Brain Recording Techniques

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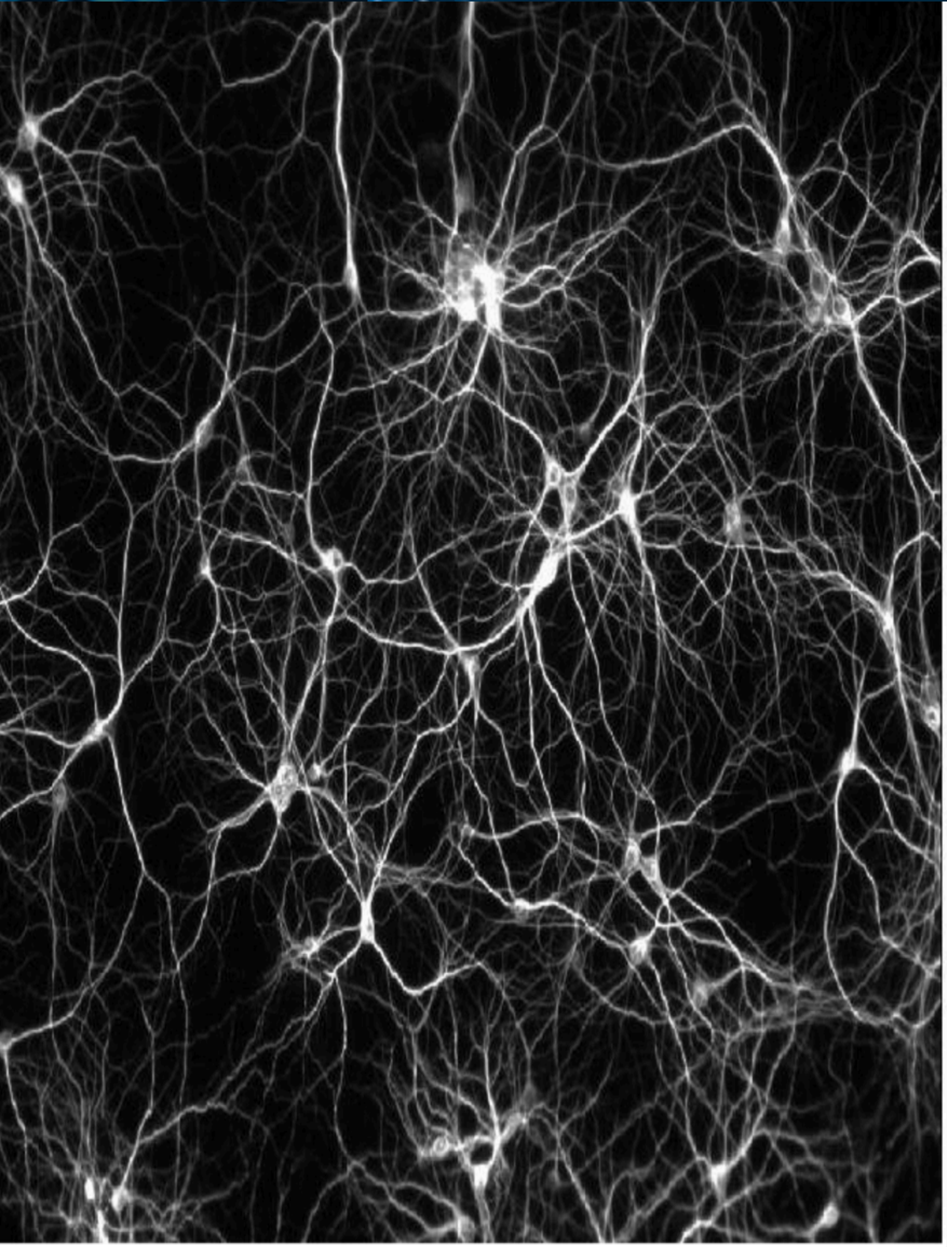
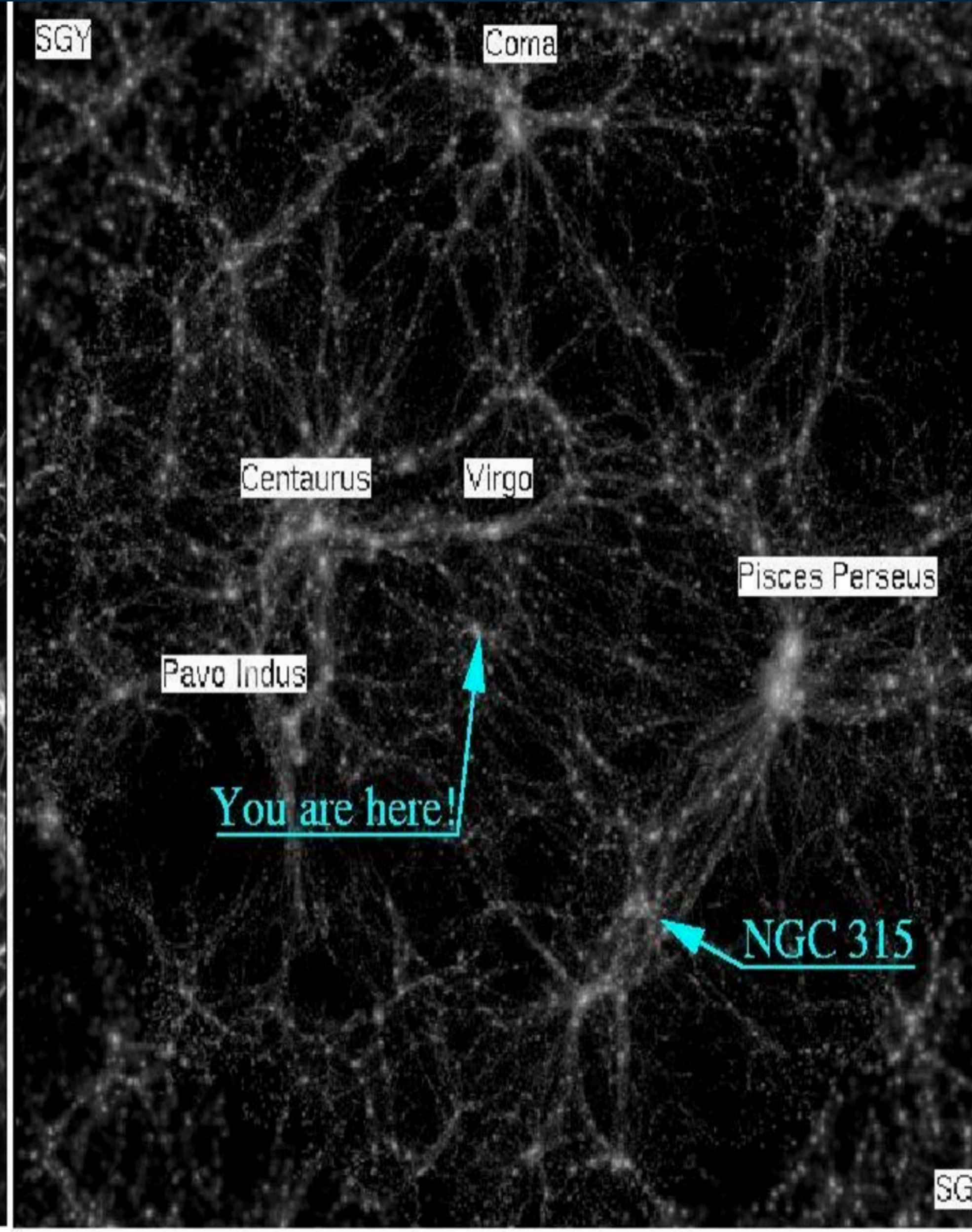
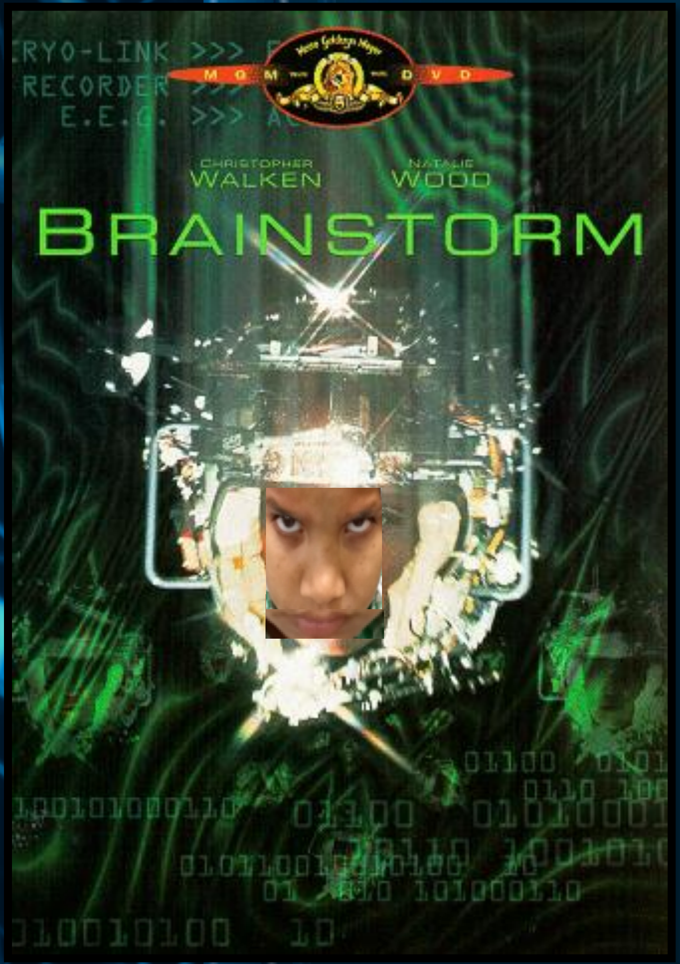
Neurocomputing lab, IIT Delhi

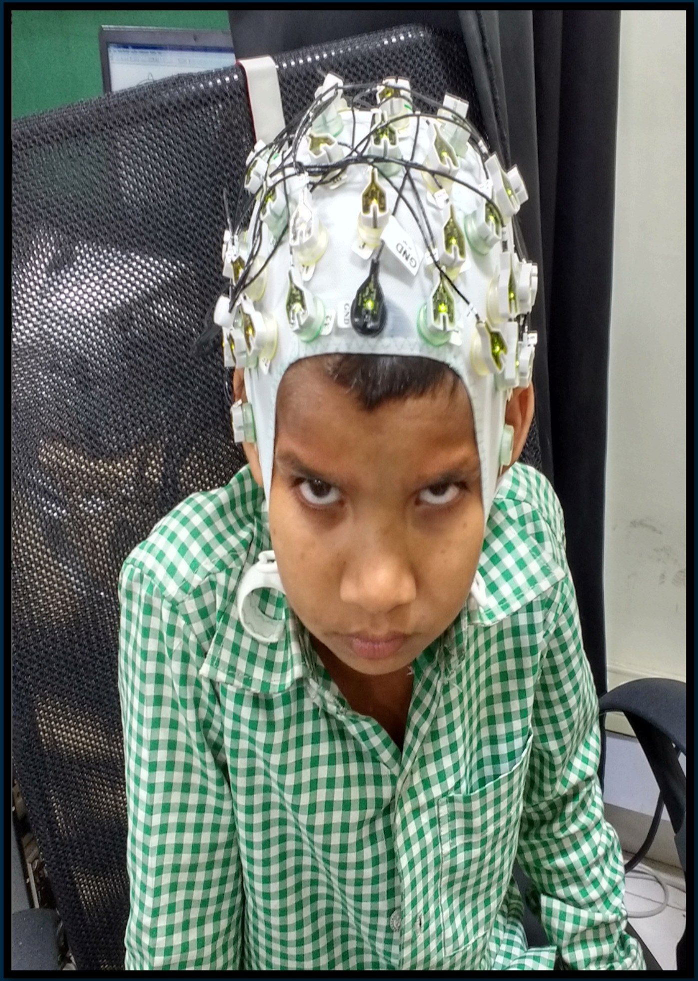




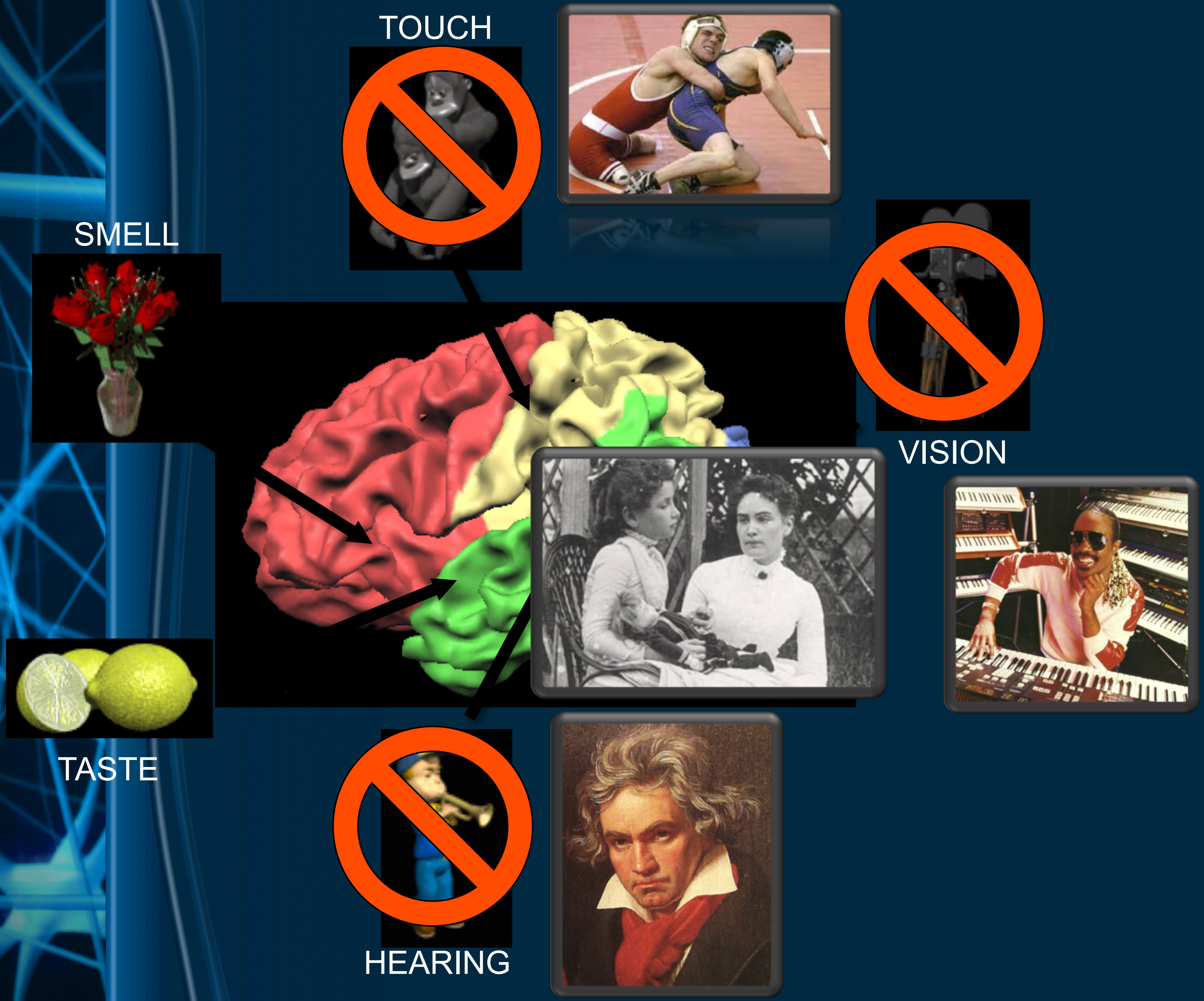
Neurons in the brain. Galaxies in the Universe



