/Cochlear implants, (DBS) neuromodulation, brain-machine interfaces, etc.

Reverse engineering the brain

Novel computing paradigms, robotics, computer vision, machine learning, AI,….

Brain (dys)functions

Men ought to know that from nothing else but the brain comes joys, delights, laughter and sports, and sorrows, and griefs, despondency, and lamentations.

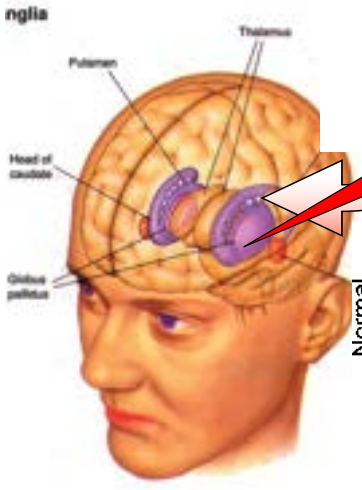
*And by this, in a especial manner, we **acquire wisdom and knowledge,** and **see** and **hear** and **know** what are foul and what are fair, what are bad and what are good, what are **sweet** and what are **unsavory**...*

*And by the same organ we become **mad** and **delirious**, and **fears** and **terrors** assail us...*

*All these things we endure from the brain when it is **not healthy**... In these ways I am of the opinion that **the brain exercises the greatest power in man**.*

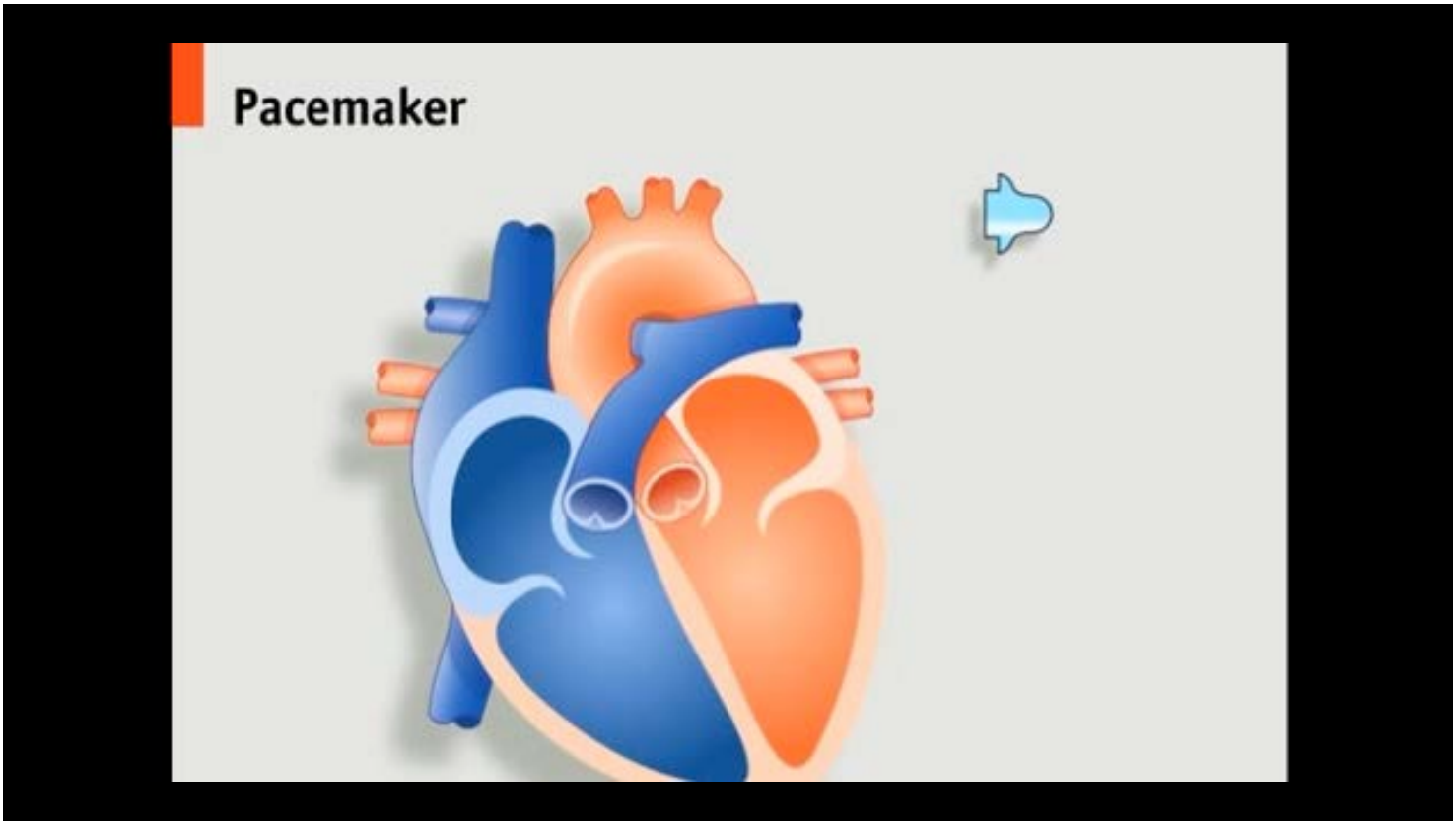
Hippocrates (fourth century B.C.): "*On the Sacred disease*"