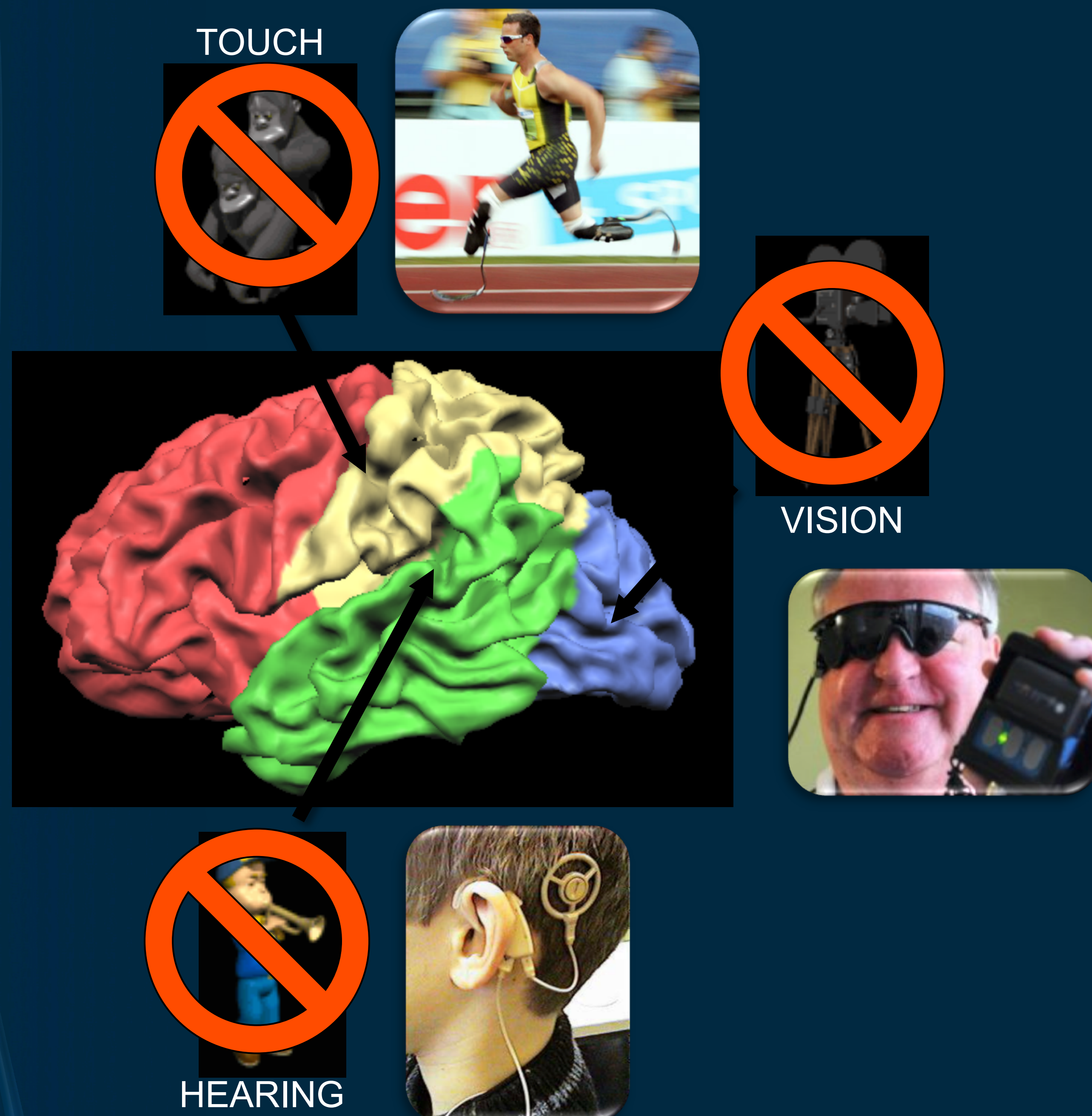
Science Fiction



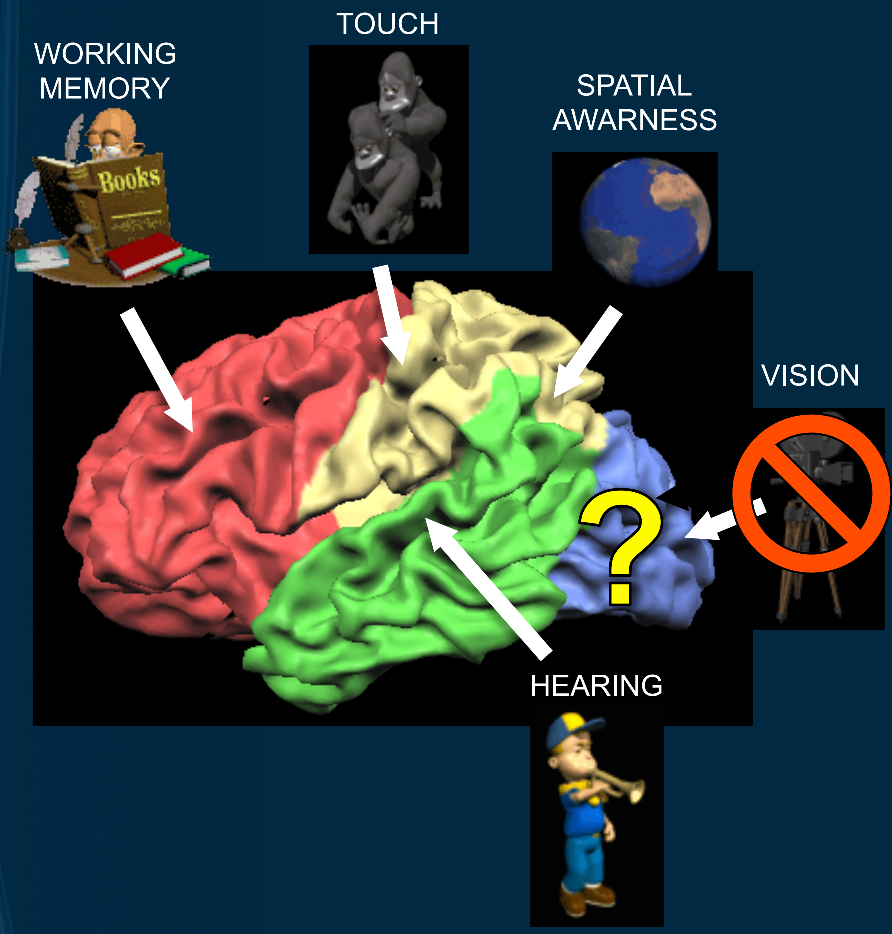
Scientific Reality



TOUCH
SMELL
VISION
TASTE
HEARING


TOUCH
VISION
HEARING

Changes in the Brain as a Result of Ocular Blindness



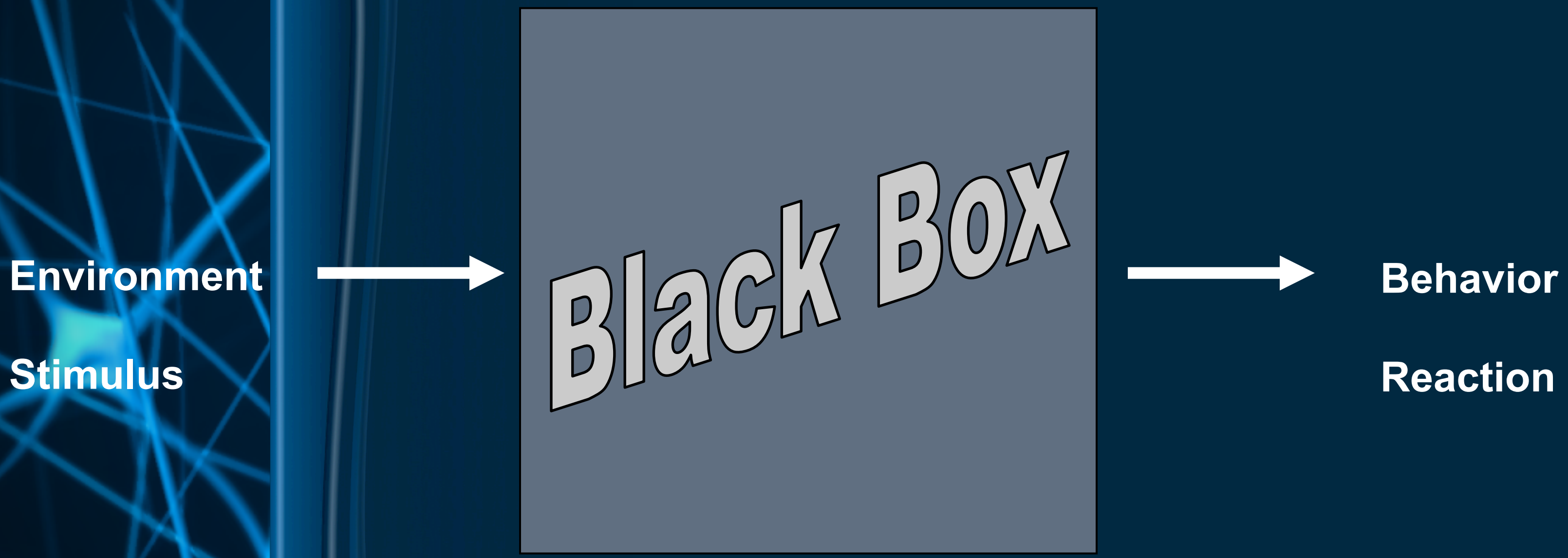
Different Approaches towards Brain and Behavior

Neuroscience:

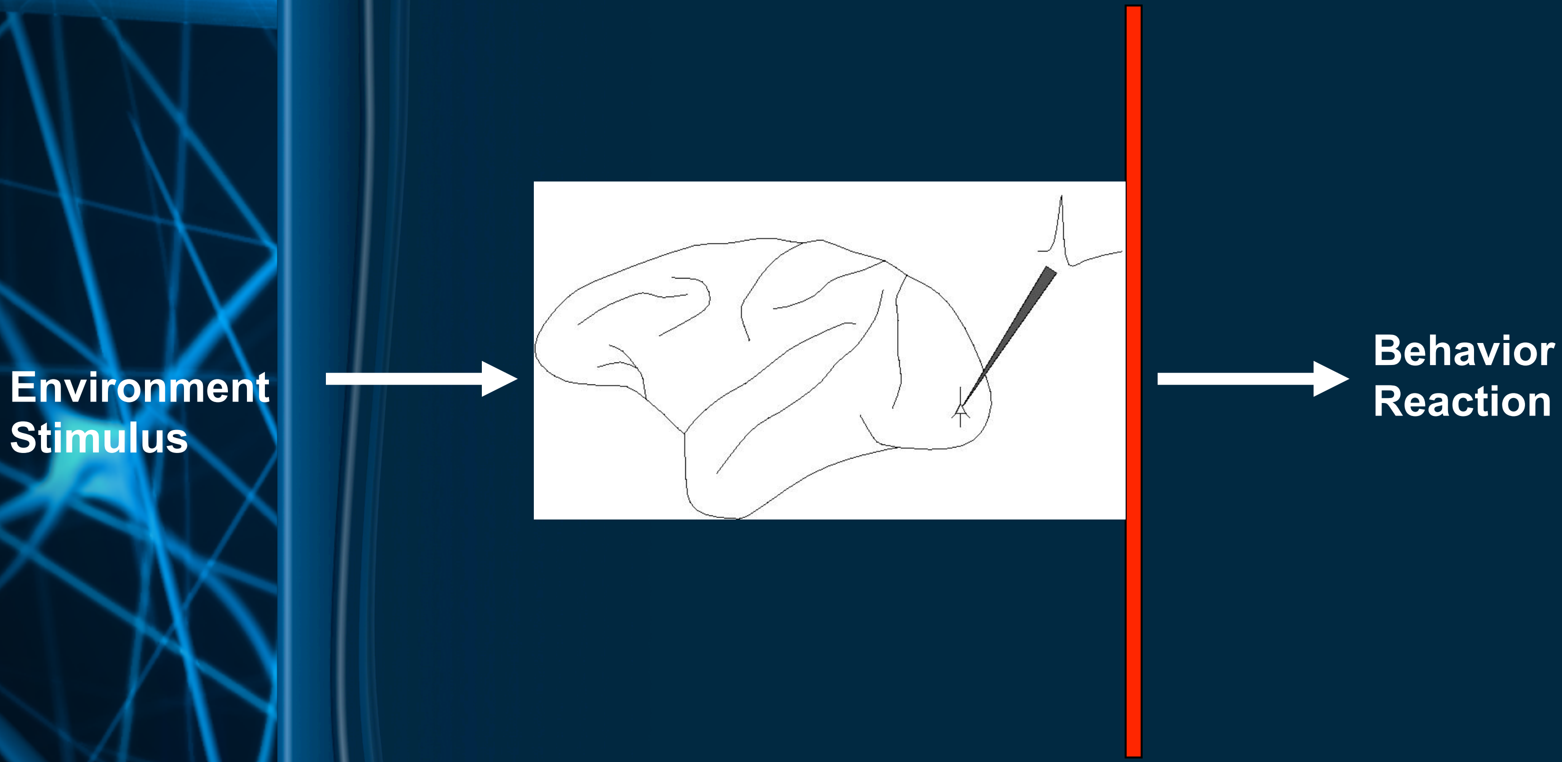
Environment →  → **Behavior**

Stimulus **Reaction**

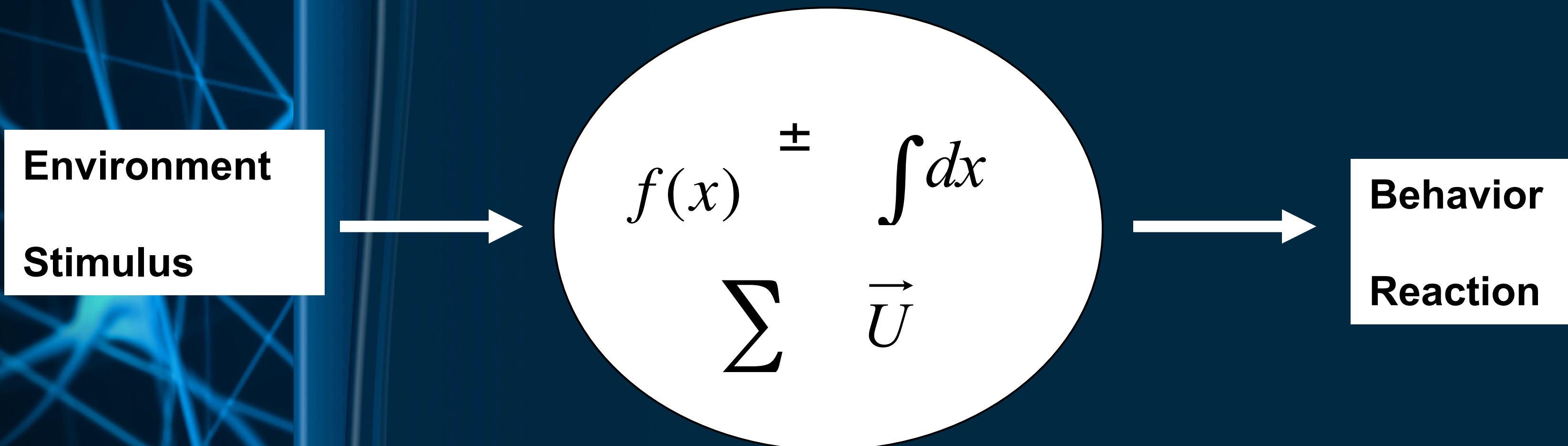
Psychophysics (human behavioral studies):



Neurophysiology:



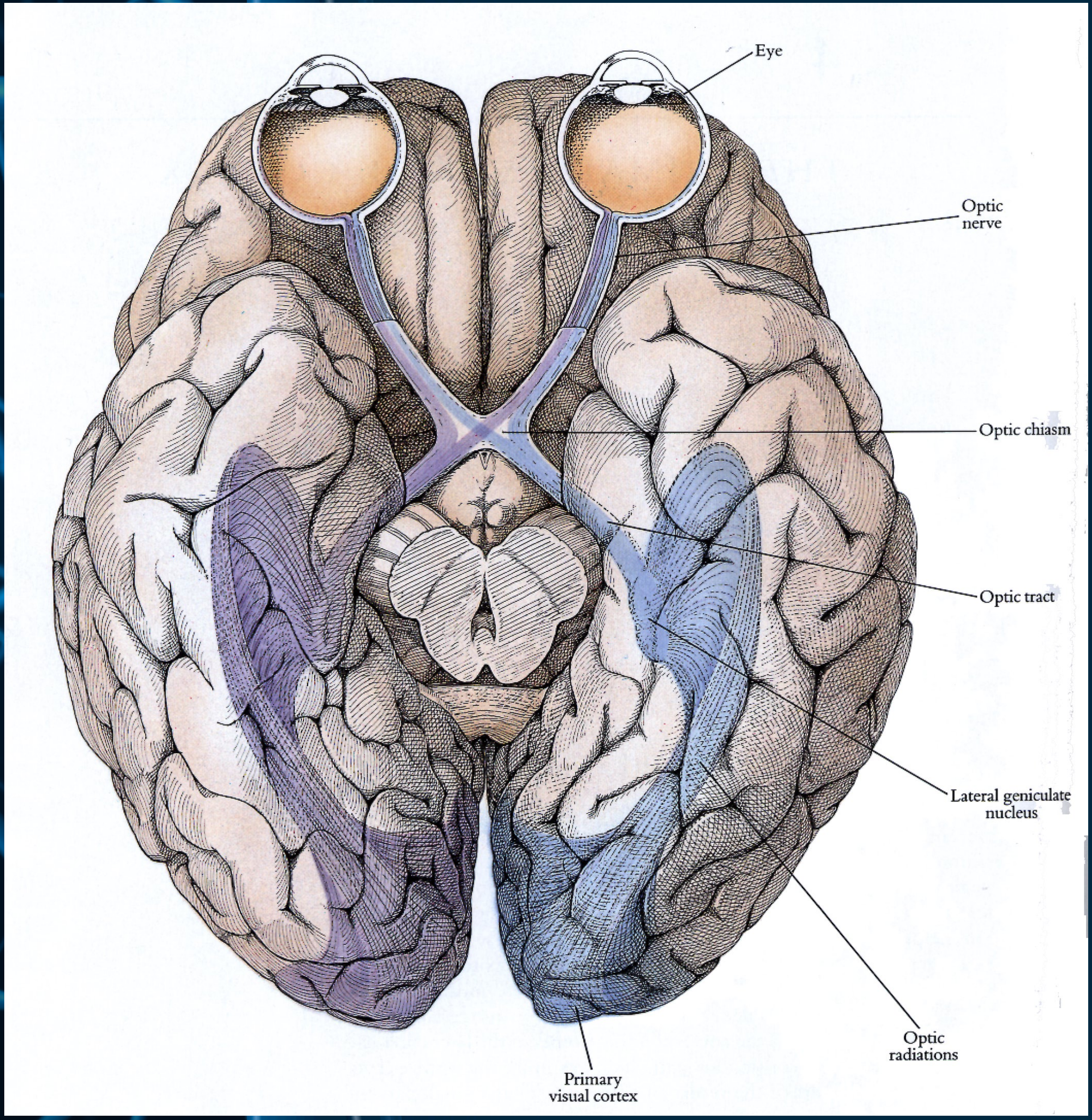
Theoretical/Computational Neuroscience:



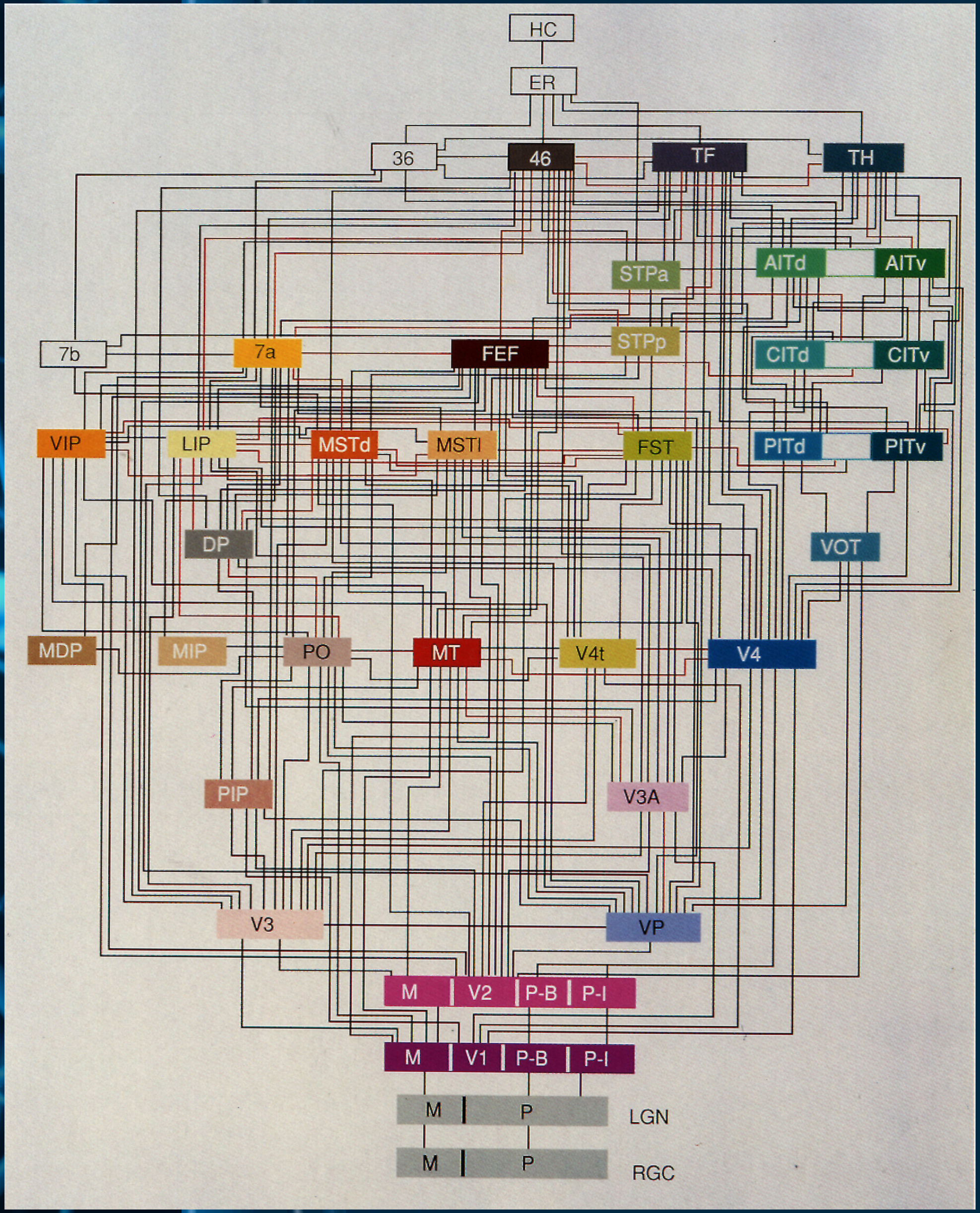
Levels of information processing in the nervous system

1m	CNS
10cm	Sub-Systems
1cm	Areas / Maps
1mm	Local Networks
100µm	Neurons
1µm	Synapses
0.1µm	Molecules

Primary visual Cortex:



Visual System:



More than 40 areas !

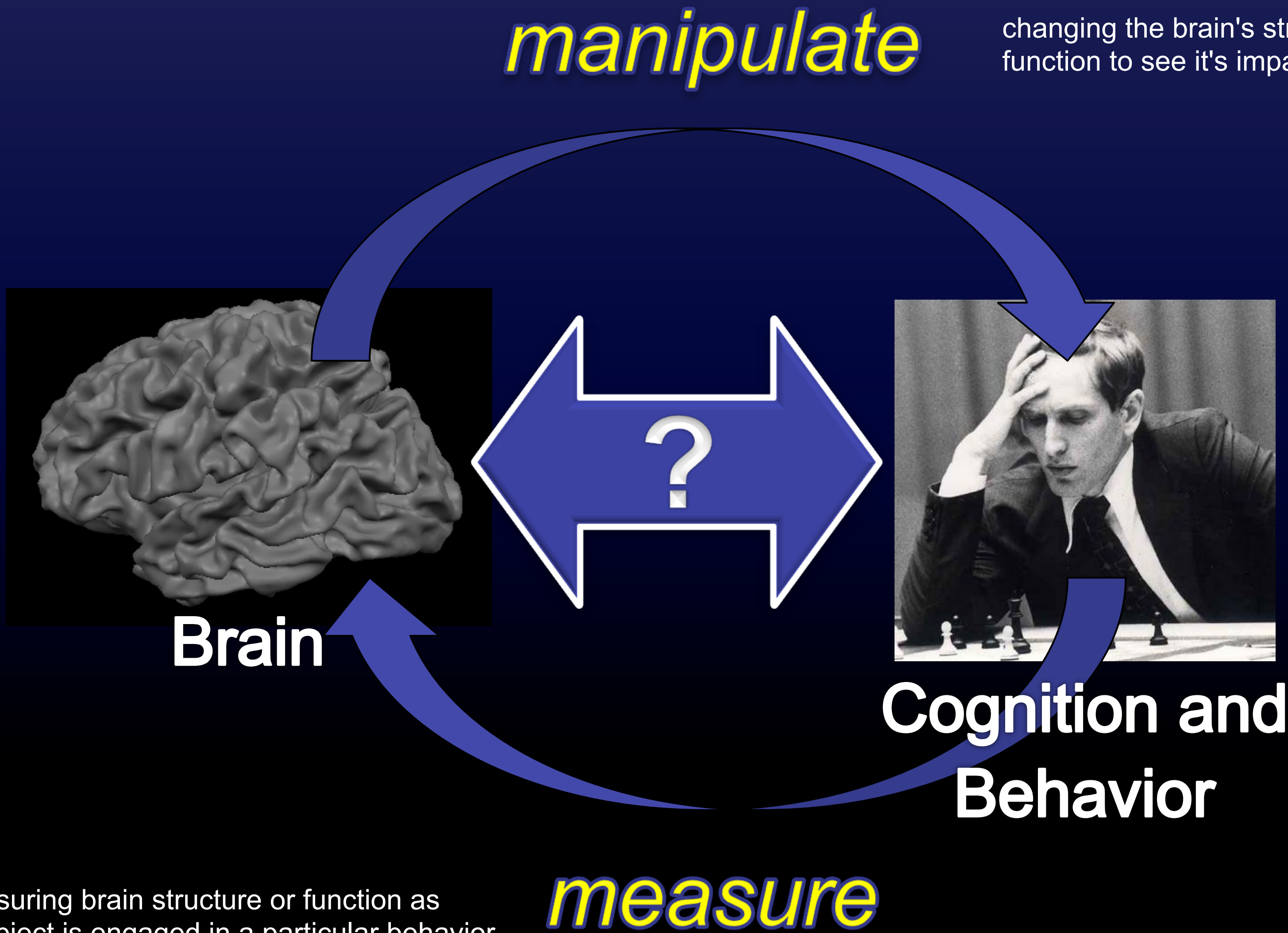
Parallel processing of pixels and image parts

Hierarchical Analysis of increasingly complex information

Many lateral and feedback connections

putting it together...

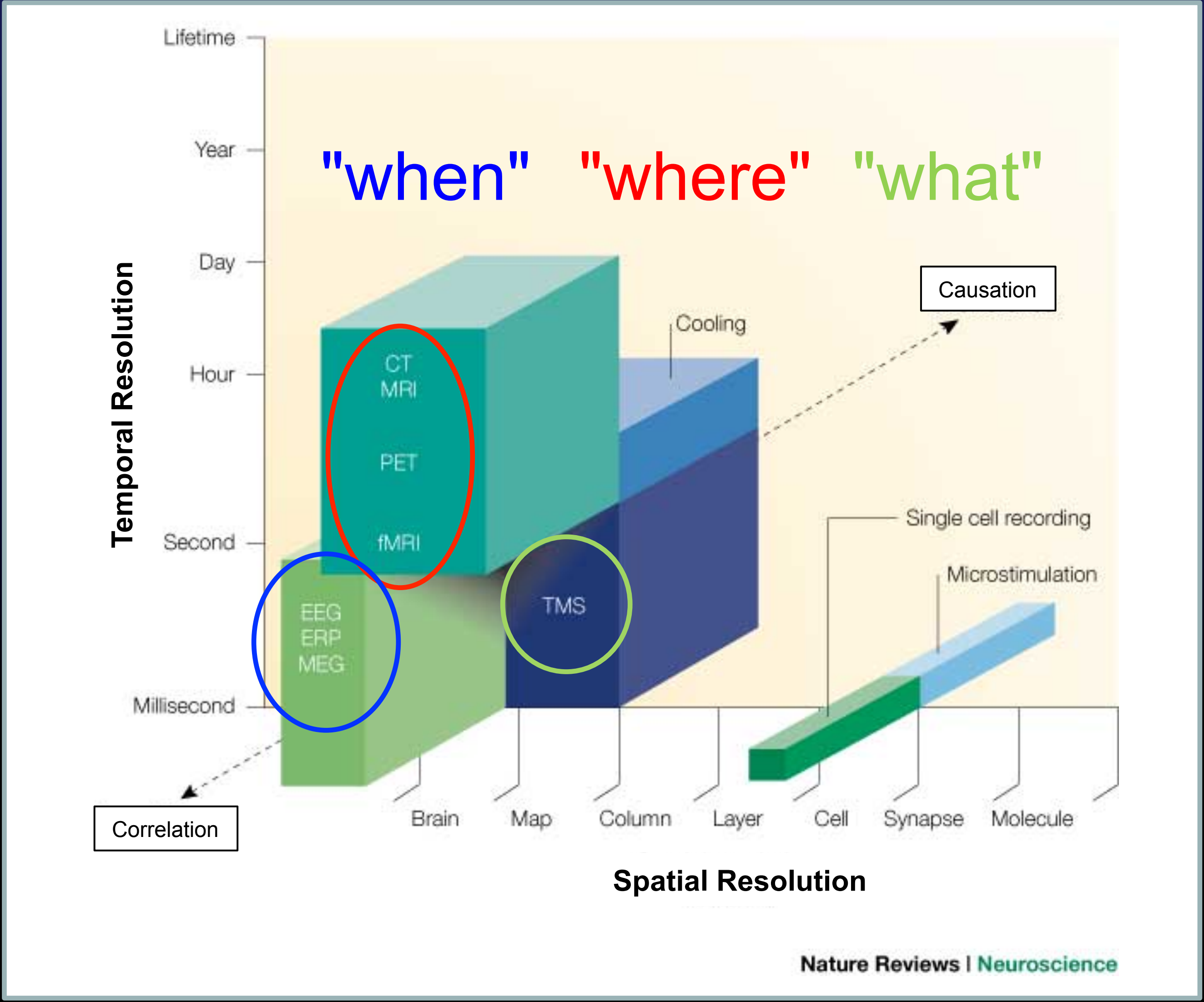
changing the brain's structure or function to see it's impact on behavior



measuring brain structure or function as a subject is engaged in a particular behavior

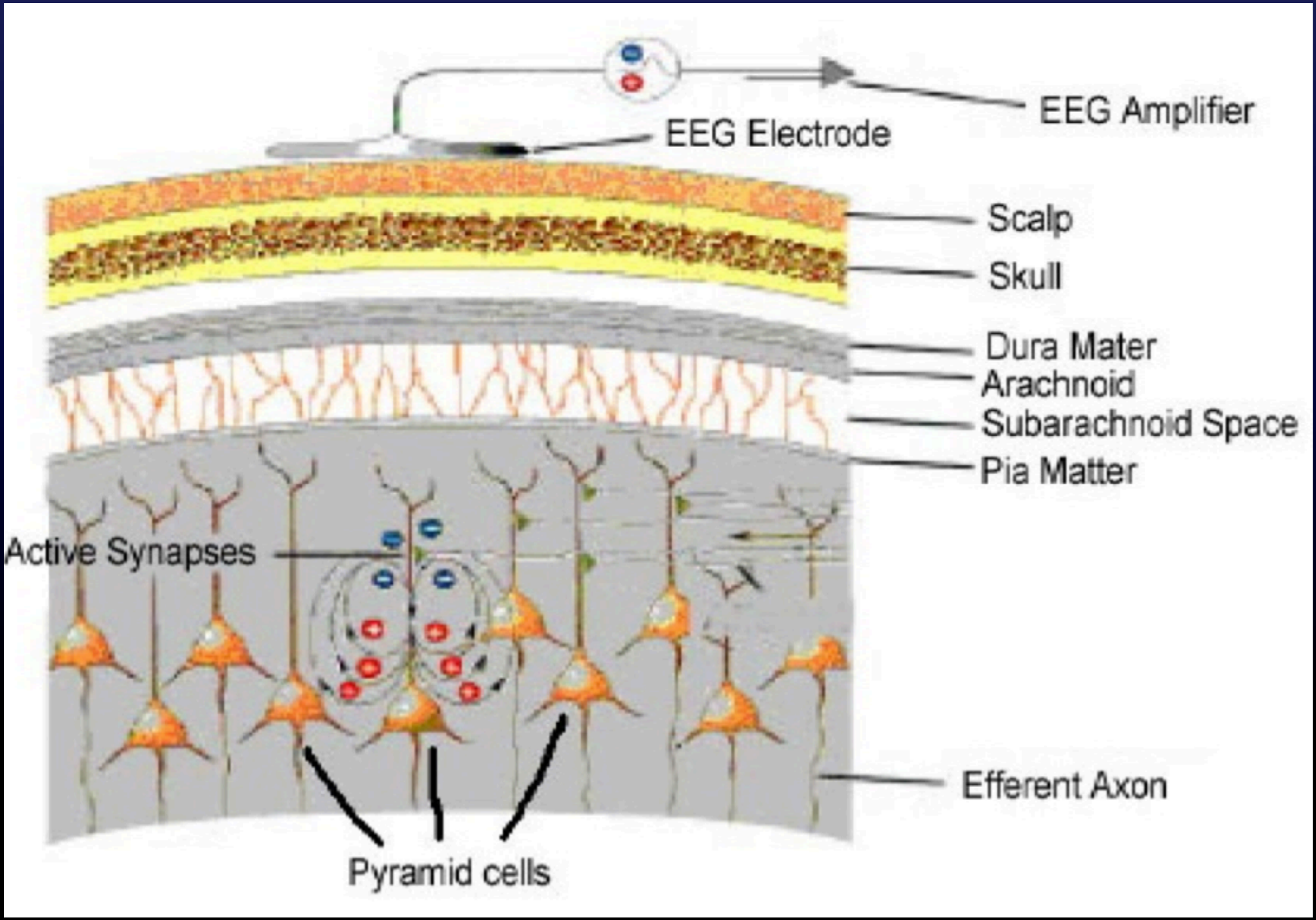
From Huettel text

Approaches to Investigating Brain Function



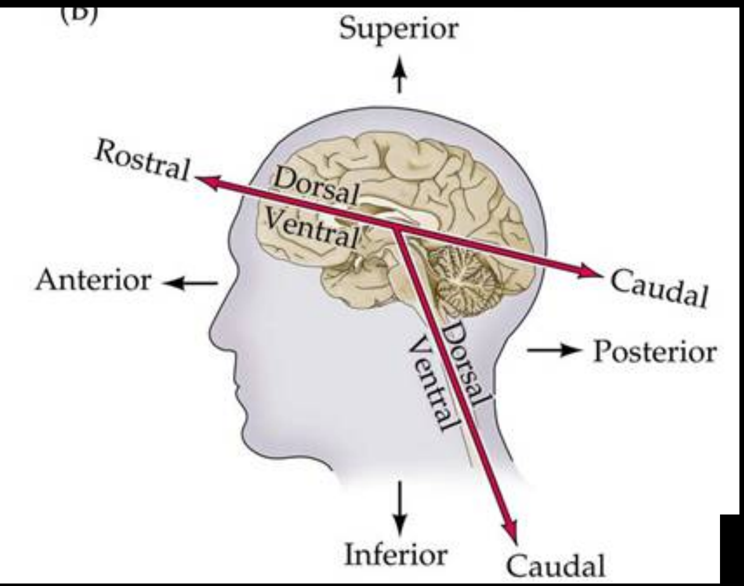

बिजली–पानी

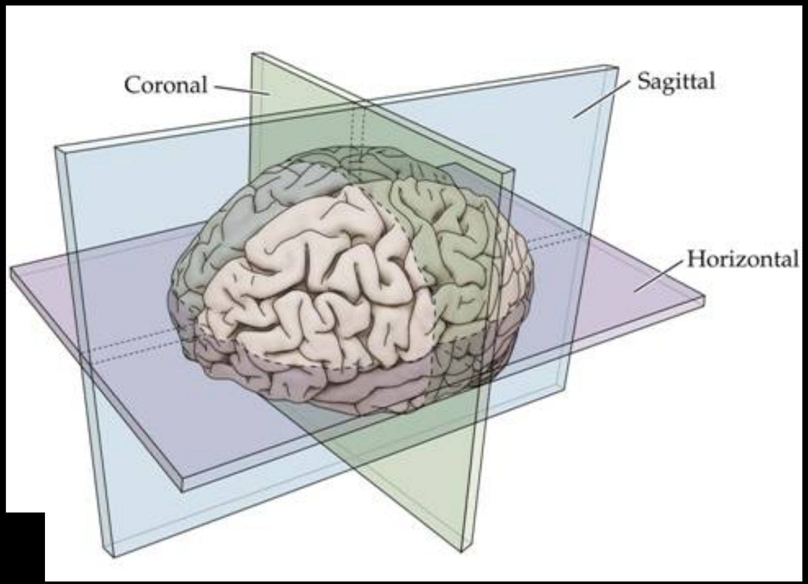
Neural Cell Activity: EEG/MEG

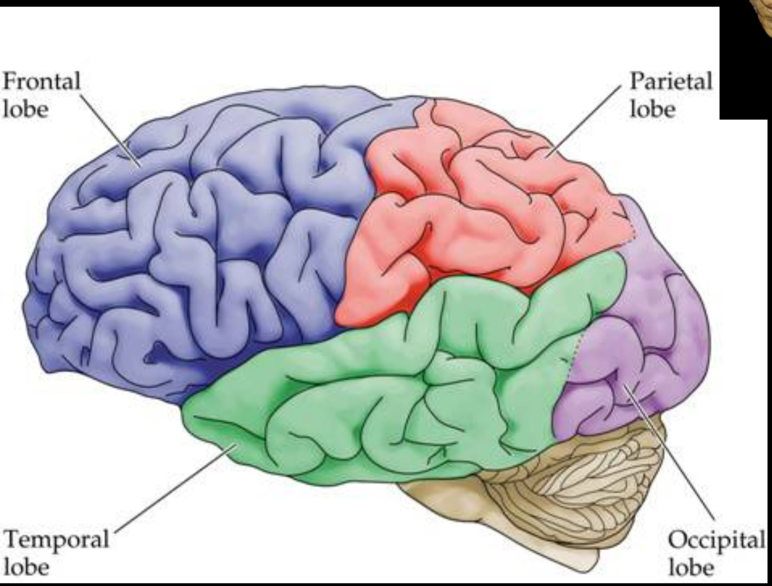


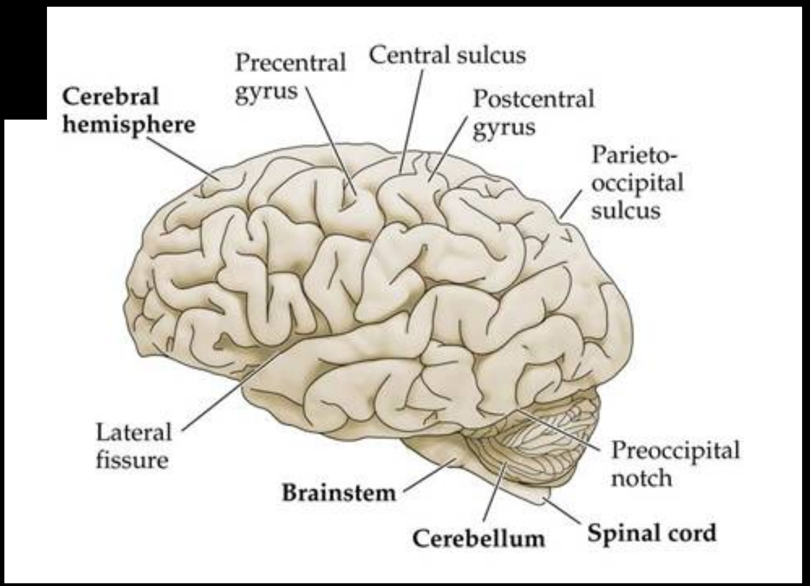
How to measure Brain function?

Human Brain


(b)
Superior
Rostral
Dorsal
Ventral
Anterior
Caudal
Dorsal
Ventral
Posterior
Inferior
Caudal

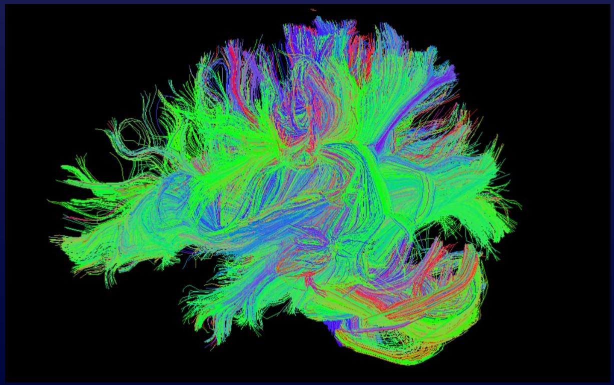

Coronal
Sagittal
Horizontal


Frontal lobe
Parietal lobe
Temporal lobe
Occipital lobe

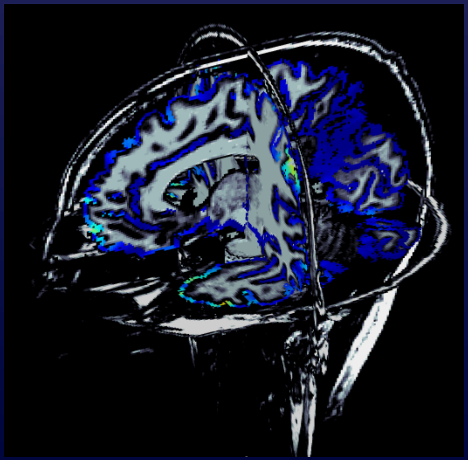

Cerebral hemisphere
Precentral gyrus
Central sulcus
Postcentral gyrus
Parieto-occipital sulcus
Lateral fissure
Brainstem
Cerebellum
Preoccipital notch
Spinal cord

Brain Imaging Techniques

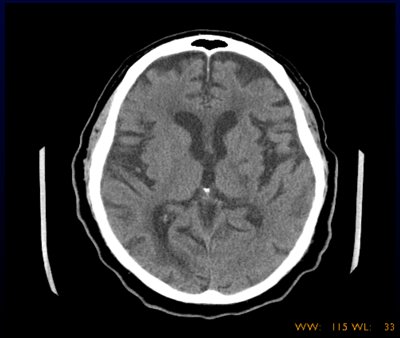
MRI



MEG

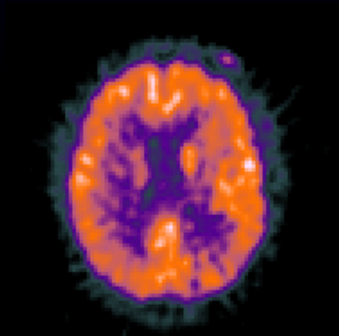


Computed Tomography



EEG

PET

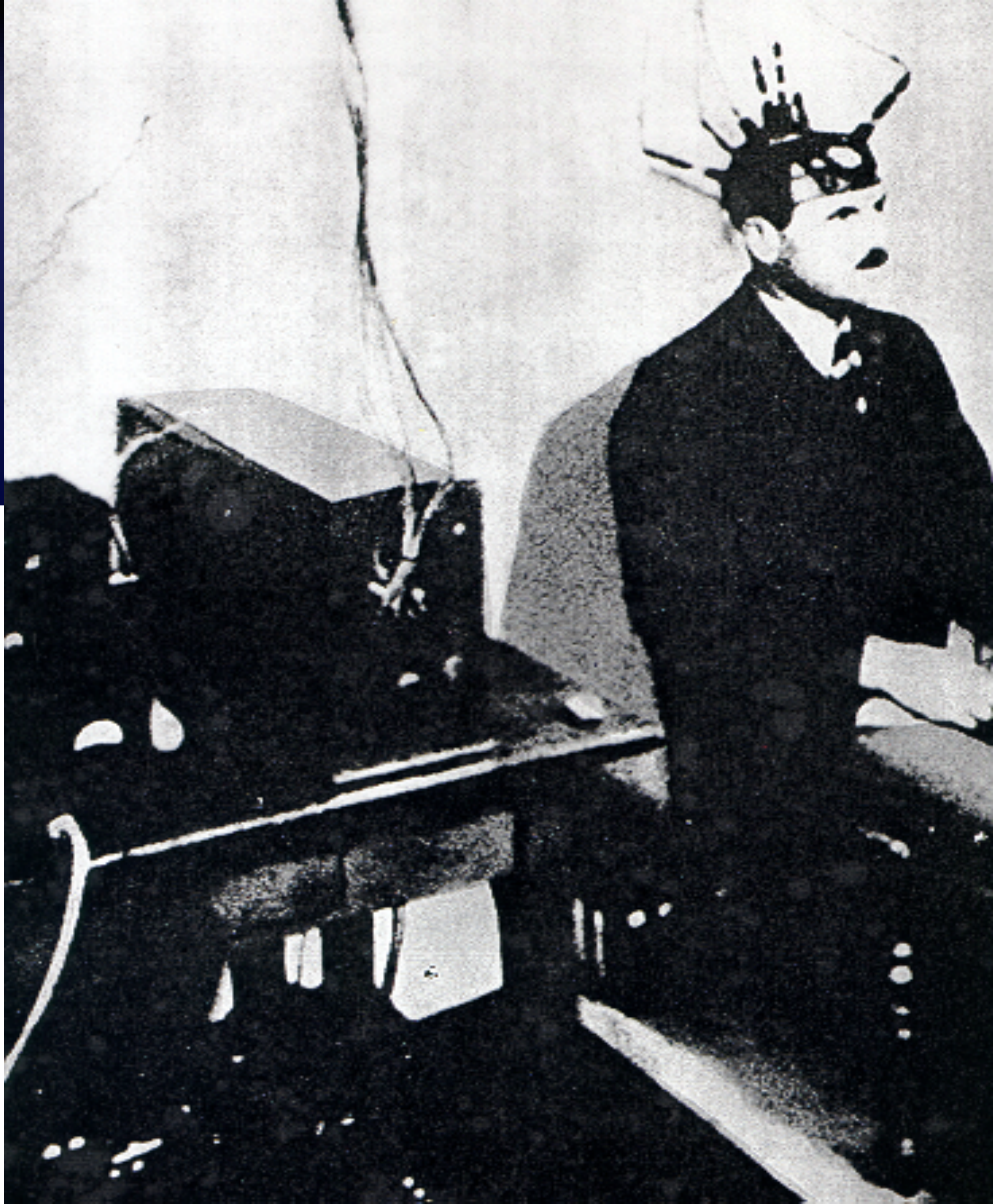


Diffusive Optical Imaging/NIRS

EEG - History

Electroencephalograpy records voltage fluctuations along the scalp. It provides a direct measurement of the electrical activity of firing neurons.