Beyond Neuropharmaca: Neuromodulation & Electroceutics



Courtesy of Hagai Berman, HUJI

The Basal Ganglia

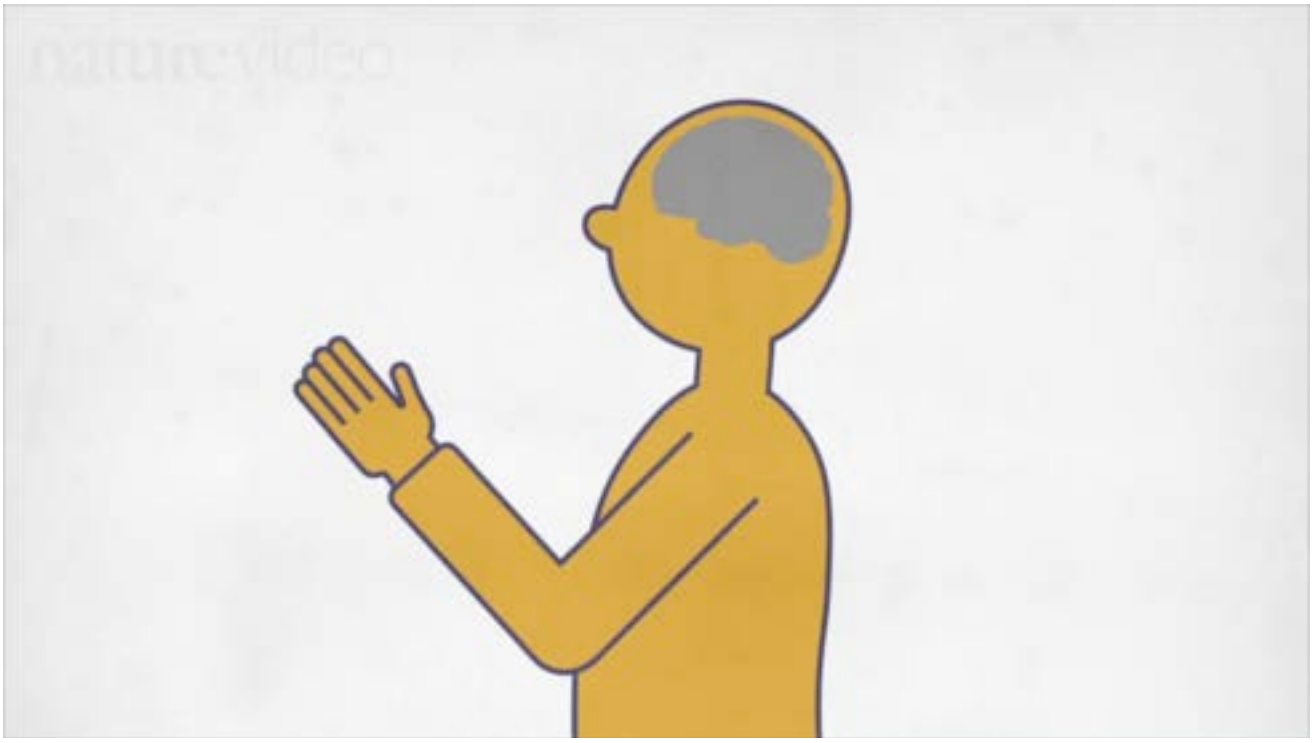


(high-frequency, electrical)
Deep Brain (extracellular) Stimulation

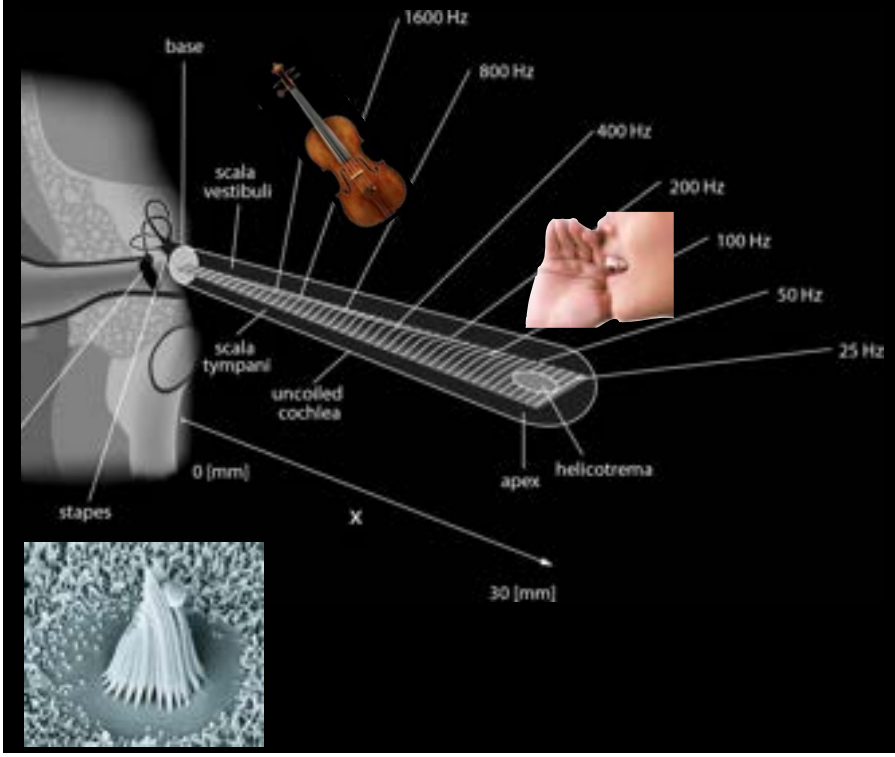
MEDTRONIC's Activa DBS Therapy

Bionics and Neuroprosthetics

Motor (& Sensory) Neuroprosthetics



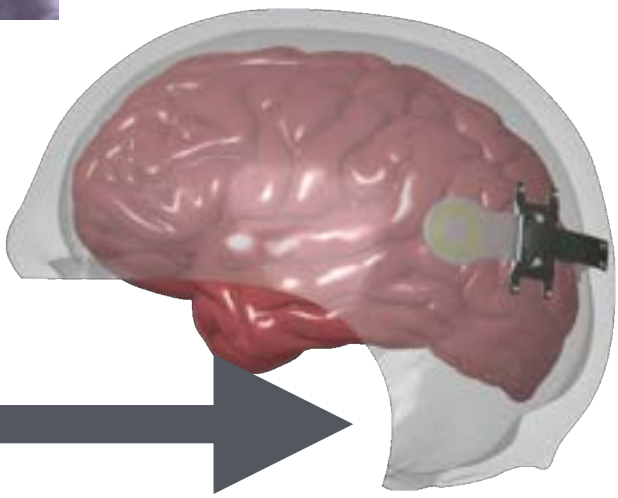
Sensory Neuroprosthetics

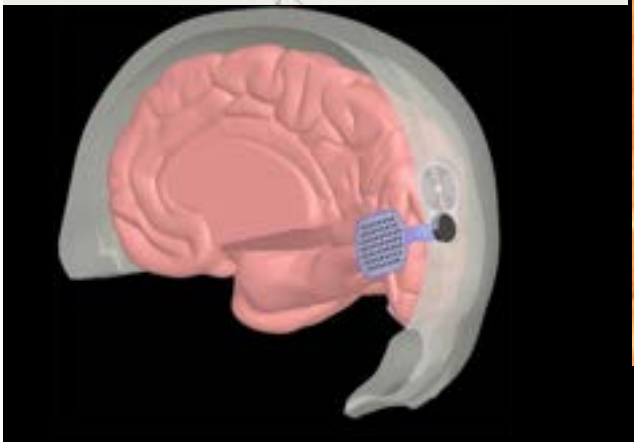


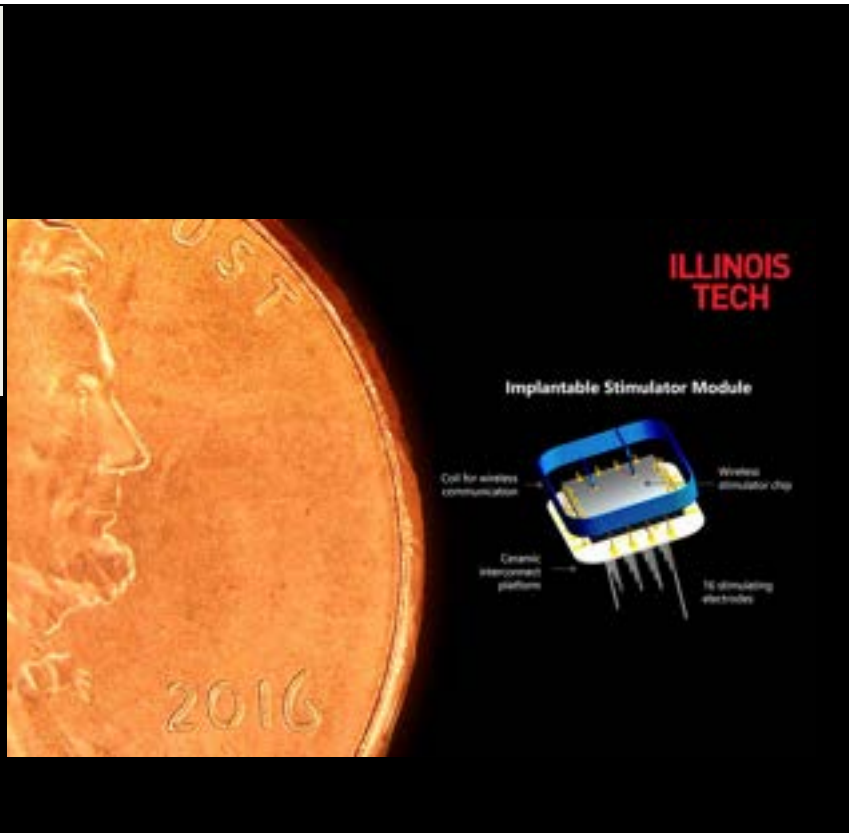
Cochlear

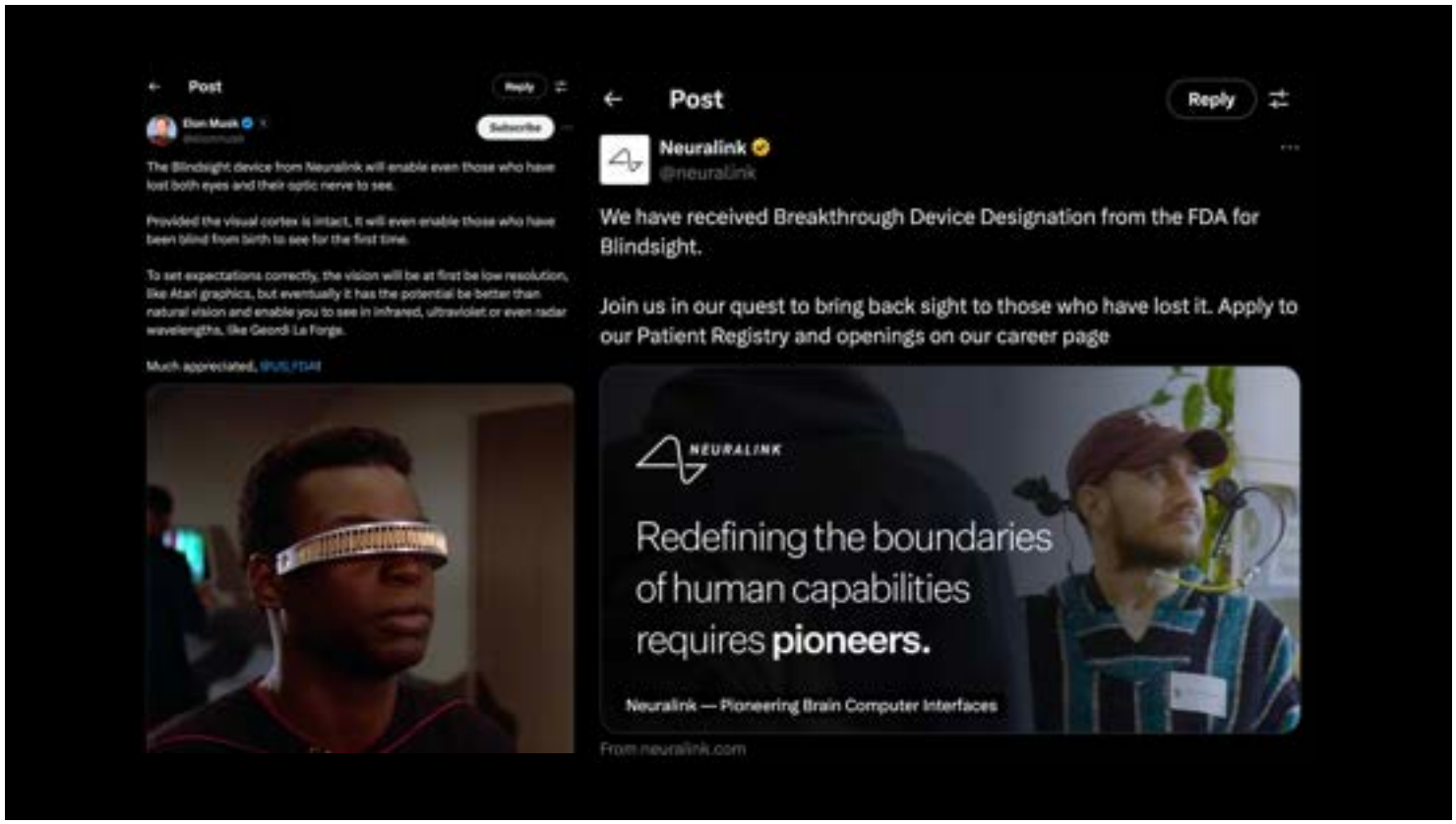
Sensory Neuroprosthetics


'Fantastic technology and a lousy company': Second Sight's 'bionic eyes' have gone obsolete while still implanted, report finds





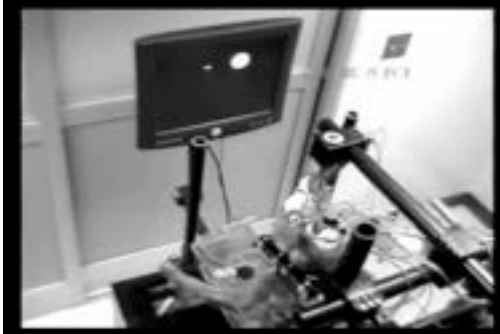

ILLINOIS TECH
Implantable Stimulator Module
2016


Post
Reply
Elon Musk
Subscribe
The Blindsight device from Neuralink will enable even those who have lost both eyes and their optic nerve to see.