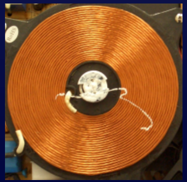
First EEG of DOG on 1902 and on Human on 1920 by Hans Berger (a German Neuropsychiatrist)



MEG - History

David Cohen: First MEG with copper induction coil (1968)

1-million turn coil



Jim Zimmerman – SQUID detectors

(L to R)

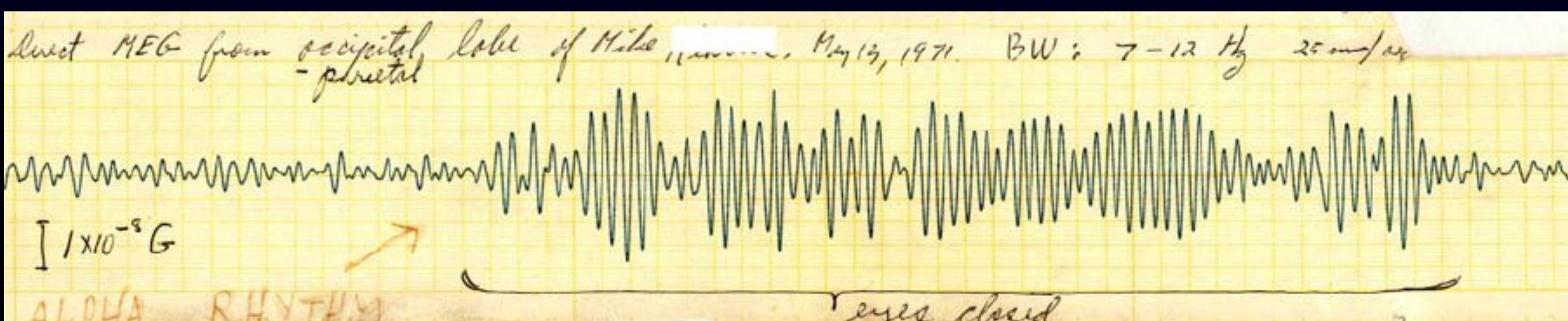
Ed Edelsack

David Cohen

Jim Zimmerman

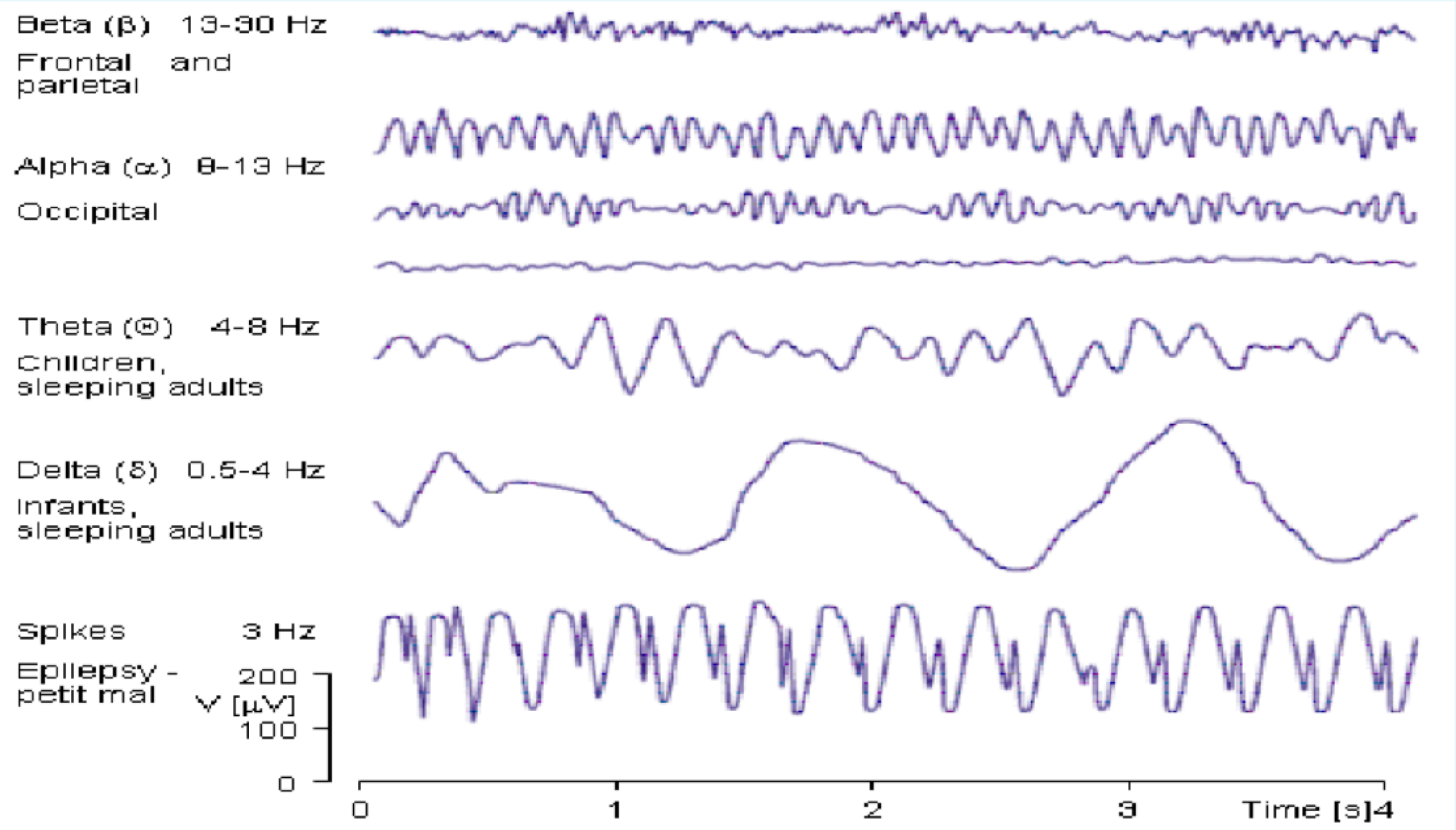
MEG - History

First low-noise MCG, Dec 1969



First MEG, alpha rhythm, Cohen – Science 1972

Graphical Representation of EEG Waves



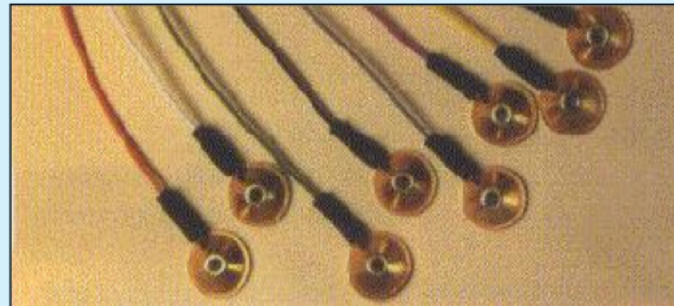
EEG

- Delta (Δ): Deep sleep, coma, infancy
- Theta (θ): Sleep, childhood, intelligence
- Alpha (α): Awake, relaxed, eyes closed,
  day dreaming, and upon deep self-introspection.
  Especially present over occipital cortex.
- Beta (β): Awake, alert, aroused, excitement and REM sleep

REM- Rapid eye movement

- **Mu Rhythm has the frequency range of 8-10Hz , which is basically recorded from Central motor region of brain**

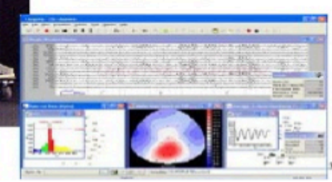
Technology for EEG



- Electrodes:

  Surface electrodes: Ag-AgCl, Au, Pt

  Needle electrodes: Stainless steel, Pt

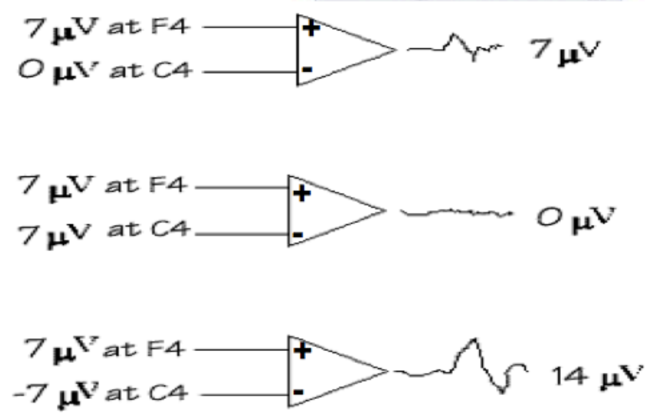


- Amplifier:

  Differential

  CMRR>100dB, Zin>10MΩ

  Band Pass filter

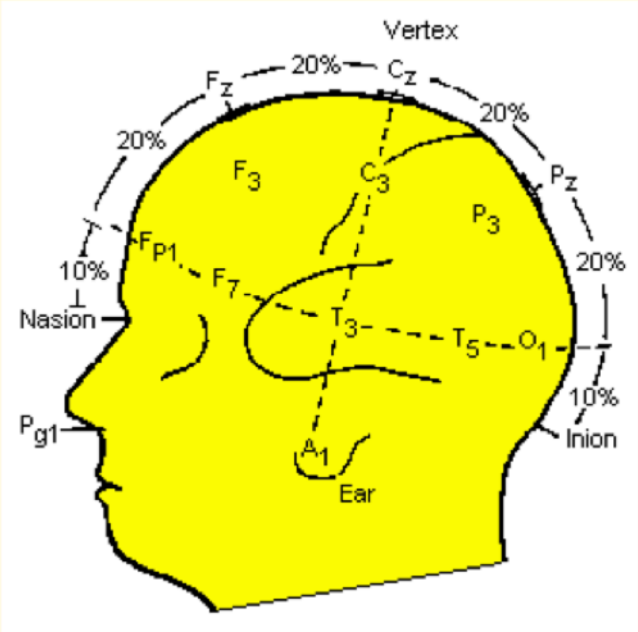


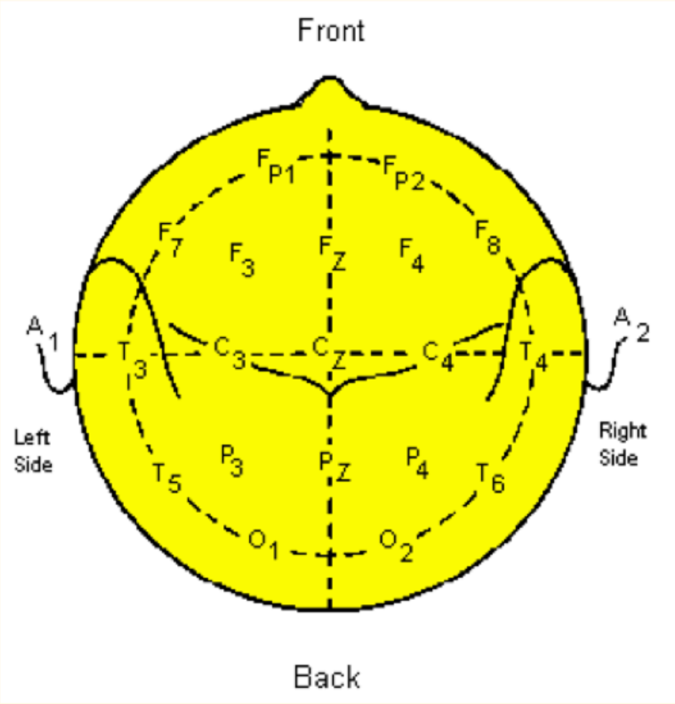
- Recorder:

  Digital EEG

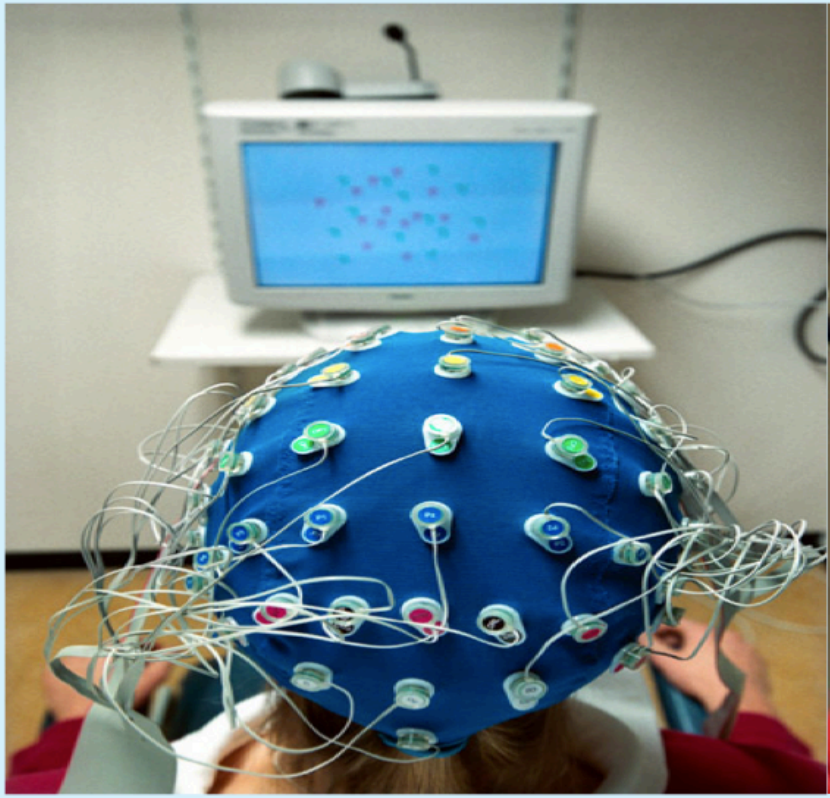
Standardized 10-20 system

The "10" and "20" refer to the 10% or 20% interelectrode distance.



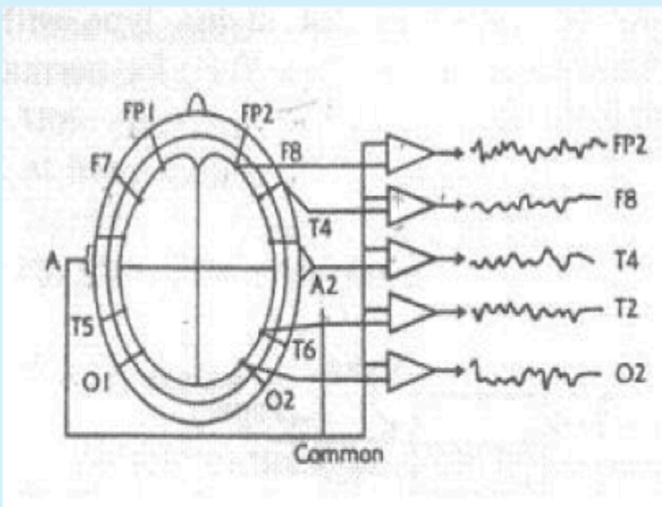


EEG Registration

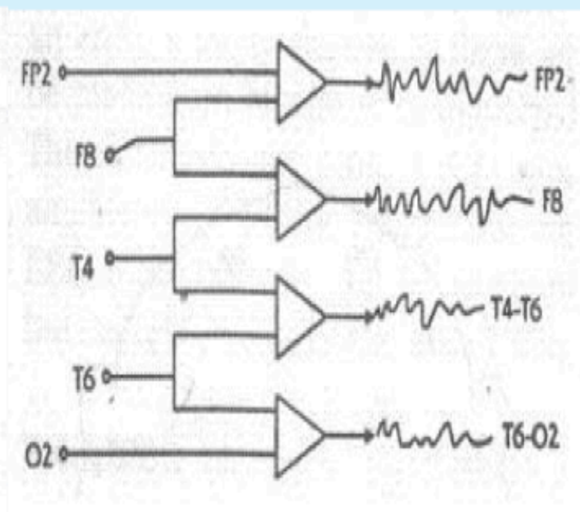


Various Electrode Configuration

- **Unipolar Mode:** Between an electrode and a common reference electrode (ear lobe)
- **Bipolar Mode:** Between two local electrodes, one may be positive going and another negative going



Unipolar Conf.



Bipolar Conf.

Clinical cortical electrophysiology – EEG

Montages

Because EEG is a relative measure must determine what to measure against

Referential vs. Differential

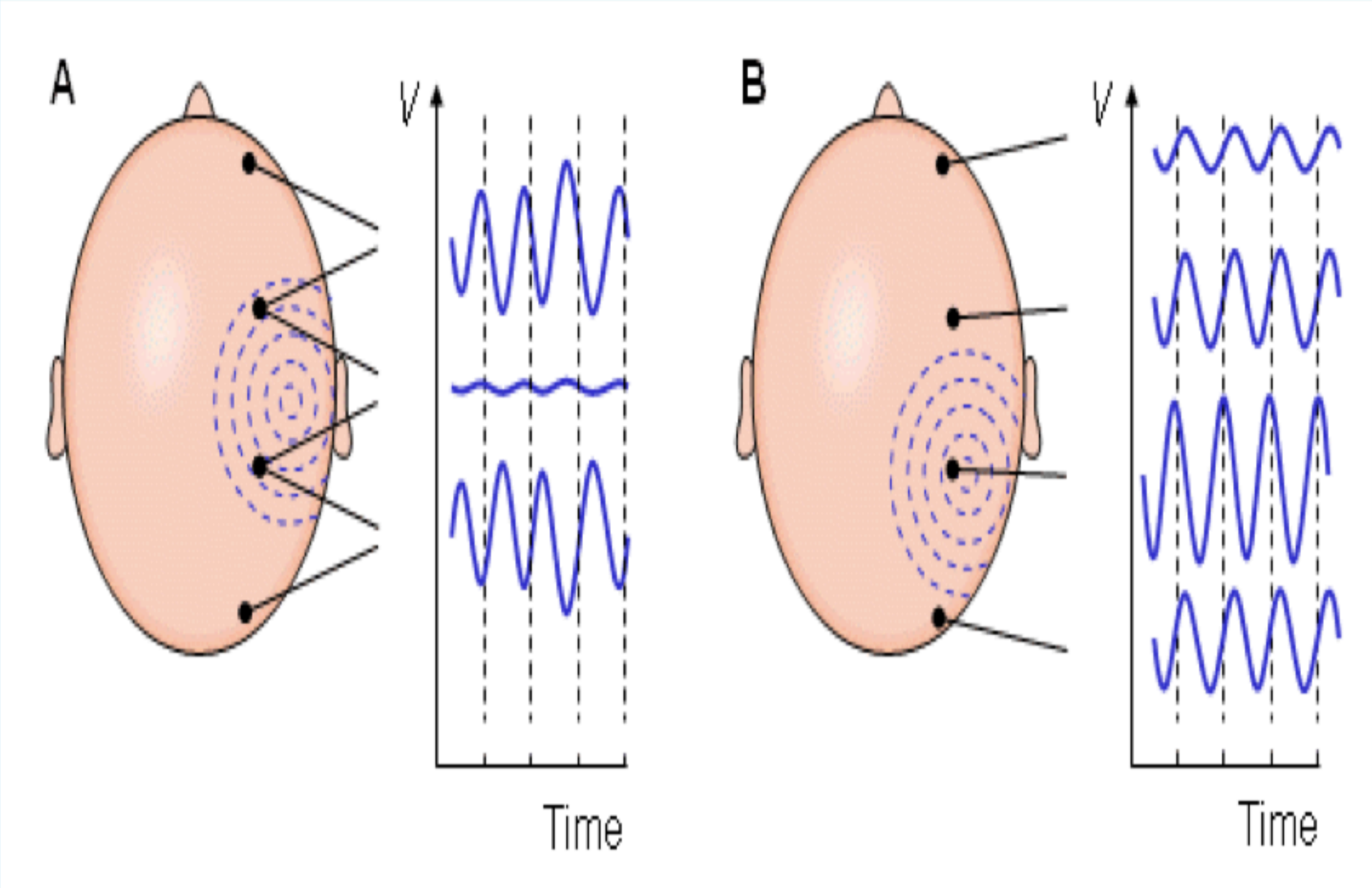
vs. a single reference:

- **i.e. top of the head, ear, back of neck**
- **ideally – inactive**

vs. another active channel:

- **can cancel out common noise and artifacts**
- **easily shows phase reversals**

Bipolar & Unipolar Mode



A) Bipolar and (B) unipolar measurements.
Note that the waveform of the EEG depends on the measurement location.

EEG

Referential

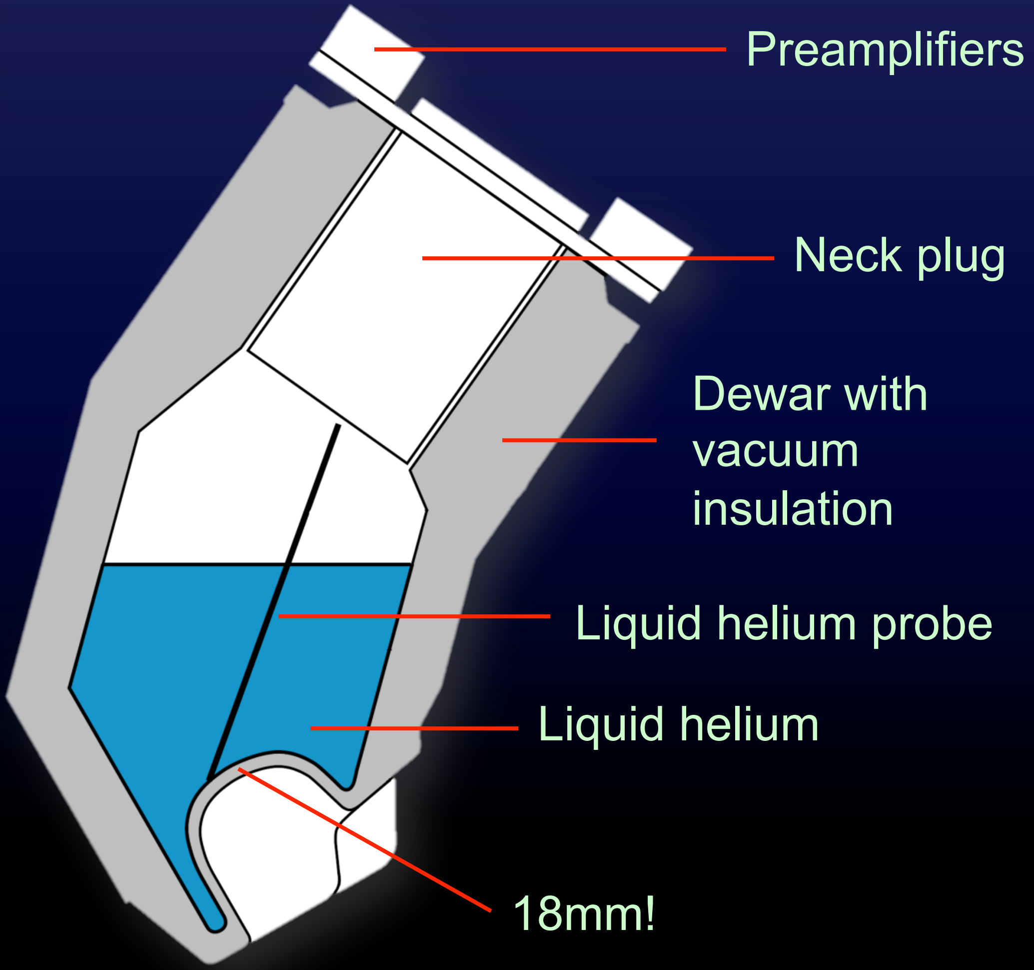
Bipolar

Applications

- Epilepsy monitoring
- Depth of Anesthesia monitoring
- Head injury, Coma & Brain death
- Sleep analysis
- Brain Computer Interfacing (BCI)
- Evoked potentials
- Biofeedback
- Cognition study

MEG @ MIT
March 2011

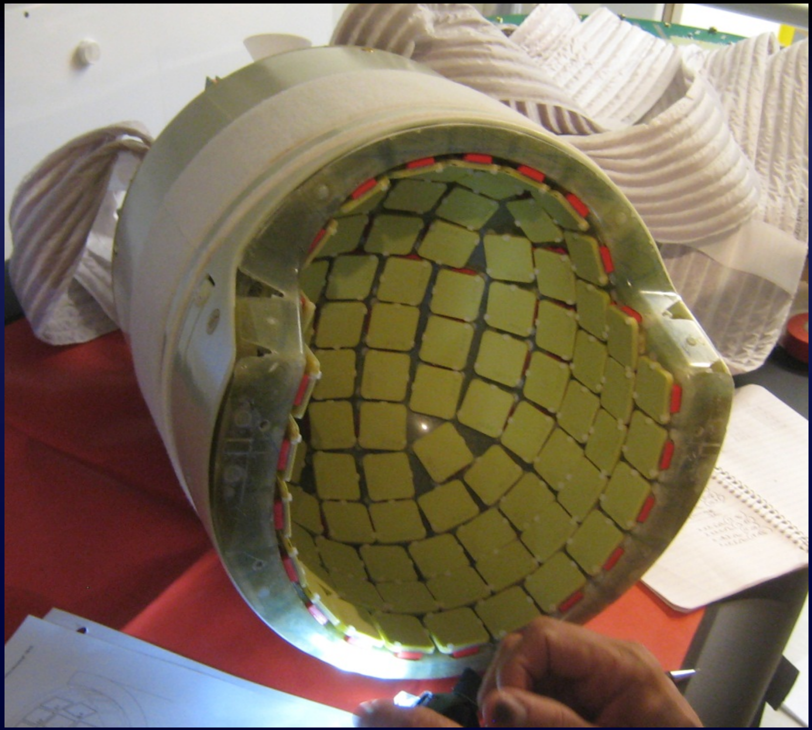
Instrumentation

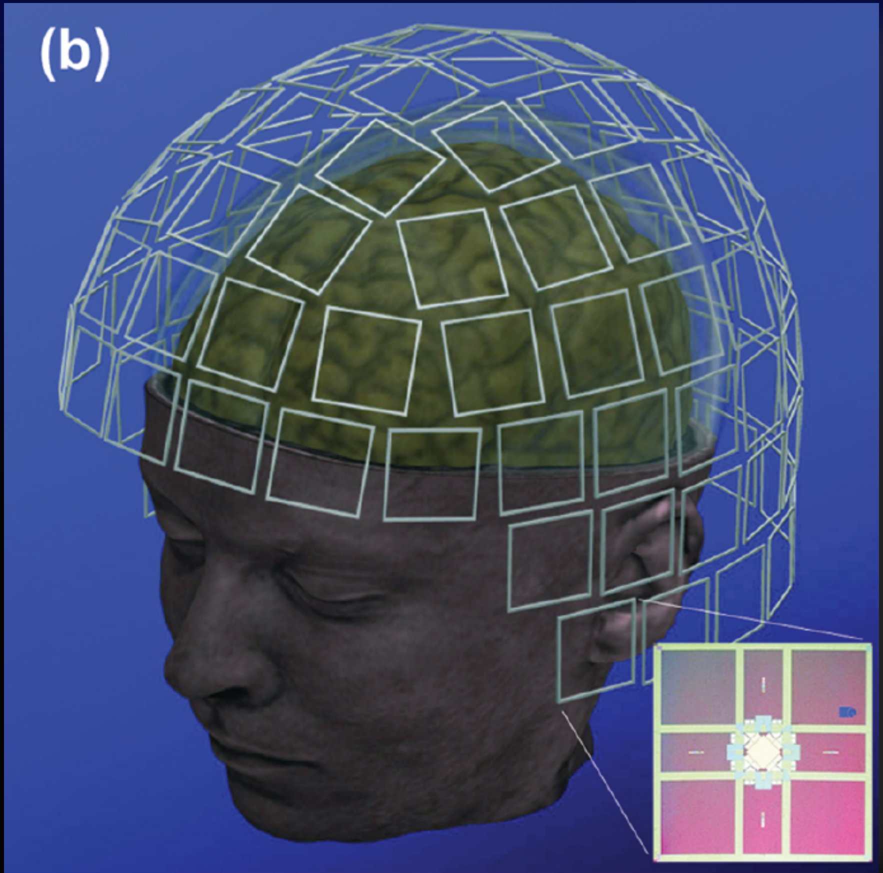


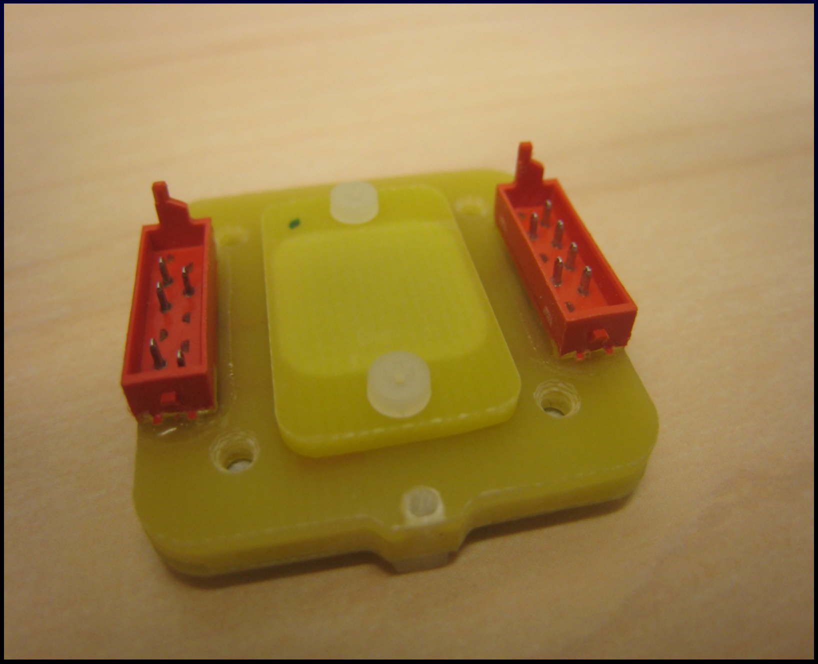
1 liter liquid helium = 750 liters of gas helium!

Boiling point = 4.2 K (-269 ^{o}C or -452 ^{o}F)

MEG Sensors



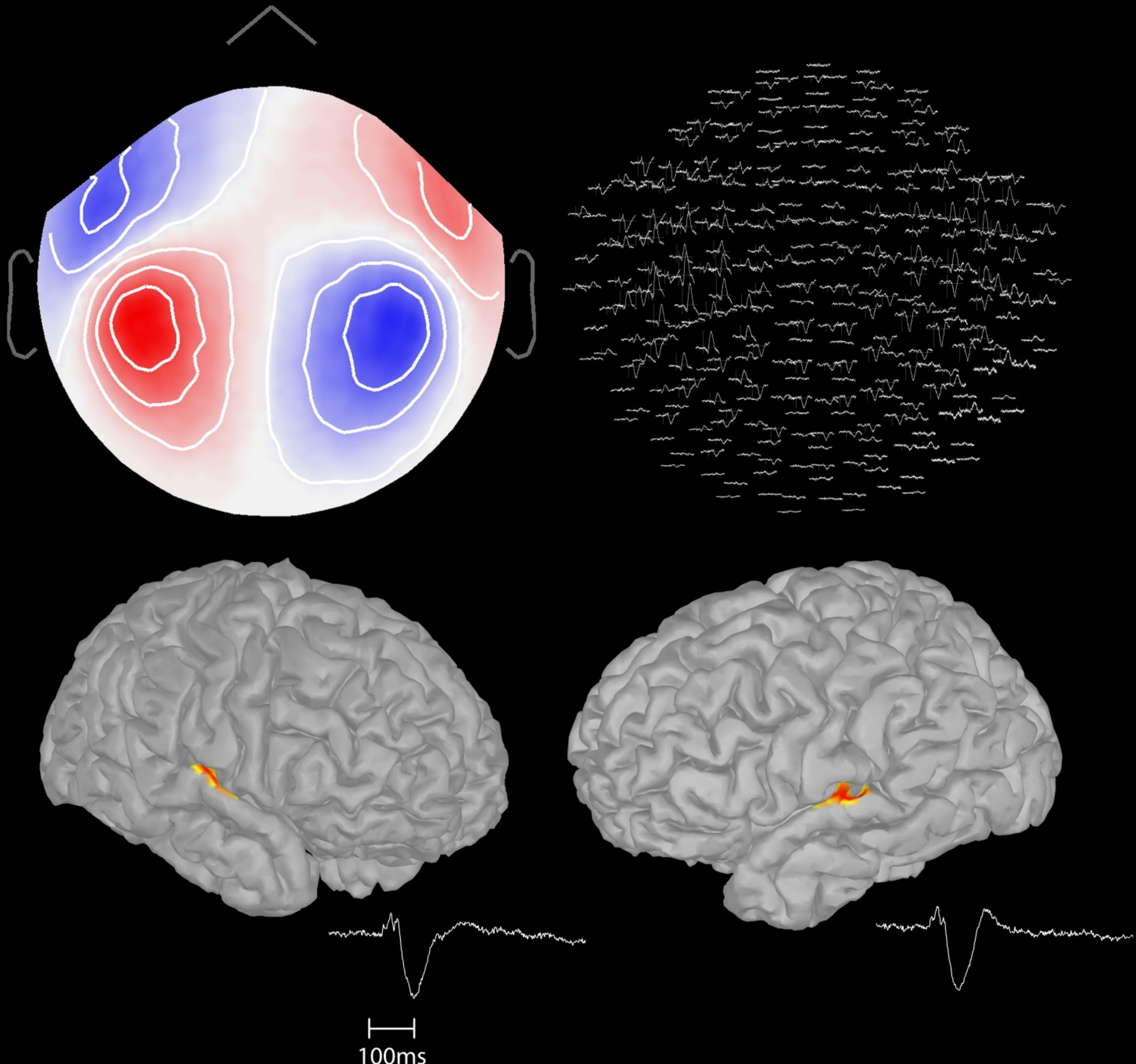




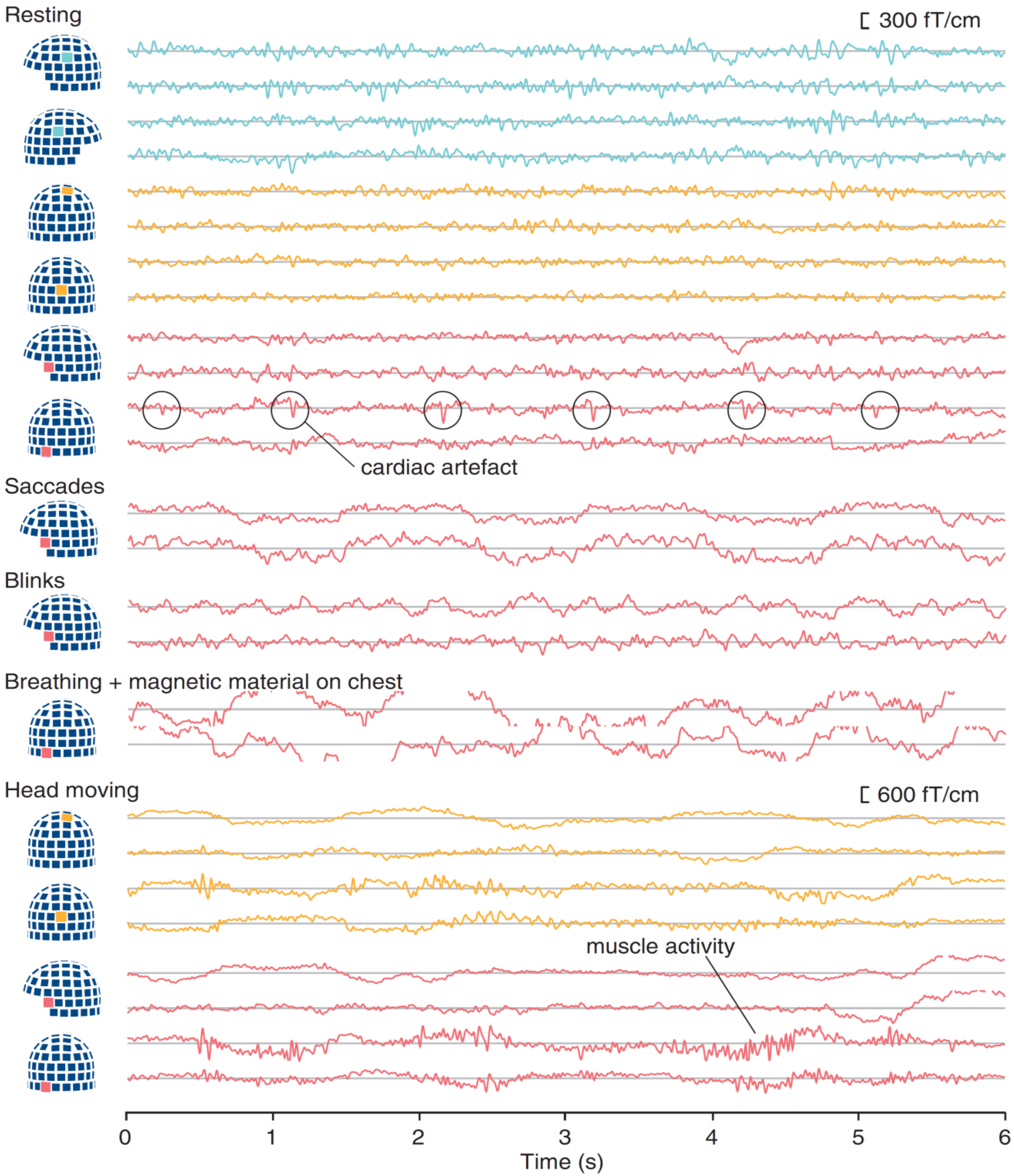
Brain auditory response

Brief tones delivered to left and right ear approximately once per second.

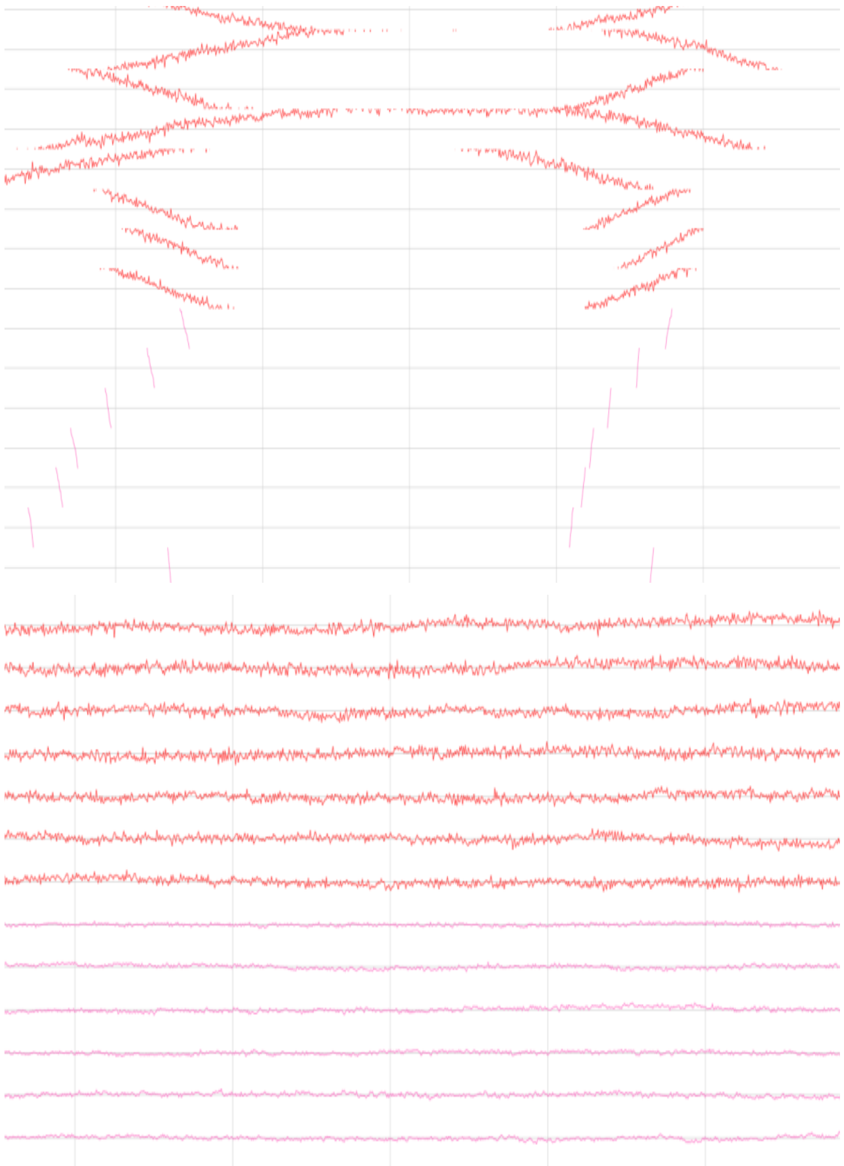
Measured time series show a deflection at 100ms, indicating transient current flows at the left and right primary auditory cortices.