Provided the visual cortex is intact, it will even enable those who have been blind from birth to see for the first time.
To set expectations correctly, the vision will be at first be low resolution, like Atari graphics, but eventually it has the potential be better than natural vision and enable you to see in infrared, ultraviolet or even radar wavelengths, like Geordi La Forge.
Much appreciated,
Post
Reply
Neuralink
@neuralink
We have received Breakthrough Device Designation from the FDA for Blindsight.
Join us in our quest to bring back sight to those who have lost it. Apply to our Patient Registry and openings on our career page
NEURALINK
Redefining the boundaries of human capabilities requires pioneers.
Neuralink — Pioneering Brain Computer Interfaces
From neuralink.com


January 2024

2003 (2008)

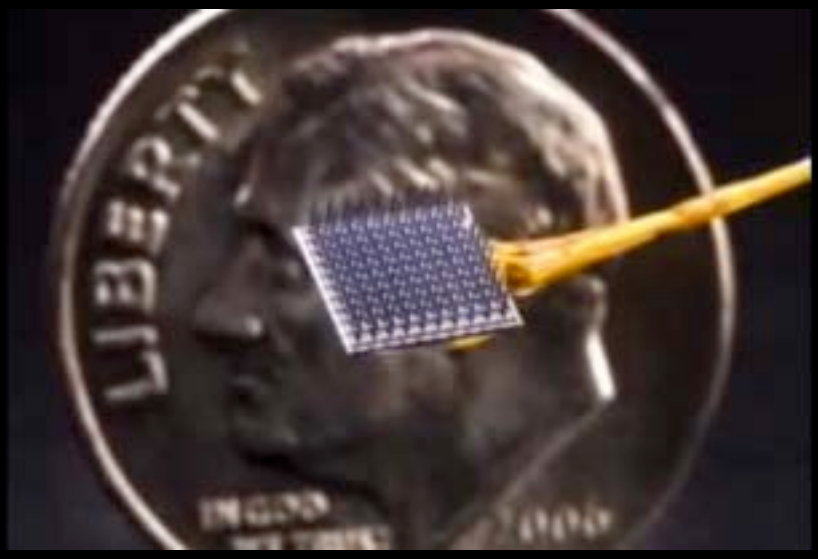
JOYSTICK CONTROL MODE

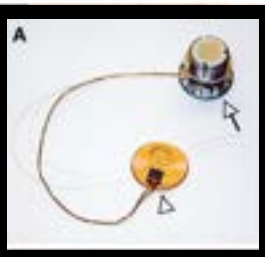


BRAIN CONTROL MODE

Miguel Nicolelis
Duke (US)