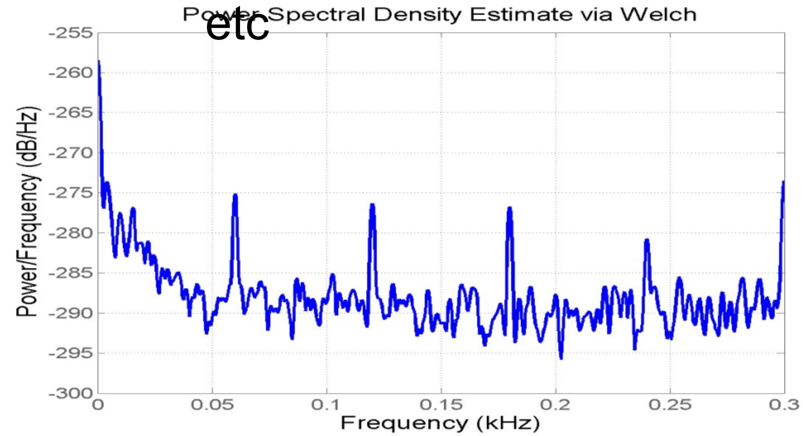
Artifacts – Biological Sources

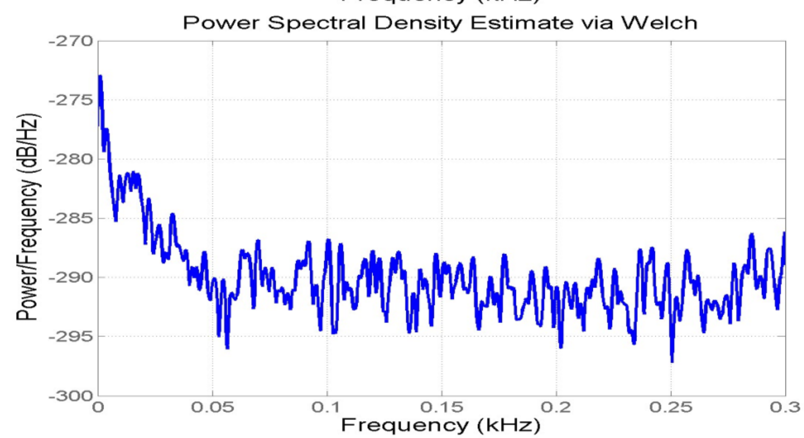


Artifacts – Environmental Sources

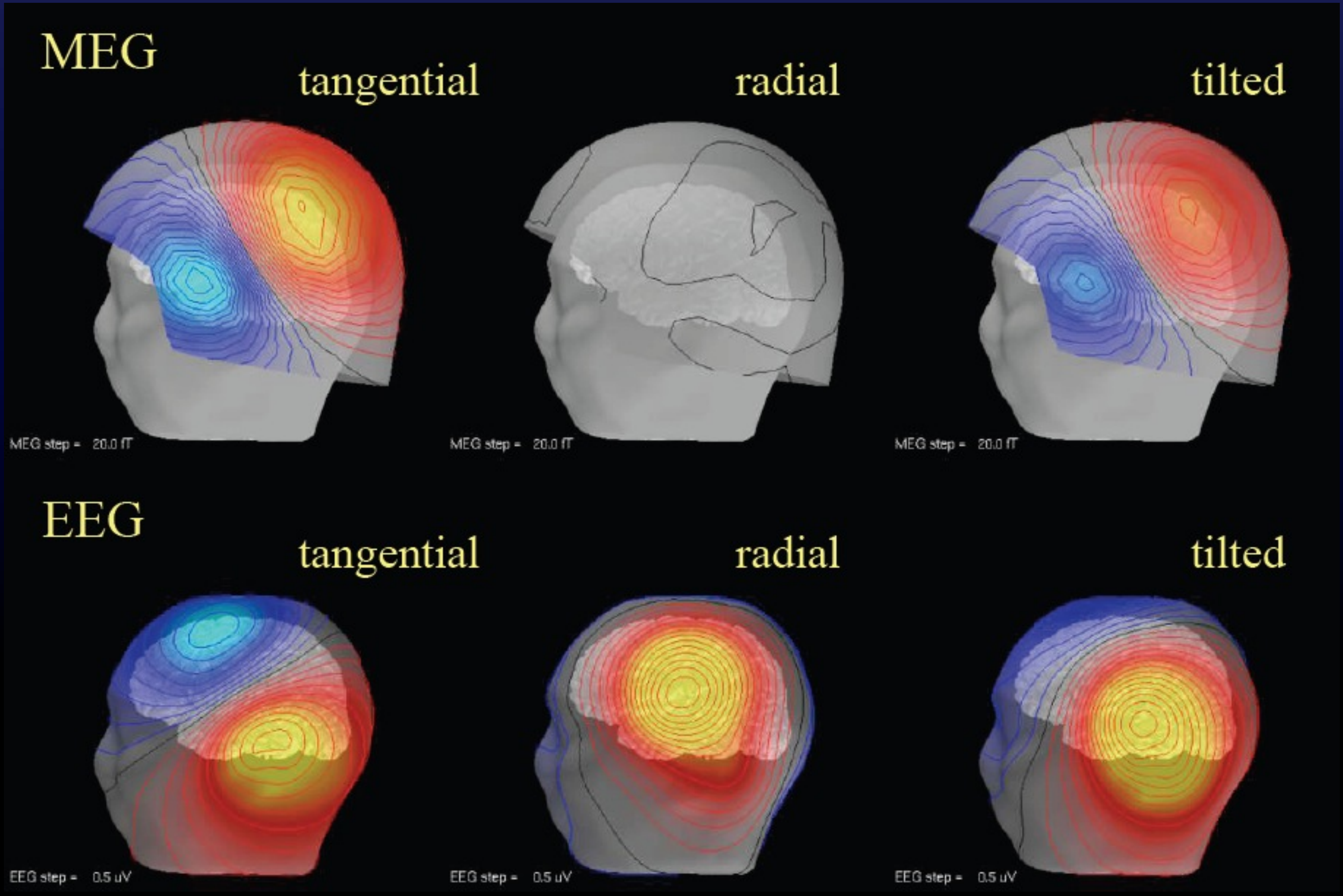


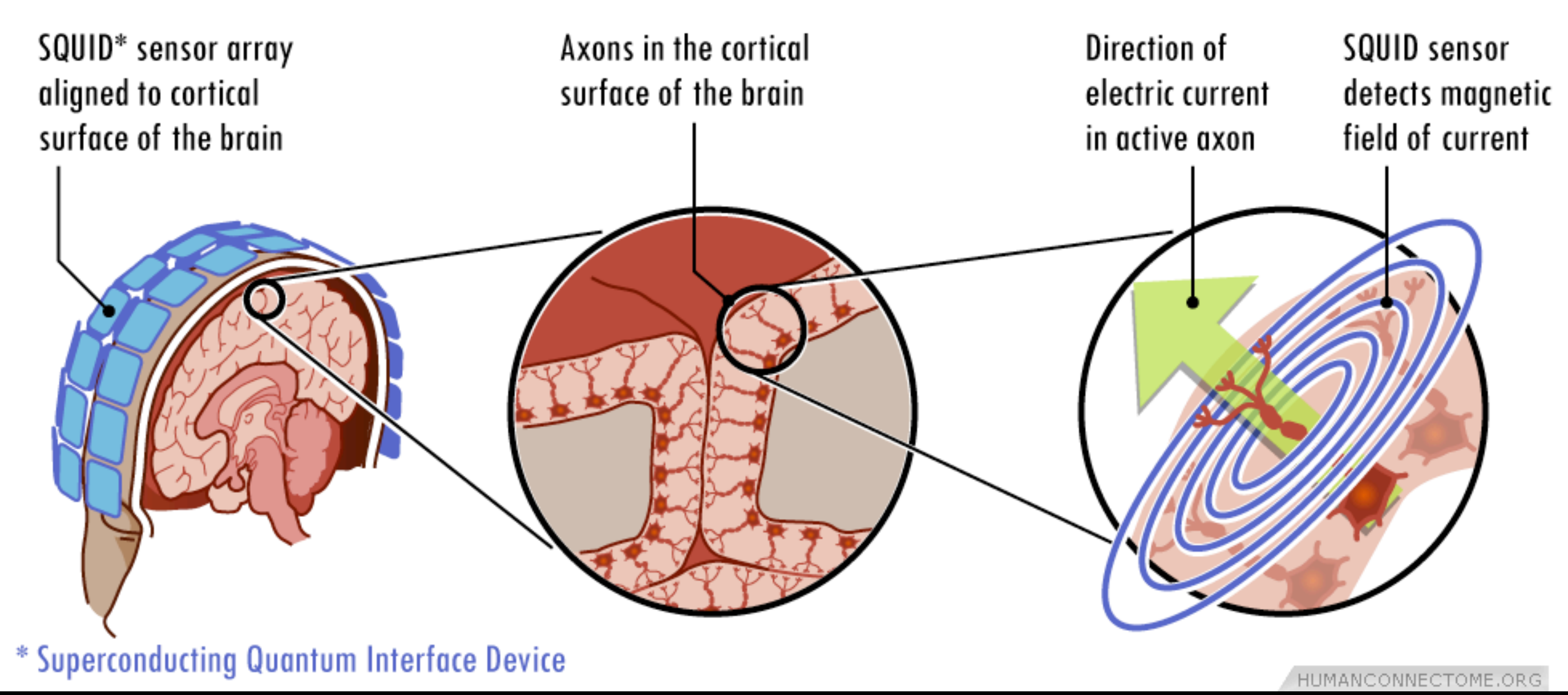
Subway
Power
lines
Cars
Elevators
etc

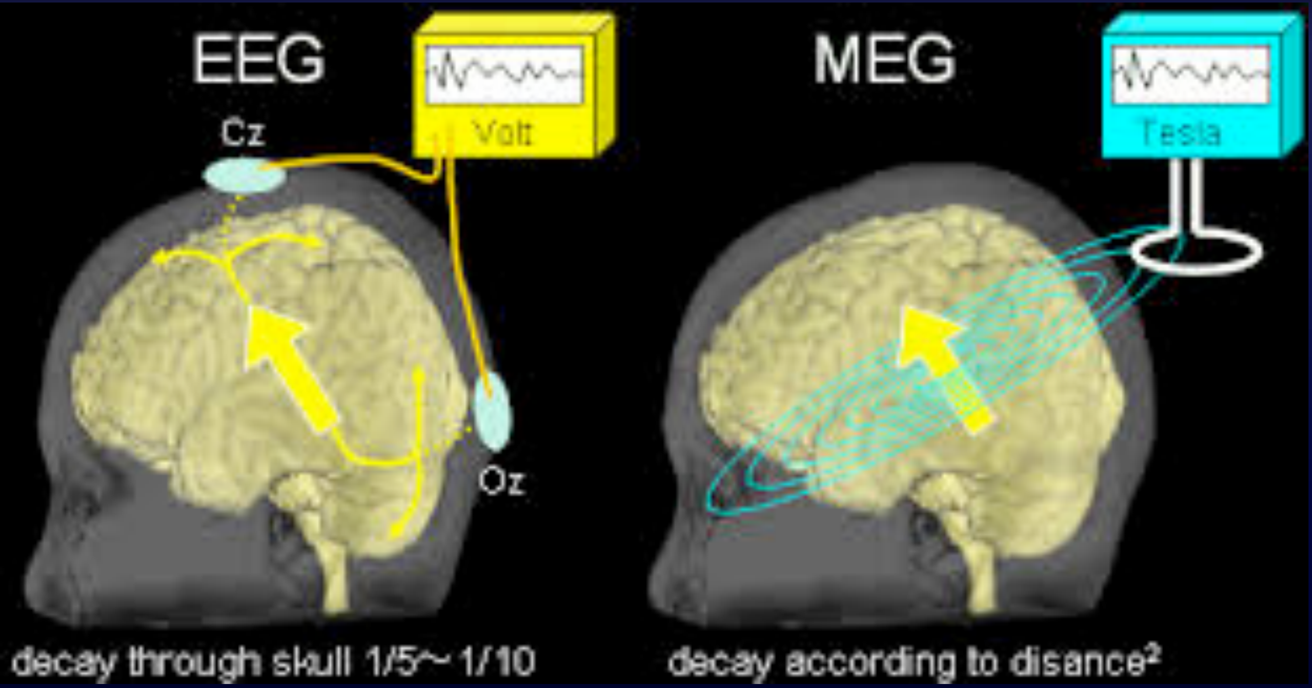


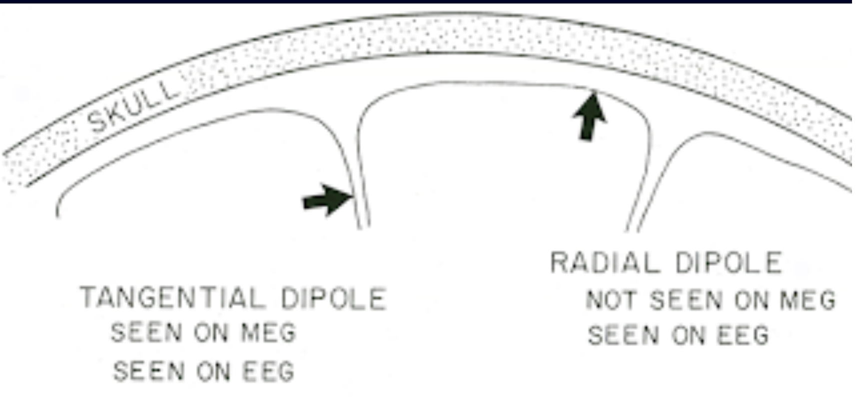


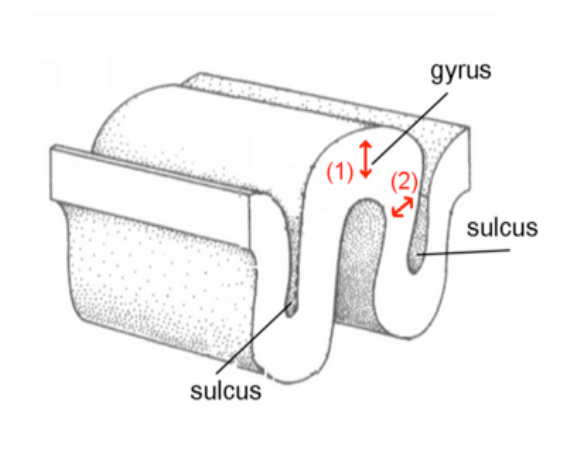
Tangential vs. Radial Sources

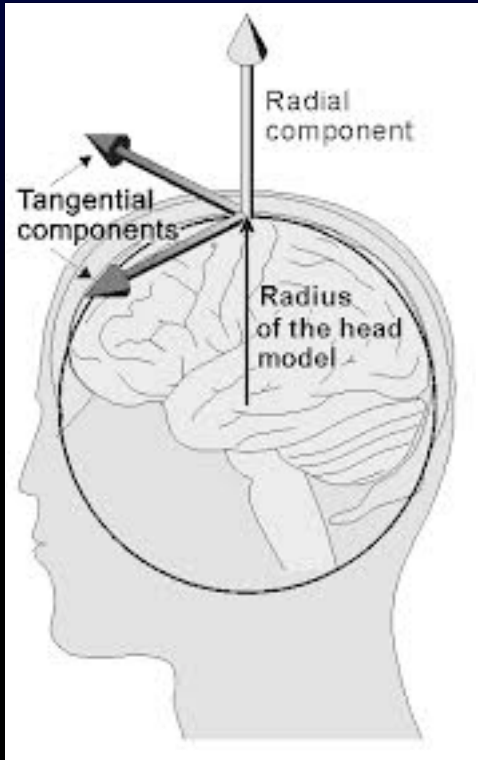



SQUID* sensor array aligned to cortical surface of the brain
Axons in the cortical surface of the brain
Direction of electric current in active axon
SQUID sensor detects magnetic field of current
* Superconducting Quantum Interface Device
HUMANCONNECTOME.ORG


EEG
Volt
Cz
Oz
MEG
Tesla
decay through skull 1/5~1/10
decay according to disance²


SKULL
TANGENTIAL DIPOLE
SEEN ON MEG
SEEN ON EEG
RADIAL DIPOLE
NOT SEEN ON MEG
SEEN ON EEG


gyrus
(1)
(2)
sulcus
sulcus


Radial component
Tangential components
Radius of the head model

MEG has substantial benefits with respect to EEG:

1. while EEG is strongly degraded by the heterogeneity in conductivity within head tissues (e.g., insulating skull vs. conducting scalp), this effect is extremely limited in MEG, resulting in greater spatial discrimination of neural contributions. This has important implications for source modeling.

2. Subject preparation time is reduced considerably.

3. Measures are absolute, i.e. they are not dependent on the choice of a reference.

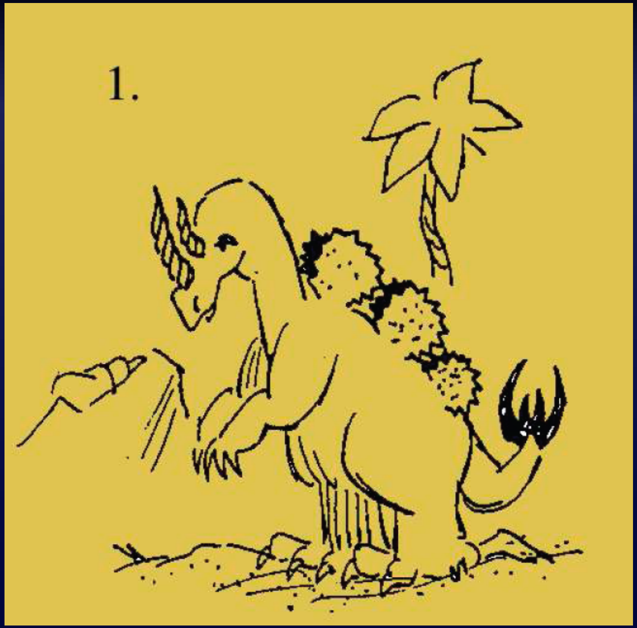
4. Subject's comfort is improved as there is no direct contact of the sensors on the skin.

MEG/EEG experiments can be run with the subjects in supine or seated positions. A caveat however concerns EEG recording in supine position, which may rapidly lead to subject discomfort because occipital electrodes become painful pressure points.

EEG detects radial and tangential currents, while MEG detects Tangential current only. EEG is sensitive to extracellular volume currents whereas MEG primarily detects intracellular currents.

In conclusion, MEG is more useful, neglecting radial current. Assumption is simpler in MEG than in EEG.Data interpretation is easier in MEG as there is no reference. MEG is sensitive to intracellular currents.