Registrazione elettrica:
neuroprotesi motorie artificiali, corticali





2008

Registrazione elettrica:
neuroprotesi motorie artificiali, corticali

2012

Machine Learning and Artificial Intelligence

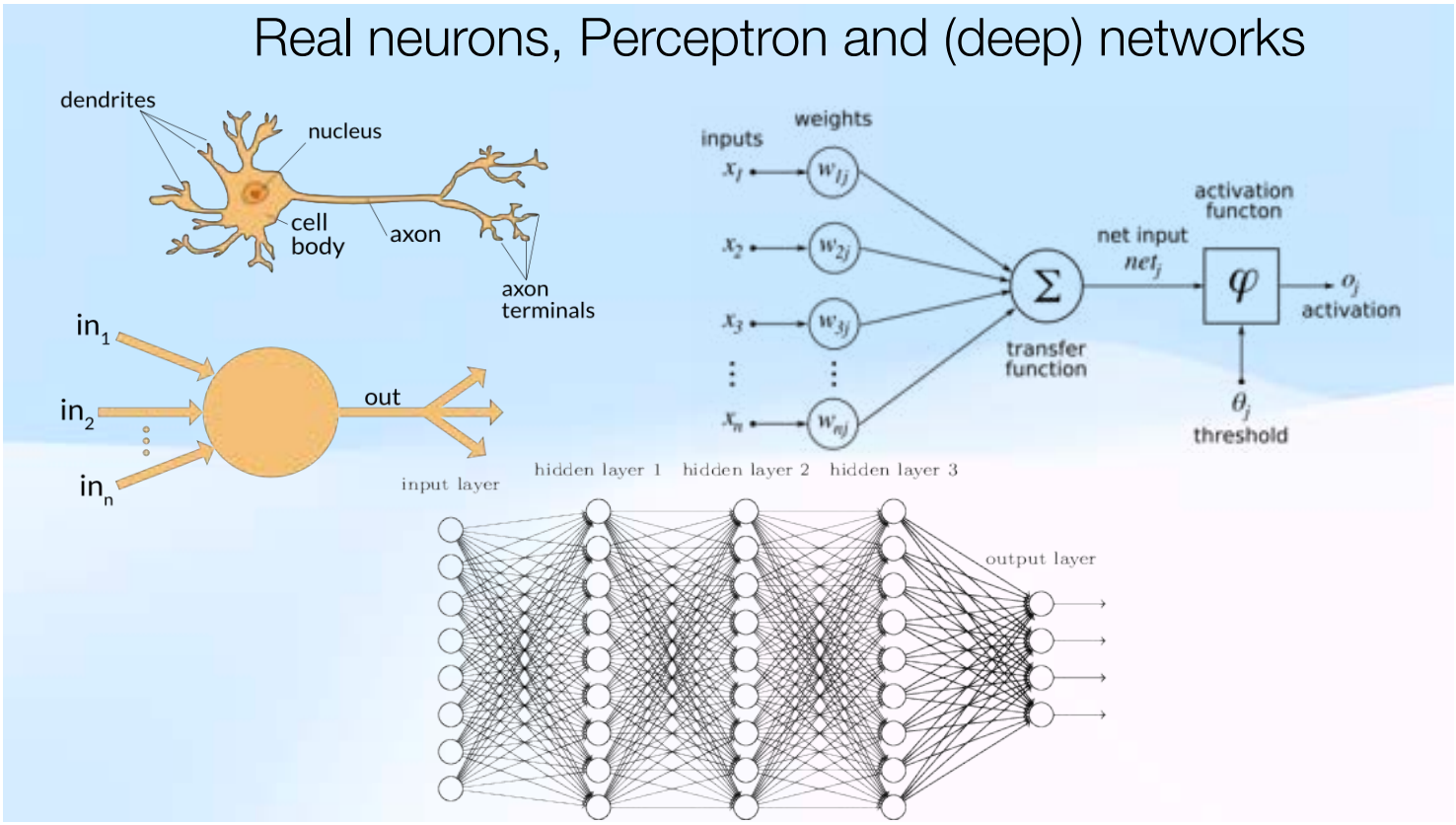
2 gigawatt-hour (GWh) for training
~1000 households over 365 days

2 Wh/query

Neuromorphic engineering

3 Wh
~phone charger

Real neurons, Perceptron and (deep) networks



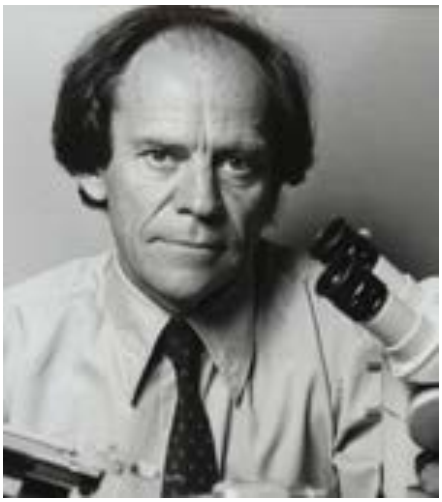
Examples

of (electrophysiological) brain signals

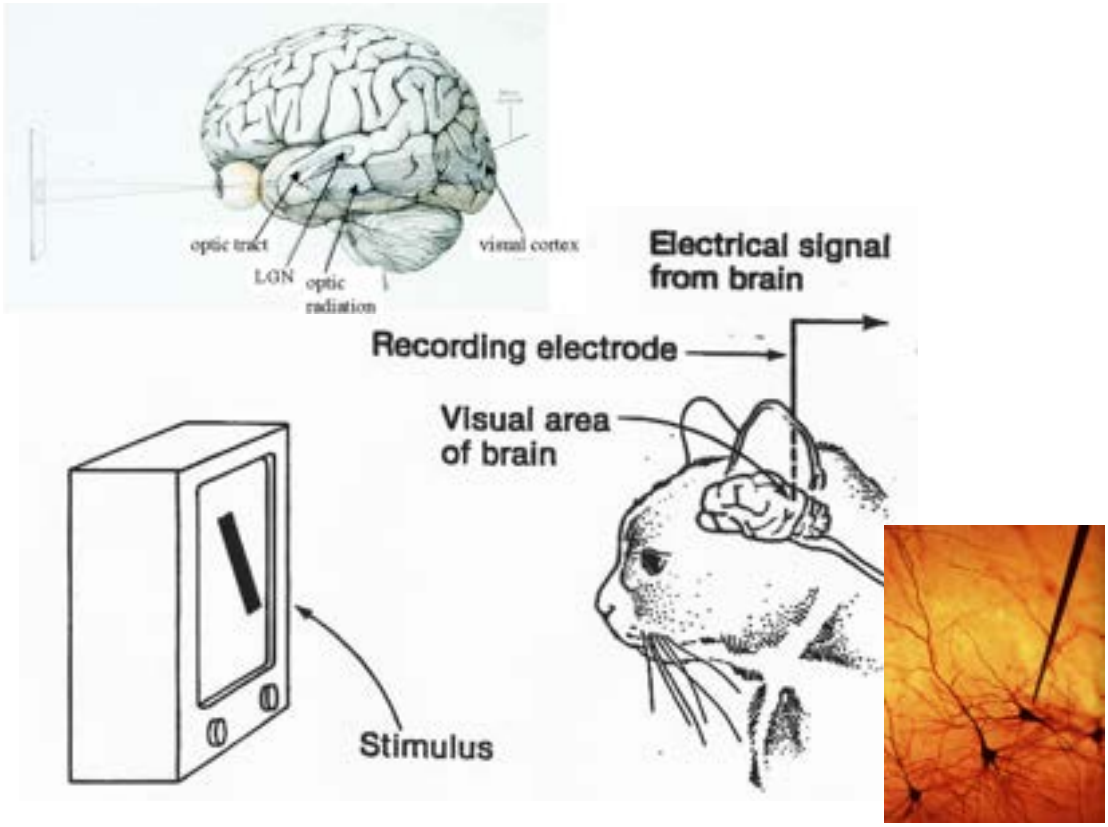
Mammalian Visual System

David Hubel

Torsten Wiesel



Nobel prize for Physiology or Medicine (1981)