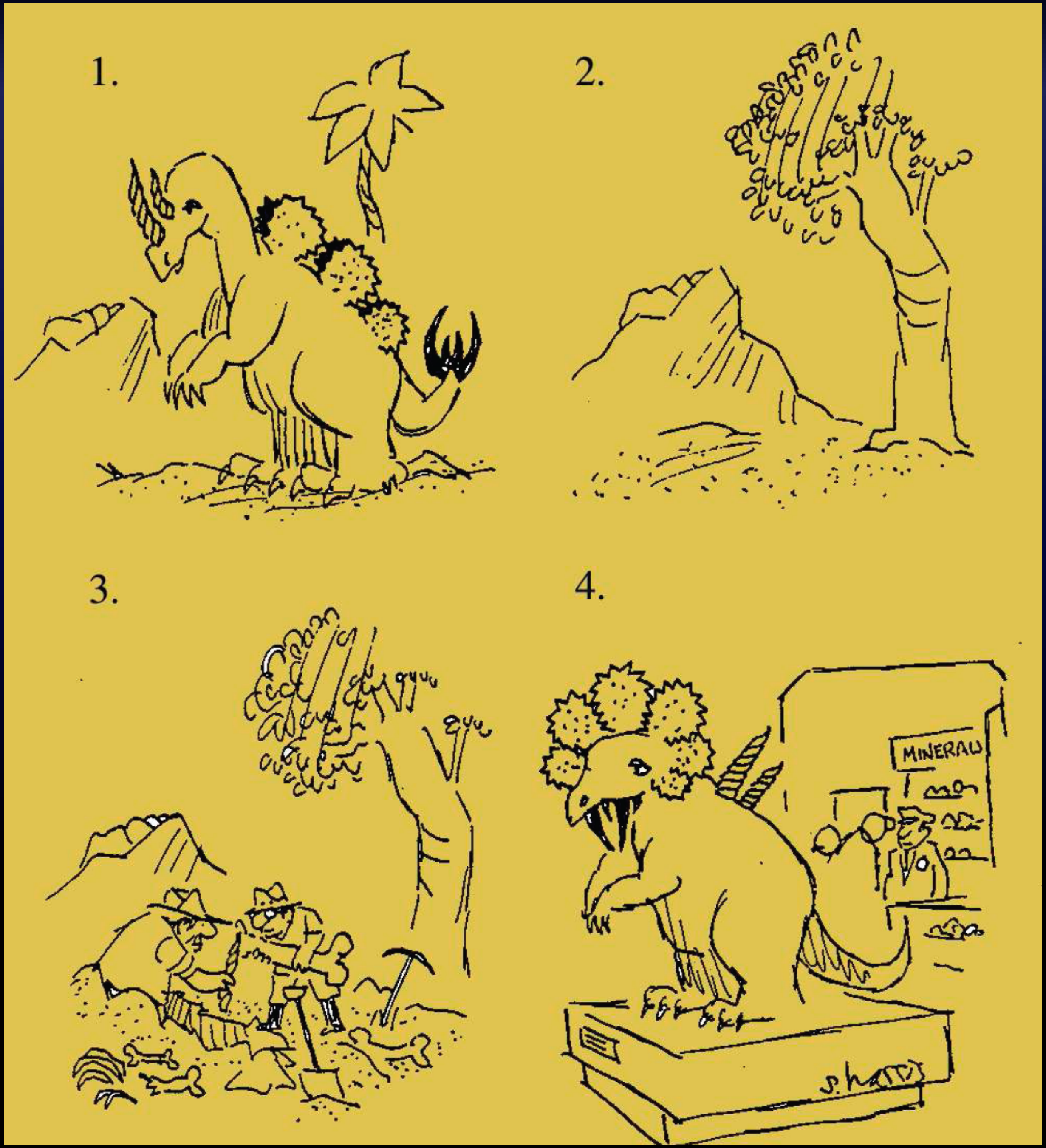
Inverse Methods



Inverse Methods

Inverse Methods

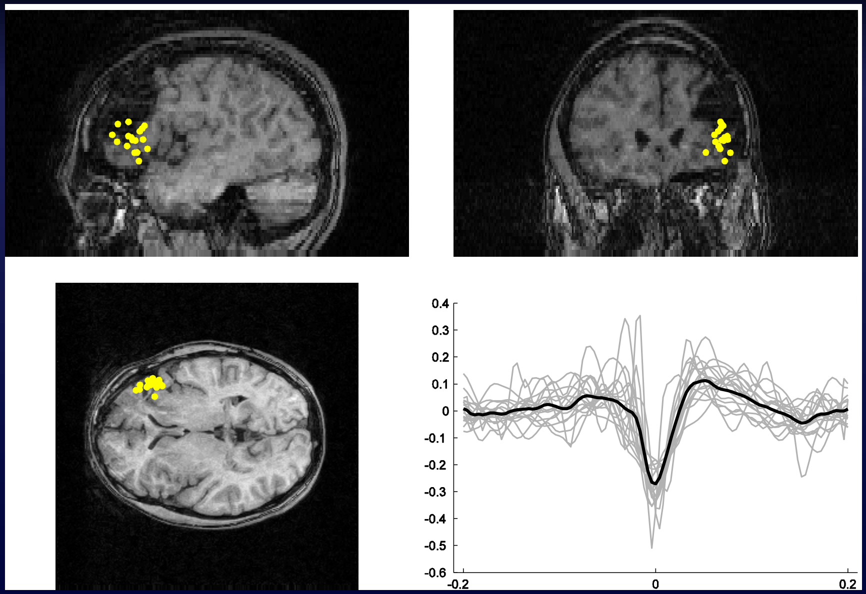
Inverse Methods



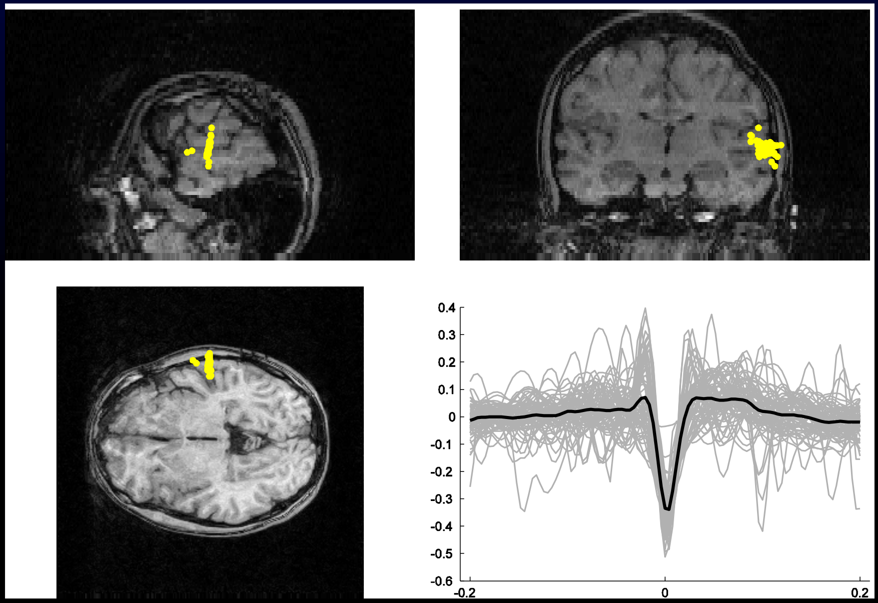
Matti Hamalainen's inverse!

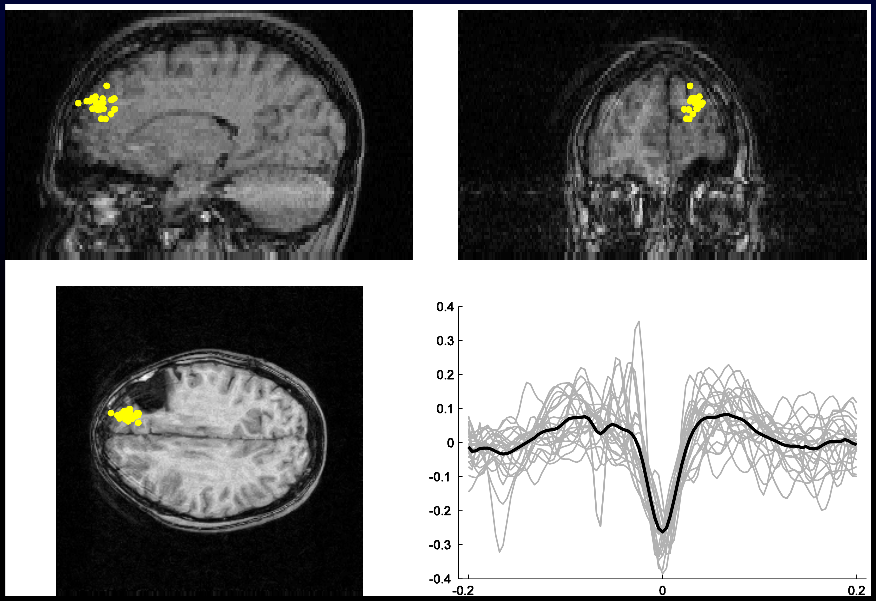
Source Localization in Epilepsy

Automated noninvasive spike detection, localization and clustering from spontaneous interictal spikes



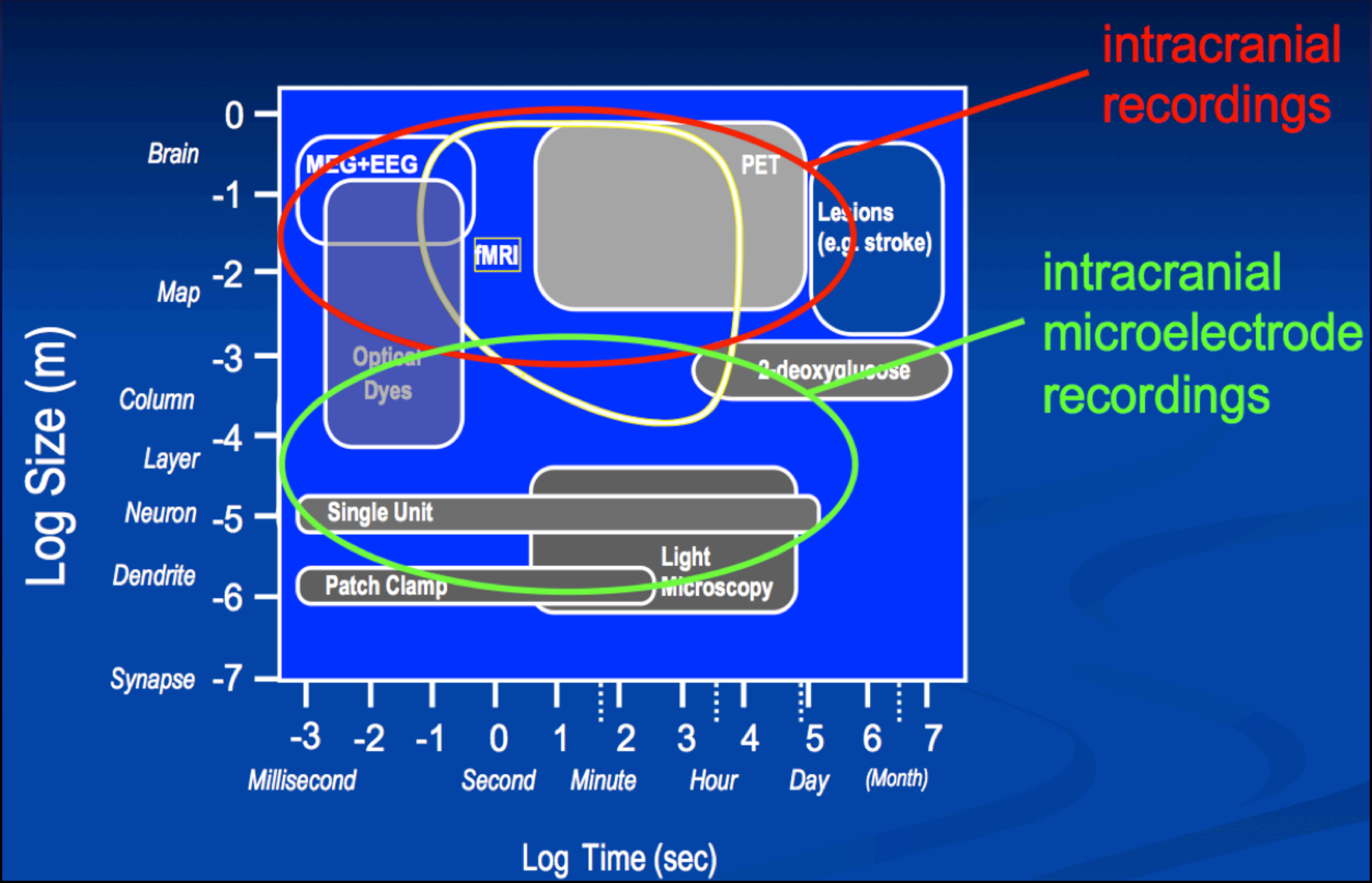
Cluster 2





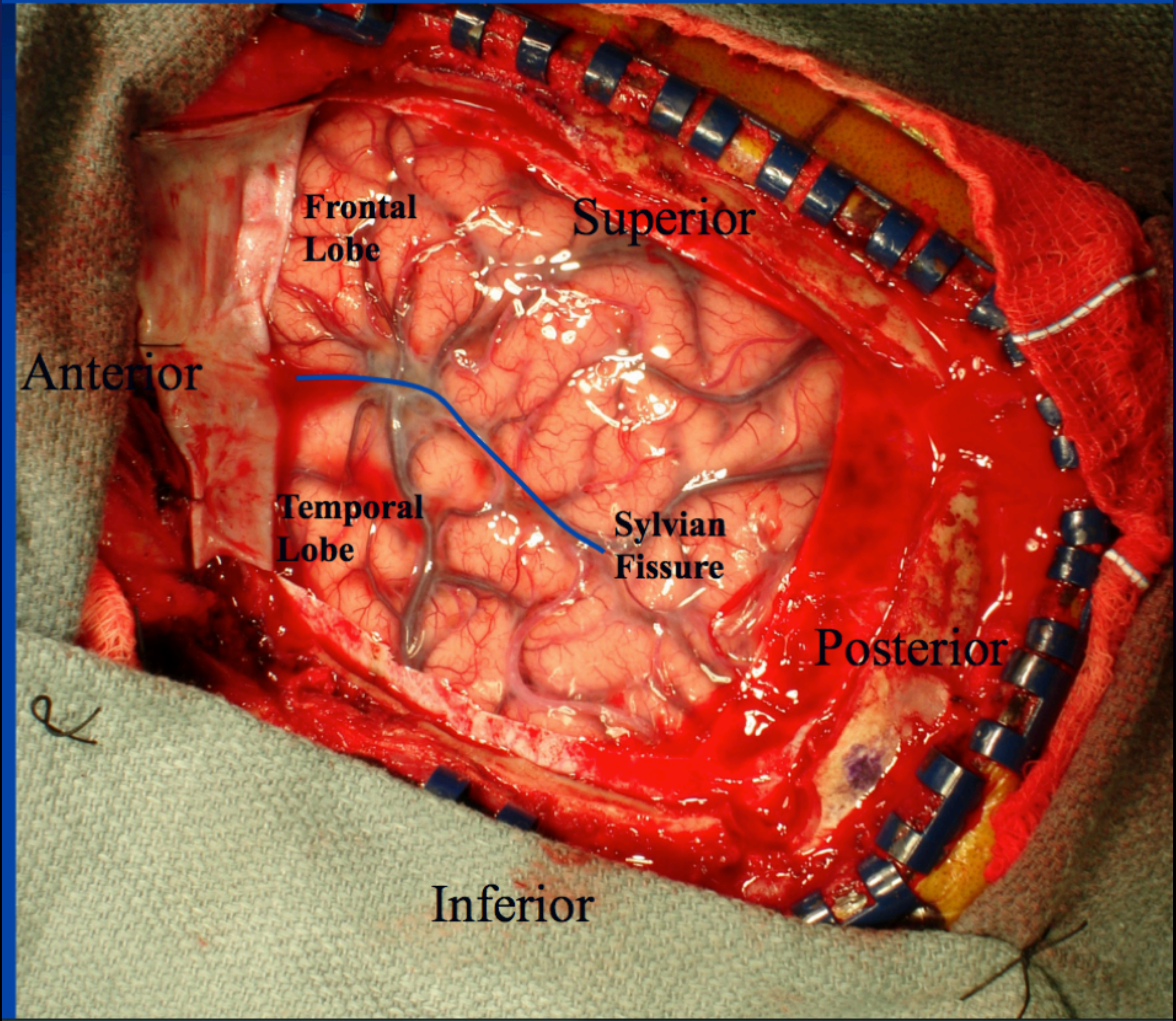
Cluster 1

Cluster 3

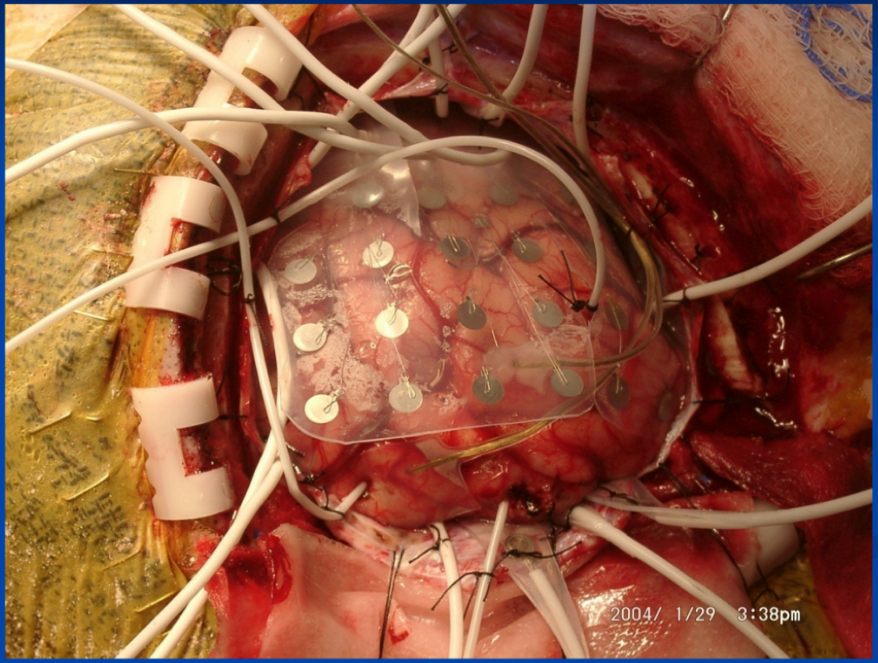


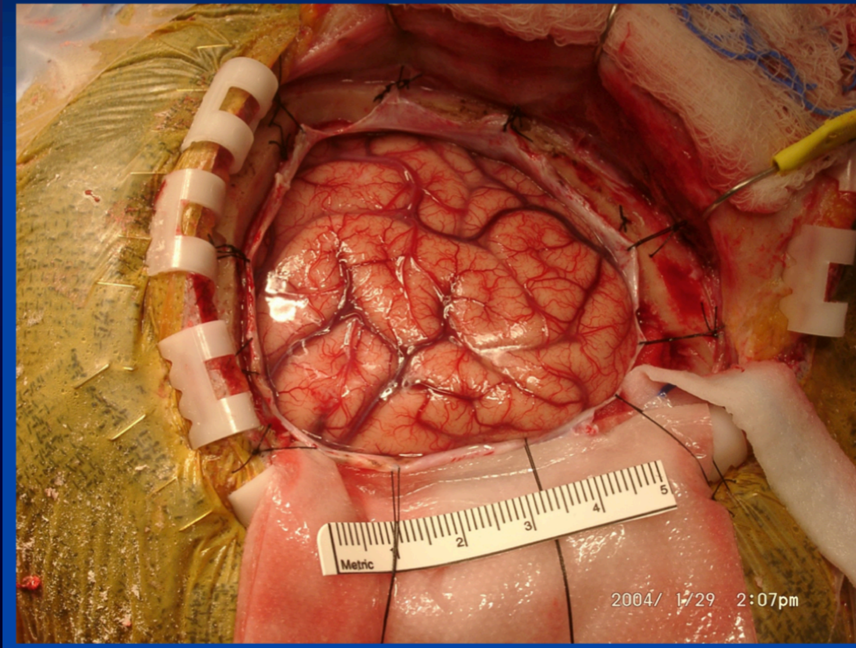
intracranial recordings
intracranial microelectrode recordings
Log Size (m)
0
Brain
-1
-2
Map
-3
Column
-4
Layer
Neuron
-5
Dendrite
-6
Synapse
-7
MEG+EEG
fMRI
PET
Lesions (e.g. stroke)
Optical Dyes
2-deoxyglucose
Single Unit
Light Microscopy
Patch Clamp
-3
-2
-1
0
1
2
3
4
5
6
7
Millisecond
Second
Minute
Hour
Day
(Month)
Log Time (sec)

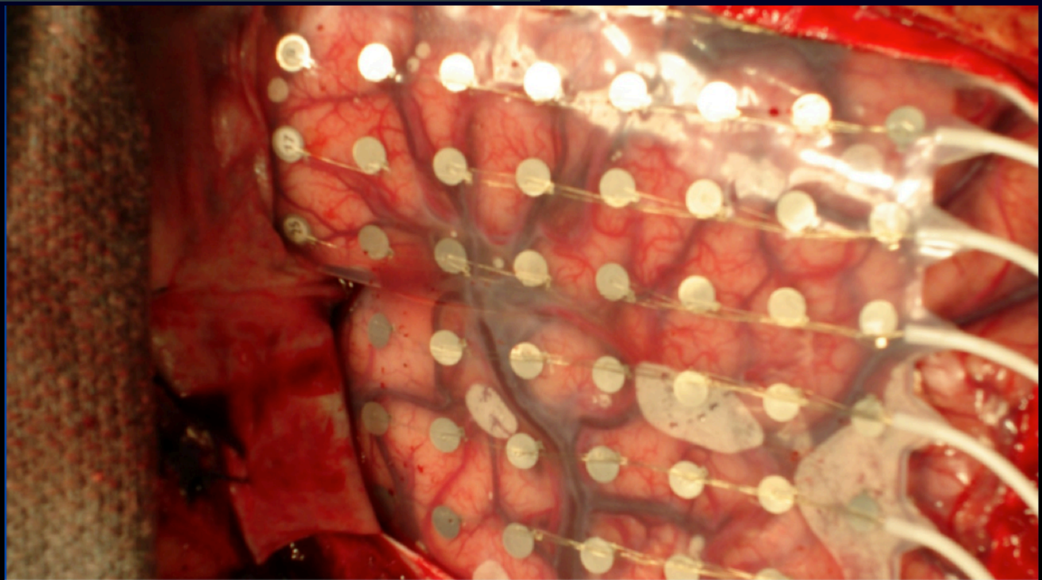
Types of Intracranial Recordings
Grids and Strips - Placement



Types of Intracranial Recordings
Grids and Strips - Placement







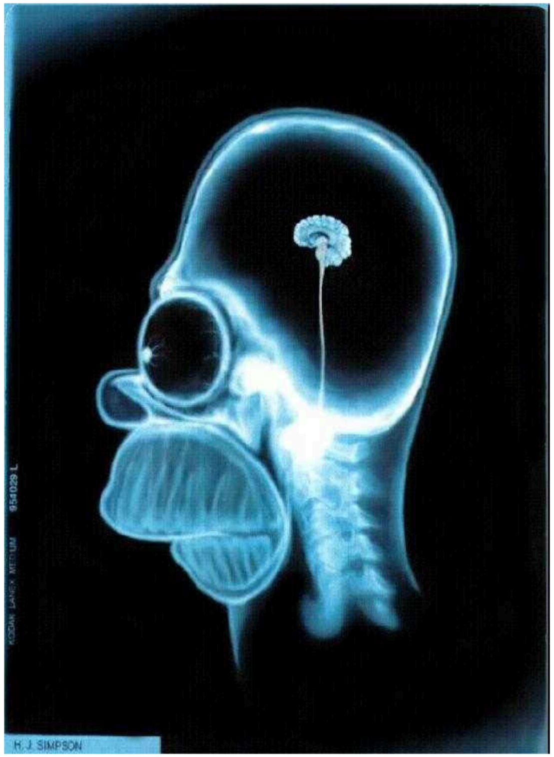
Magnetic Resonance Imaging

- uses magnetic fields and radio waves to produce high resolution images of brain structures without the use of ionizing radiation (e.g. X-rays in CT scanners).