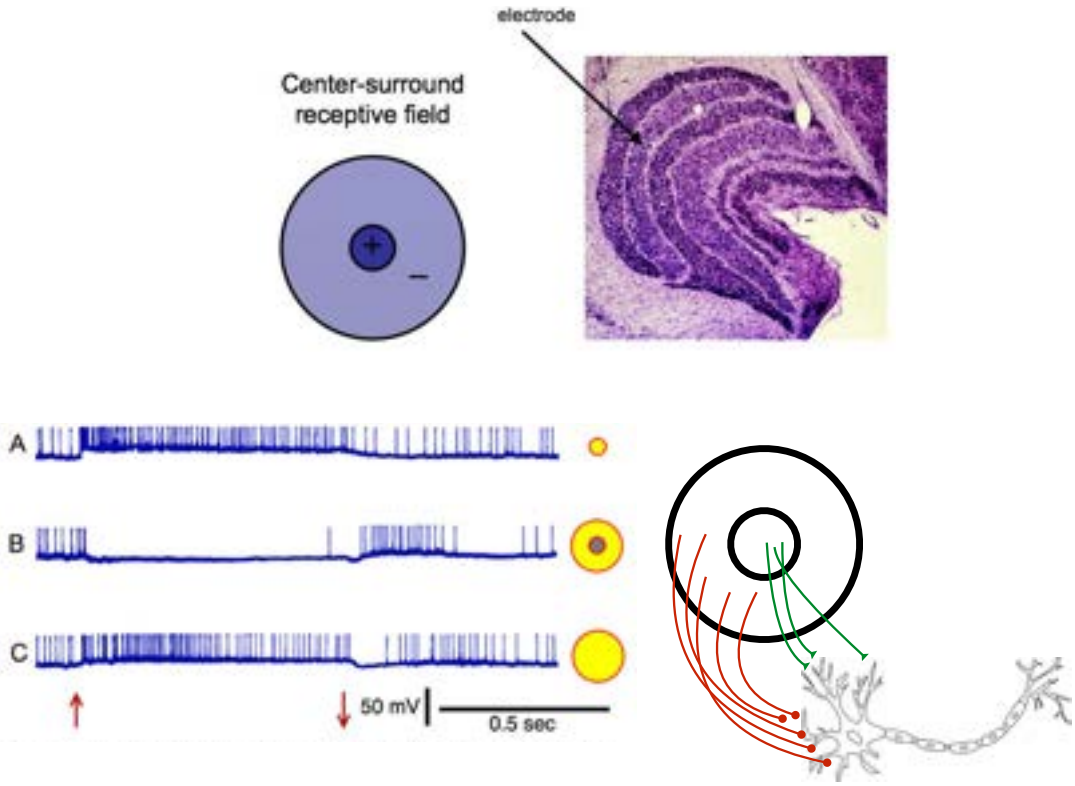


Ganglion cells / LGN cells

center ON - surround OFF

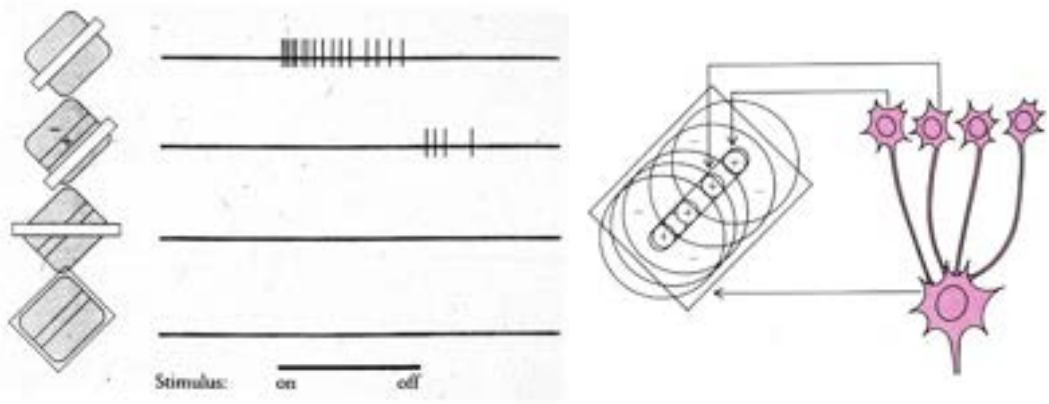
- exist a specific, circular receptive field
- no orientation selectivity
- cells fires action potentials spontaneously, at low rates
- cell fires action potentials when the light is in the center
- cells suppresses its firing when the light is the surround
- cells fires action potentials if light is everywhere
- firing responses are not sustained in time, fatigue, adaptation
- switching off the light over the surround causes rebound firing
- other cells show center OFF - surround ON

It is a contrast feature detector! (detects and relays info on **edges**)


electrode
Center-surround
receptive field
+
–
A
B
C
50 mV
0.5 sec

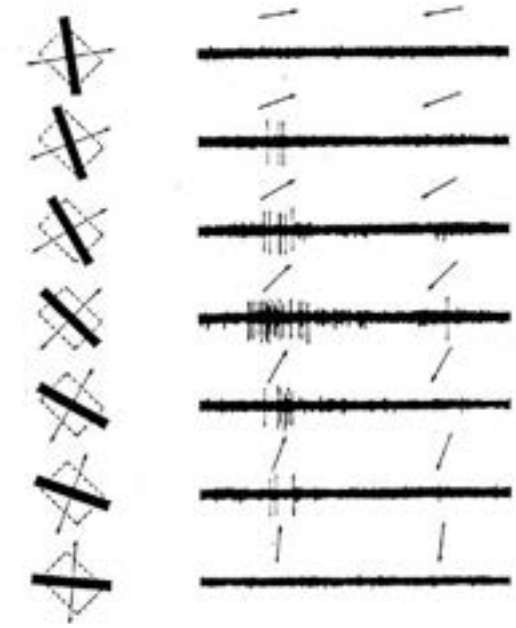
V1 (simple) cells

orientation selective, center-surround



V1 cells

orientation and direction selective



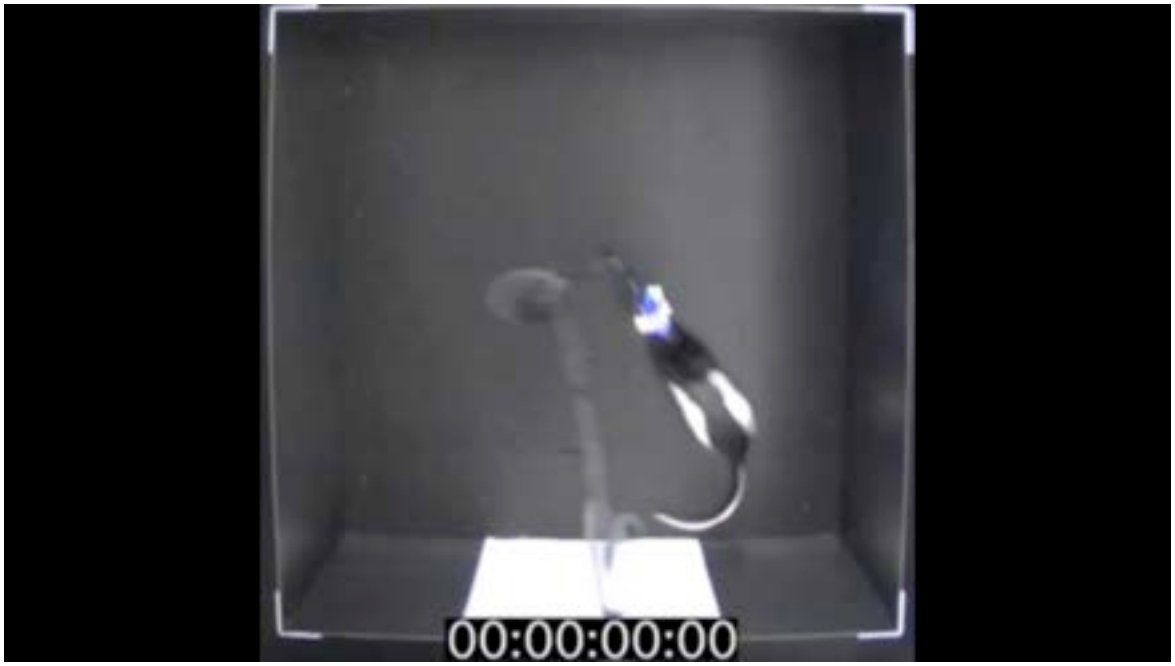
Hippocampus, Enthorinal Cortex: cognition/memory

O'Keefe

Moser & Moser

Nobel prize for Medicine (2014)

Hippocampal “place” cells



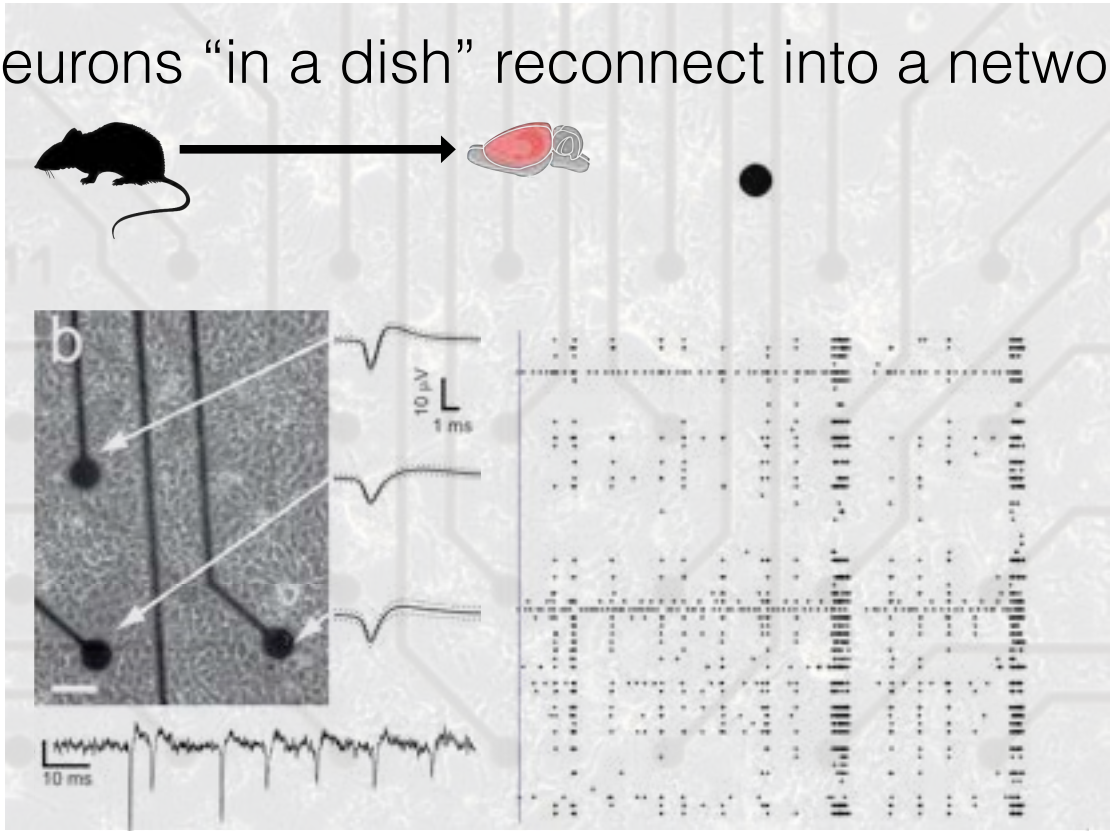
Hippocampal “replay” of memories?
Yes! During stillness and (non)-REM sleep!

Reading the Minds of Rats | Matt Wilson | TEDxCoconutGrove
(20 mins TED Talk)

https://www.youtube.com/watch?v=Vf_m65MLdLI

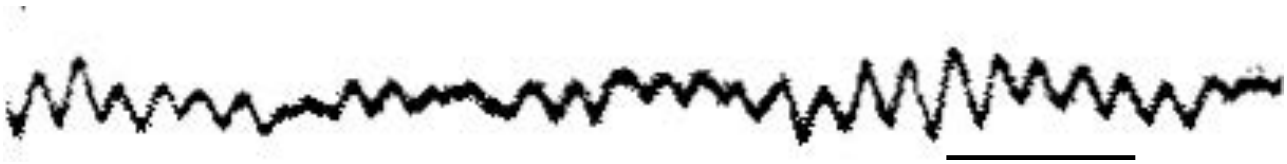
Enthorinal cortex “grid” cells

Neurons “in a dish” reconnect into a network

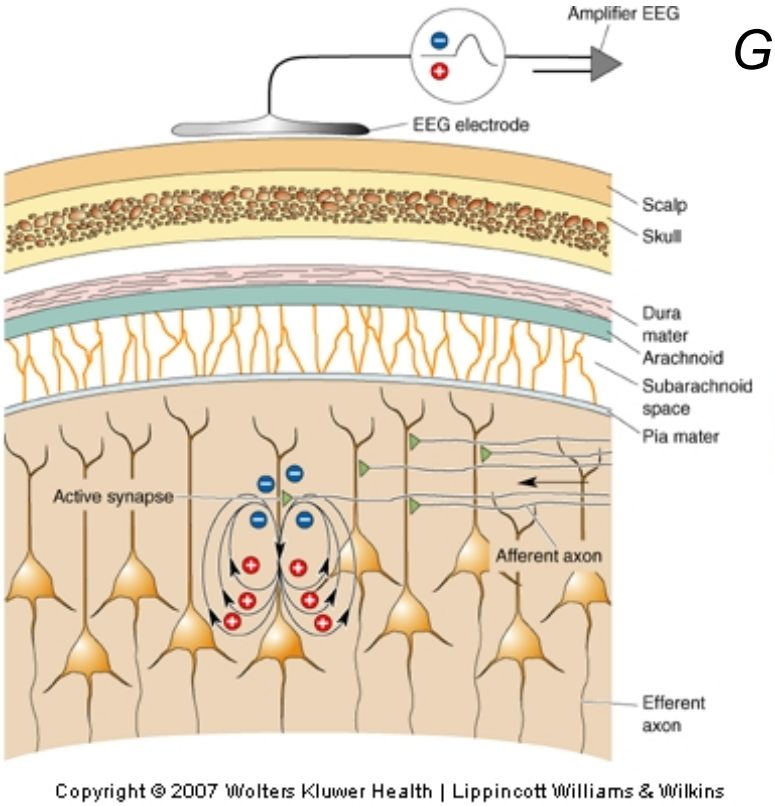


Hans Berger
(1873-1941)

Electroencephalography
EEG



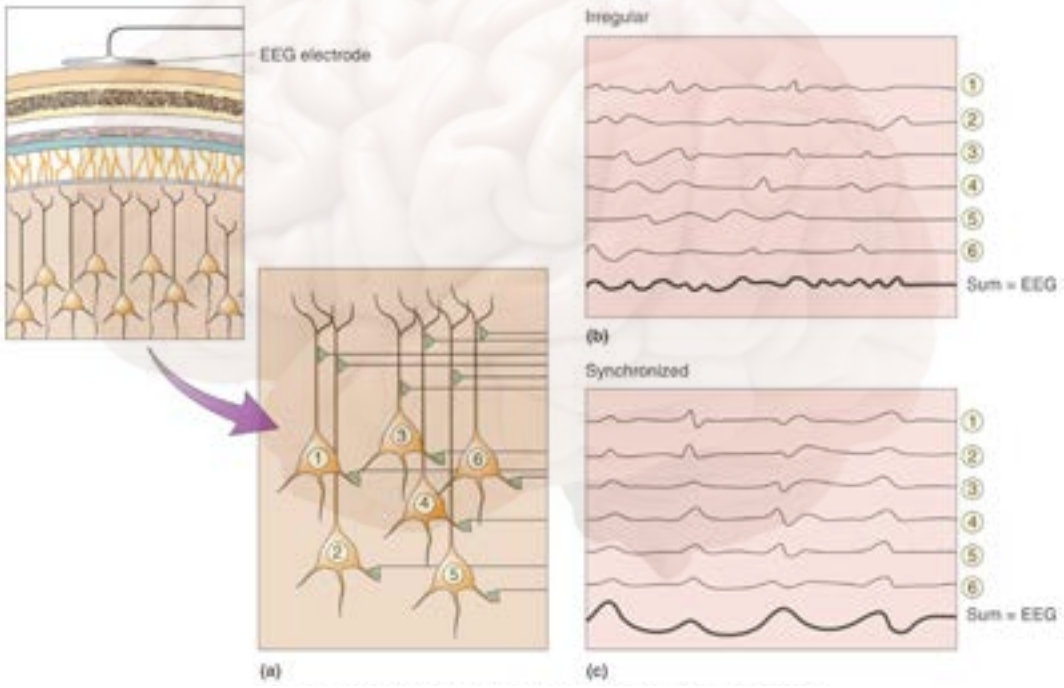
1924



Generation of EEG?

…by the synaptic inputs to the pyramidal neurons
(~80% of cortical cells)

Rhythms in EEG: how?