MRI Scanner

MRI vs. fMRI

MRI studies brain **anatomy**.

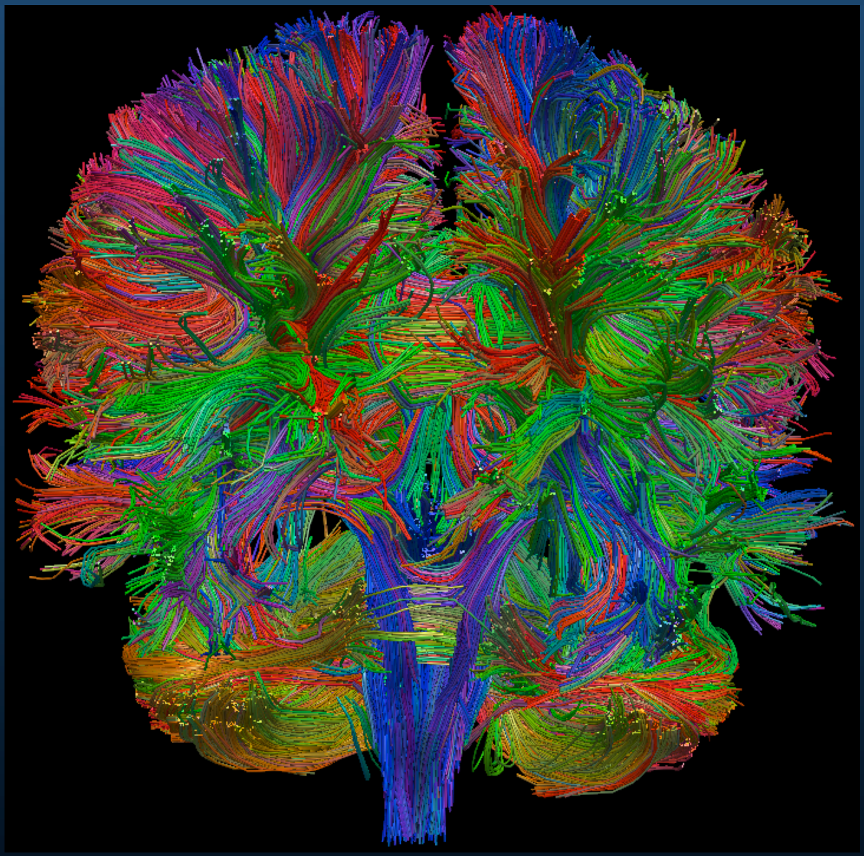


- shows difference between different types of tissues ("difference in space", e.g. white vs. gray matter)

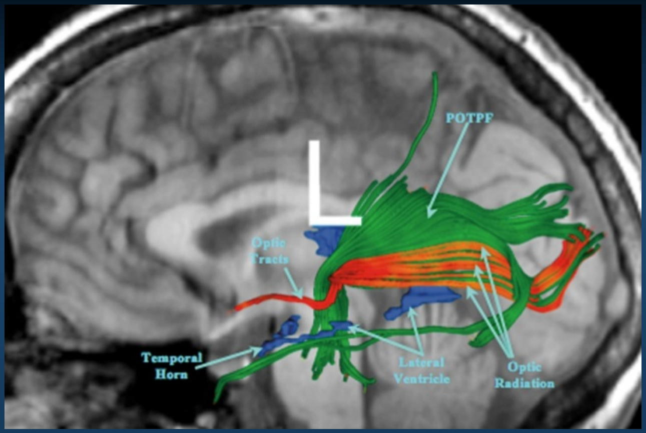
Functional MRI (fMRI) studies brain **function**.

shows difference between stimulated and non-stimulated tissue ("difference in time")

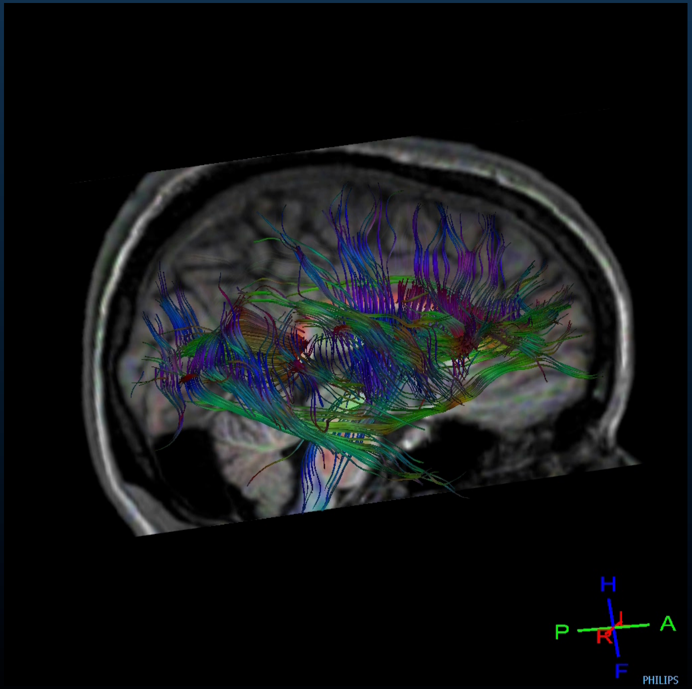
Fiber Tracking with DTI



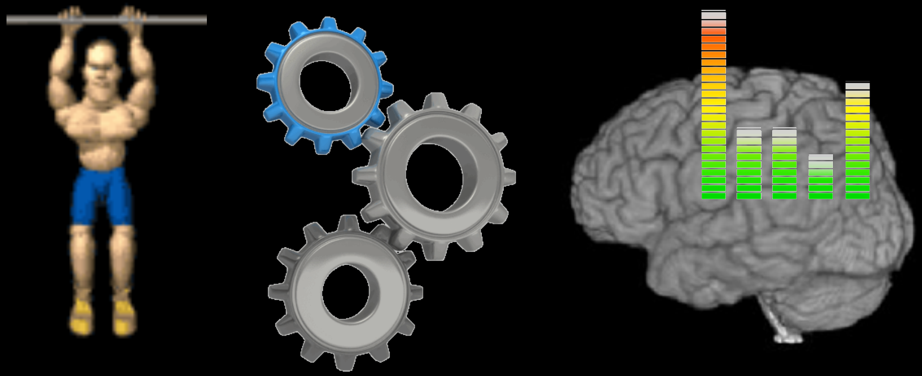
ccn.ucla.edu

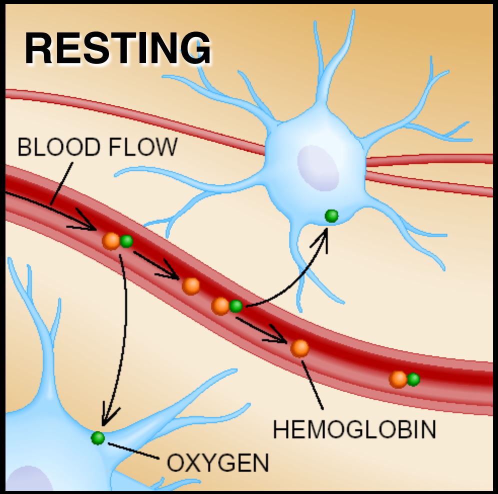


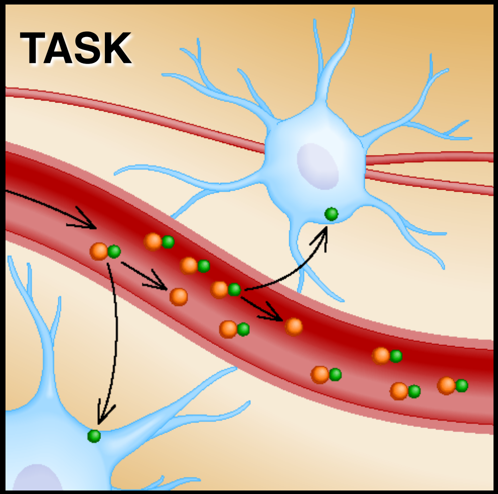
http://www.exploredti.com/



Watching the Brain in Action:

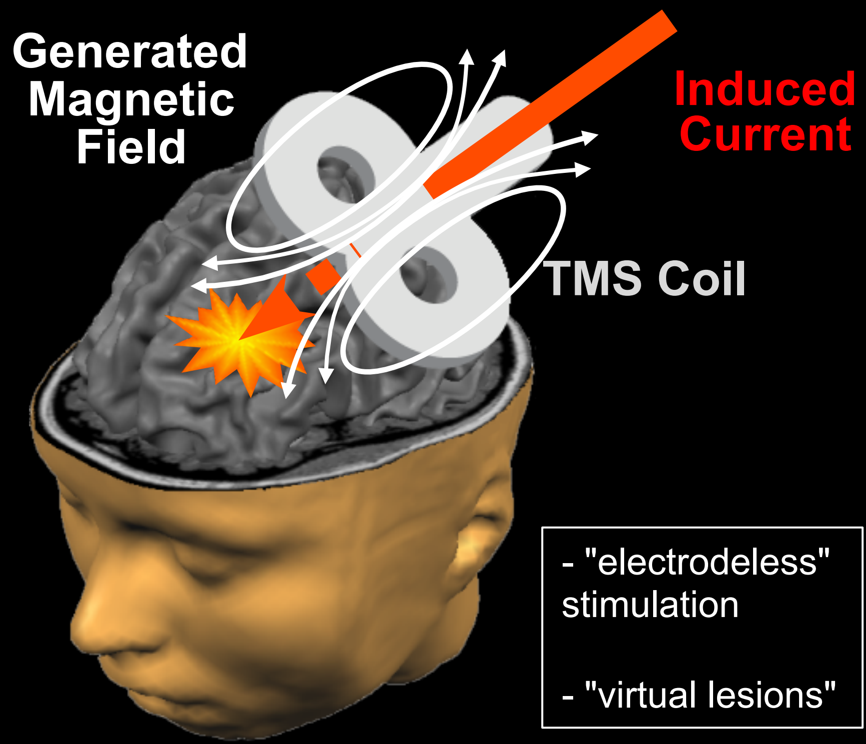




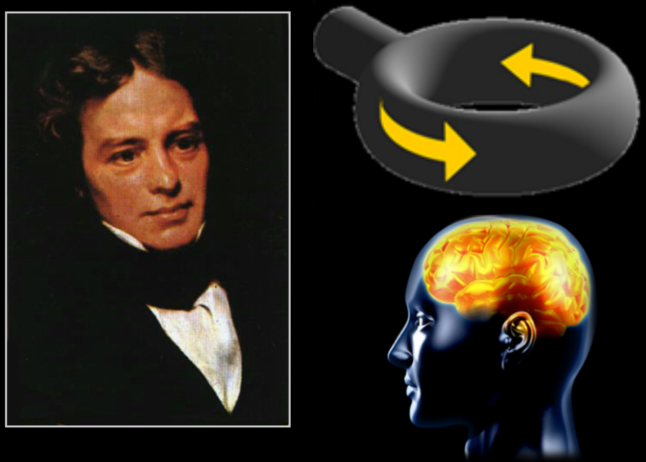


Activity ⟺ Metabolic Demand ⟺ Blood Flow ⟺ Oxygen Consumption

TRANSCRANIAL MAGNETIC STIMULATION (TMS)



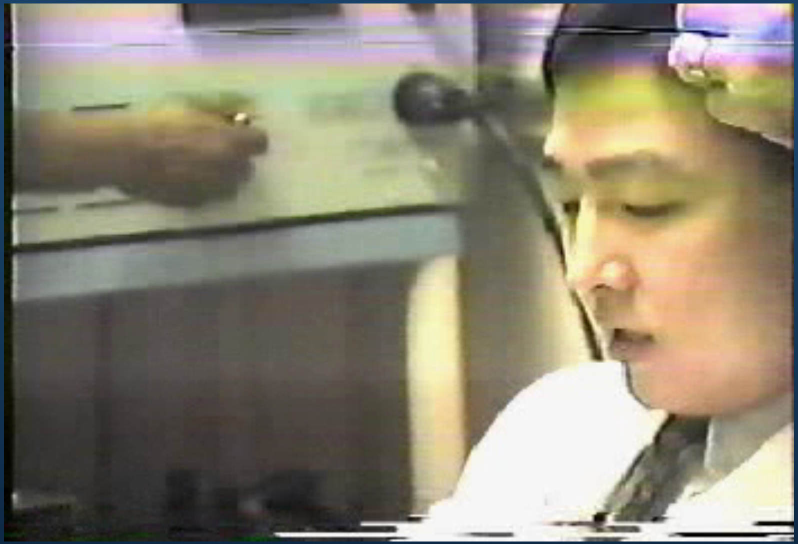
- "electrodeless" stimulation
- "virtual lesions"



Michael Faraday
The Principle of Electromagnetic Induction

very good for probing function

Repetitive Transcranial Magnetic Stimulation (rTMS): "virtual brain lesions"



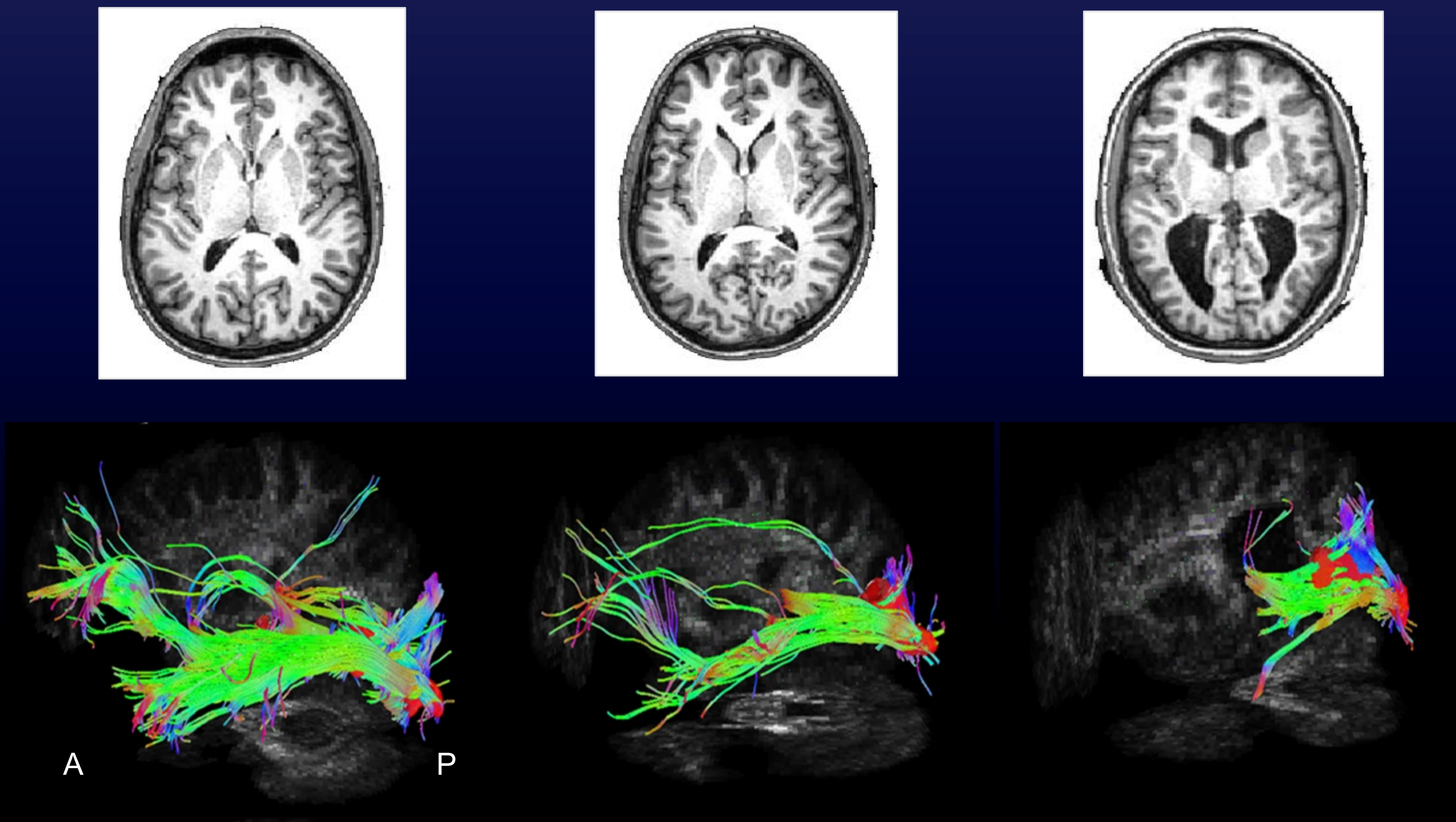
Low frequency (e.g. 1 Hz) = lowered excitability
High frequency (e.g. 10-20 Hz) = increased excitability

BUT…
- risk of seizure
- discomfort/distraction…especially for "on-line" stimulation

video: Chip Epstein

White Matter Tractography/Fiber Reconstruction

A. Control | B. Ocular Blind | C. CVI



"Where?"
- fMRI
- PET

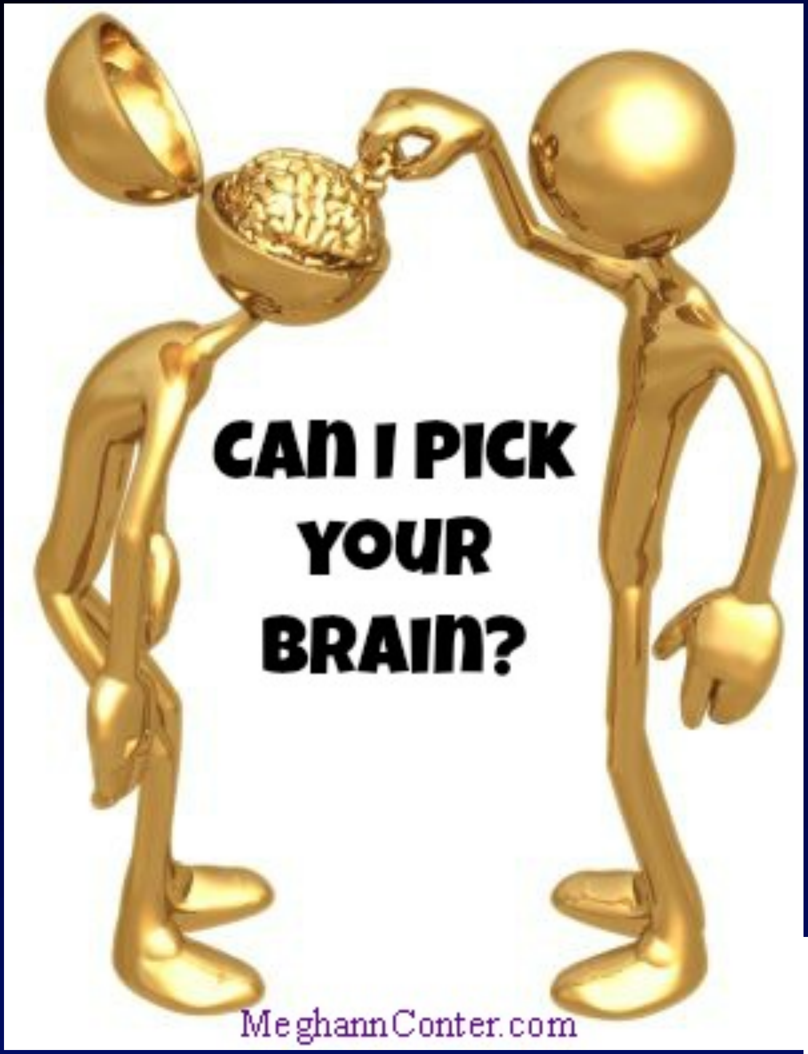
(strong spatial, relatively weaker temporal resolution)

"When?"
- EEG
- MEG
- VEP

(strong temporal, relatively weaker spatial resolution)

"What?"
- Brain Lesions
- Brain Stimulation

(function lost vs function gained to establish causality)


CAN I PICK YOUR BRAIN?
MeghannConter.com


THANK
Y U!