EEG Rhythms

- EEG Rhythms e.g.
  - Categorization of rhythms based on frequency
    - Beta: Greater than 14 Hz, activated cortex
    - Alpha: 8-13 Hz, quiet, waking state
    - Theta: 4-7 Hz, some sleep states
    - Delta: Less than 4 Hz, deep sleep
  - Deep Sleep
    - High synchrony, high EEG amplitude

Abnormal rhythms & synchronization

epilepsy (~1% of the population)

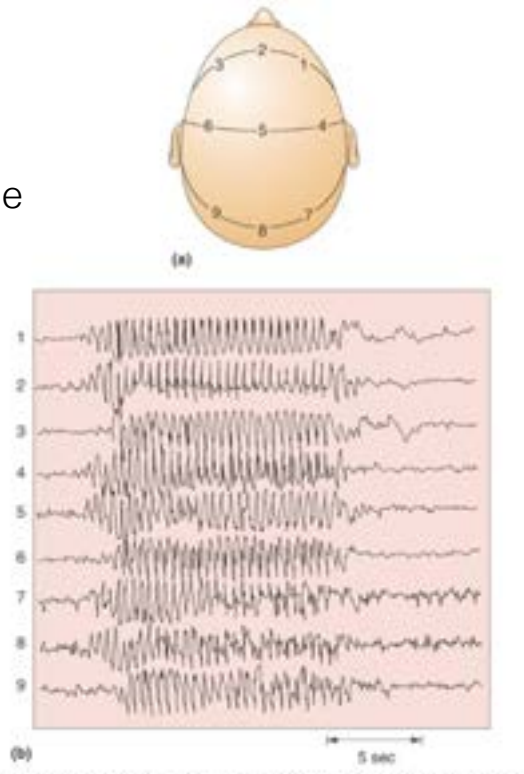
It is a symptom, not a single disease (60% is treated by drugs): spontaneous and recurrent occurrence of **seizures**, a sudden excessive discharge of CNS electrical activity, causing unexpected changes in behavior, motor function, sensation, consciousness.

400 B.C. Hippocrates; Gospel; Witch hunting (~1400 A.D.)

Epilepsy

- seizures lasting <10 min do not cause brain damage
- no correlation to IQ, to violence..
- not necessarily inherited - unknown causes

- *petit* mal (absence seizures)
- *grand* mal (tonic-clonic seizures)



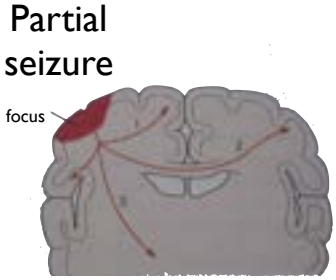
Seizure classifications

- Focal s. (known also as "partial", spatially constrained)
  restricted to only one part of the cortex
- Generalized s. (involving thalamo-cortical circuits??)
  spread to the entire cortex, simultaneous

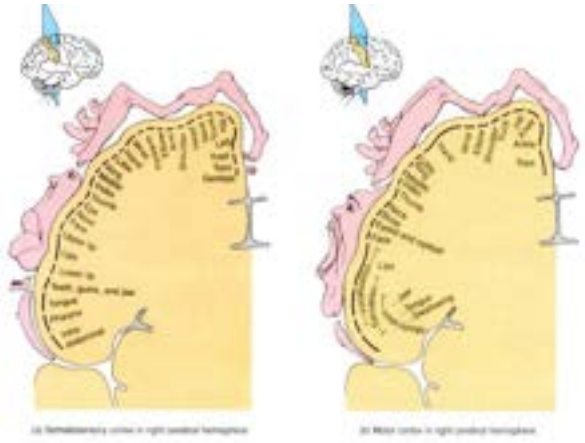
- Simple s.
  consciousness is unaffected (full awareness, although possible impairments in speech)
- Complex s.
  consciousness is impaired during the event (memory system, emotion processing,..)

- Motor s.
  motor areas are involved - tonic - clonic - atonic
- Sensory s.
  sensory areas are involved

(focal, motor) Seizures



Here, not spreading to other areas.



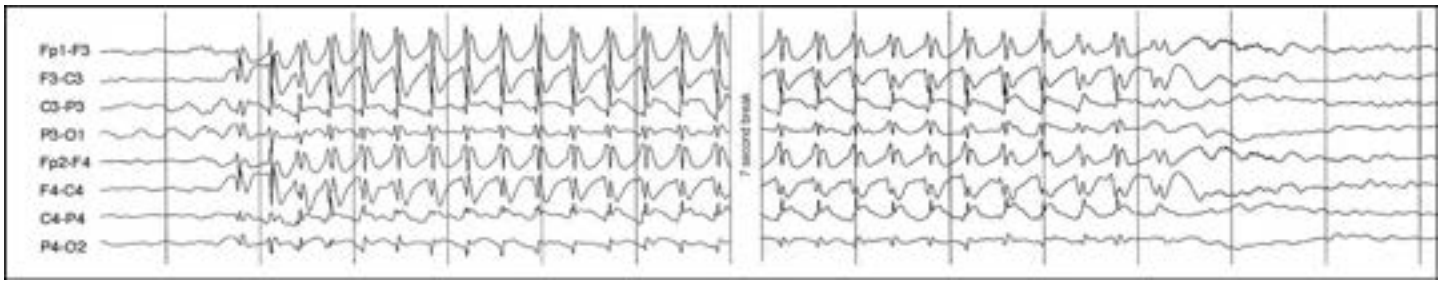
Cortical *homunculus* (Penfield's)

intermittent (clonic) motor activity, consciousness unaffected, unilater character, localization

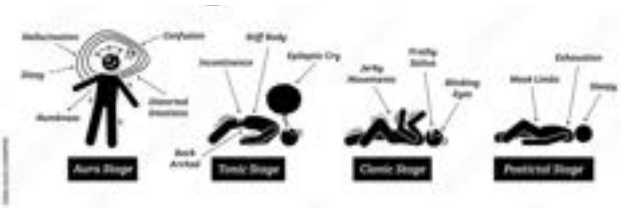
Any idea why it is intermittent ???

(generalized) *Absence* Seizures

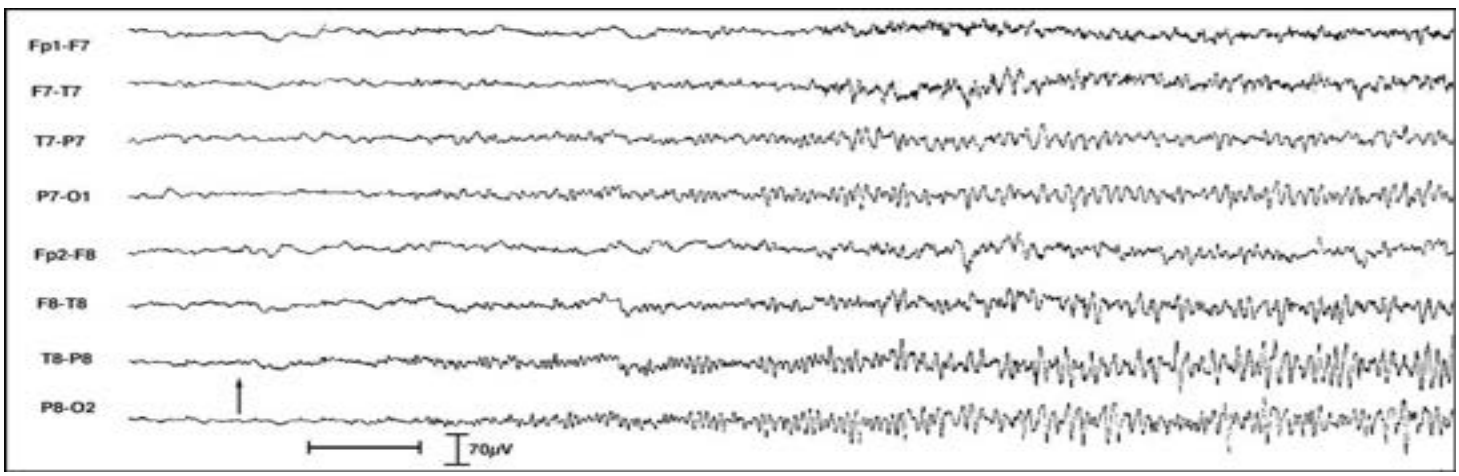
- 2 - 30 seconds episodes, absence, twitching eye movements
- 1-2 times - 100 times a day
- prepubertal age
- stereotypical spike & wave, 3 Hz



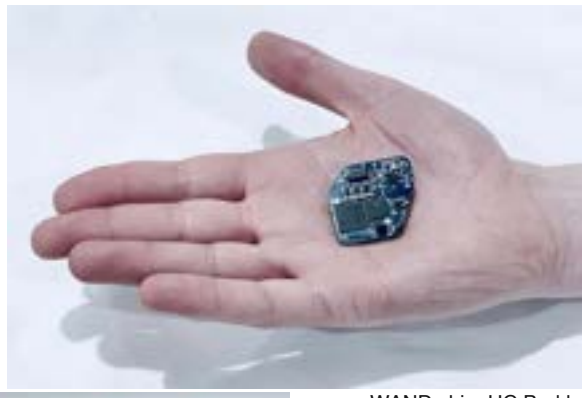
Generalized seizure



Generalized seizure

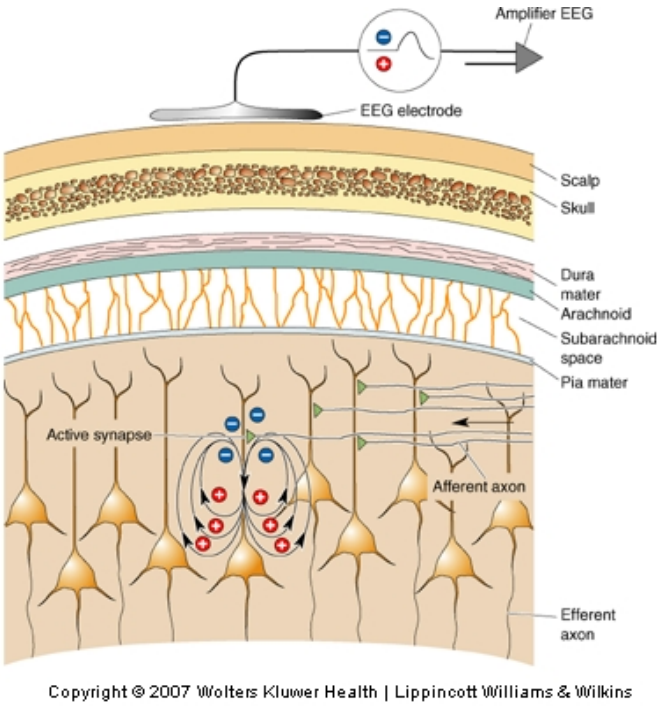


Brain pacemakers… for epilepsy



WAND chip, UC Berkley

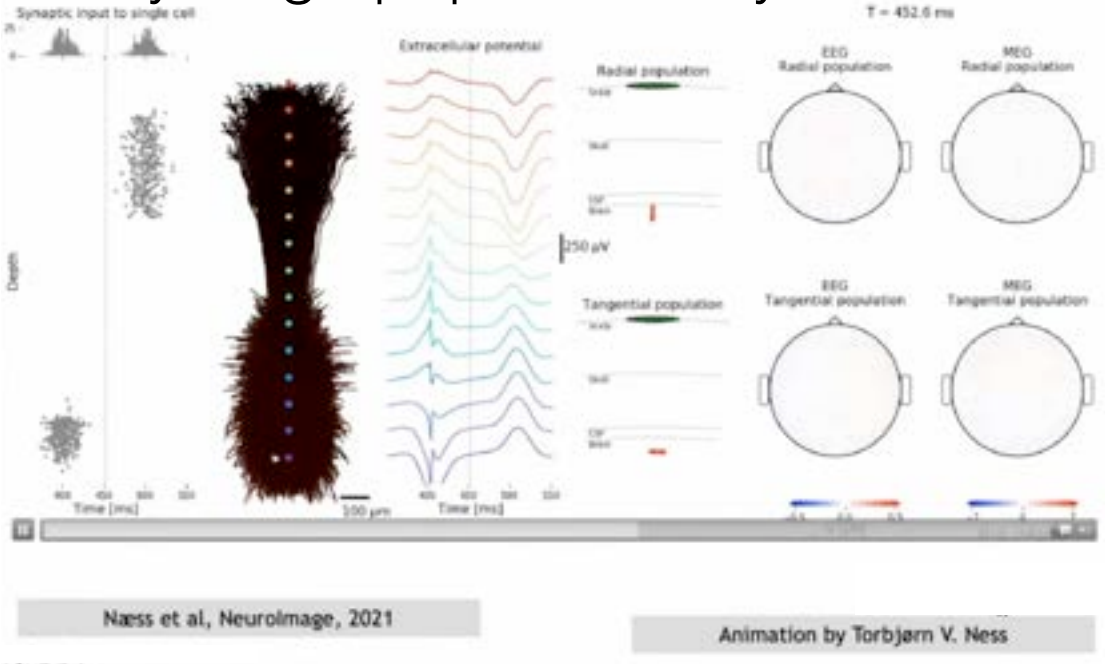
Robert Desimone



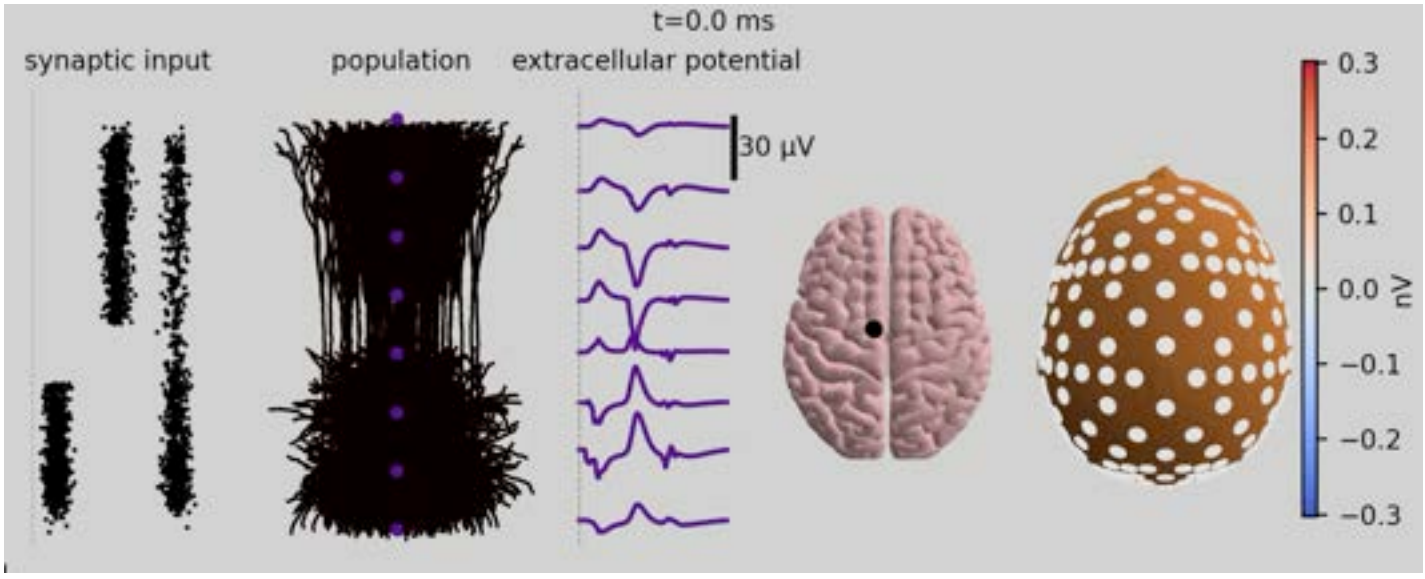
Complex generation!

It calls for an **in-depth** understanding!

Intracellular signals, extracellular signals, geometry, large population, dynamical state…



Courtesy of G. Einevoll



Torbjørn V. Ness's YouTube Channel