HOW TO:

NEUROSCIENCE

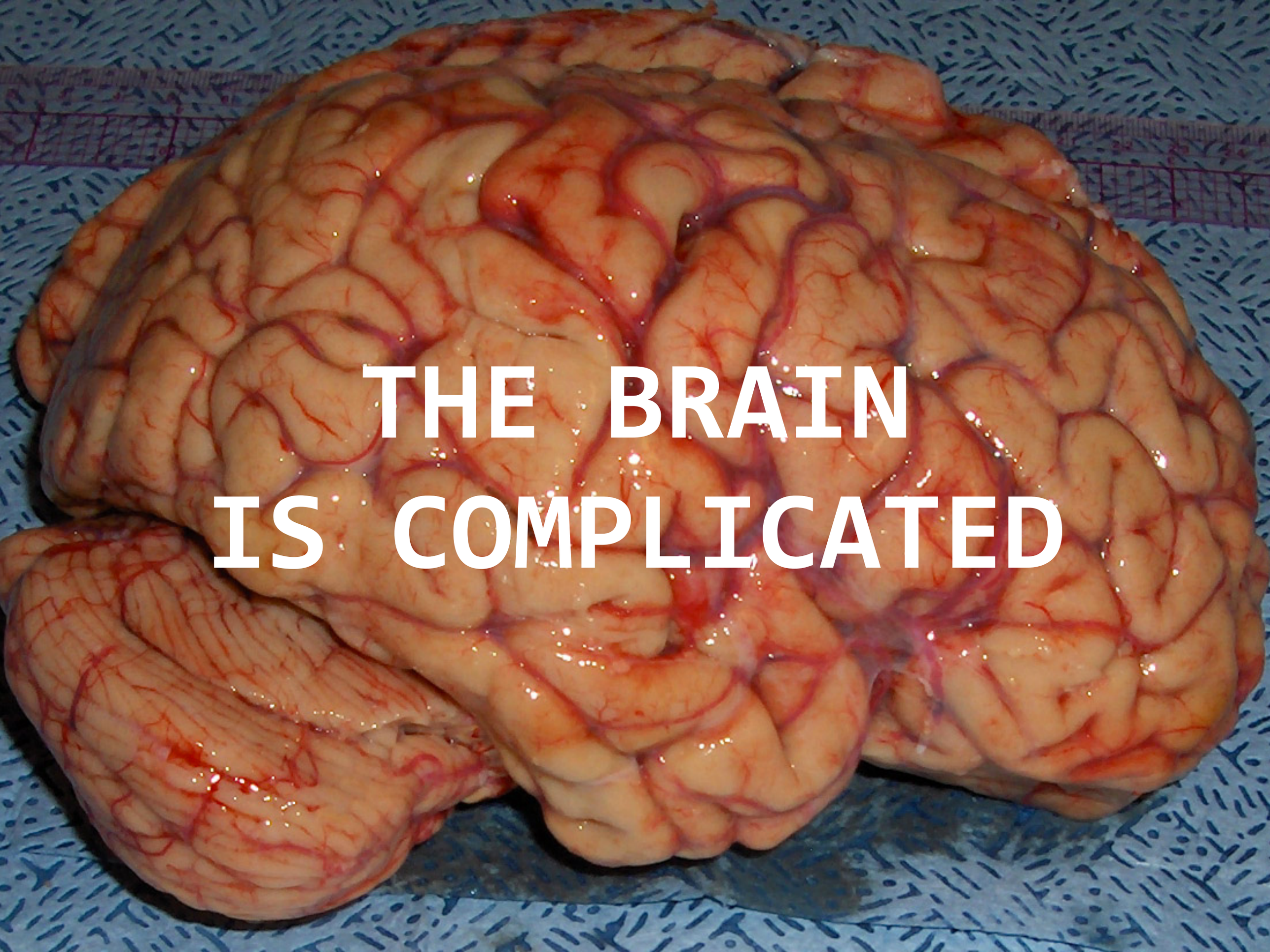
Prof. Alexander Huth

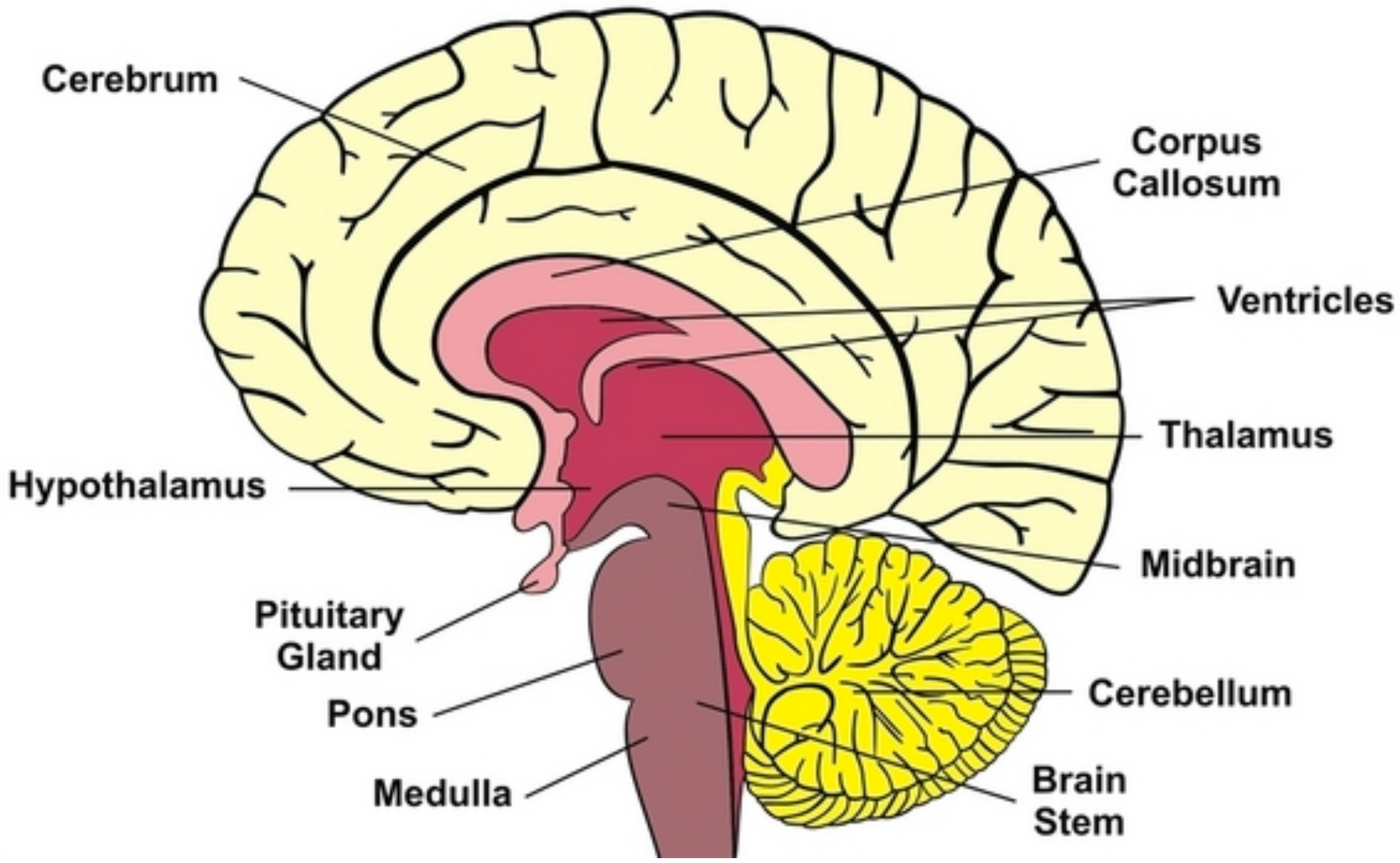
9/5/2017

TODAY

* Brief introduction to the human brain

* The tools of neuroscience


THE BRAIN
IS COMPLICATED


Cerebrum
Corpus Callosum
Ventricles
Thalamus
Hypothalamus
Midbrain
Pituitary Gland
Cerebellum
Pons
Brain Stem
Medulla

THE BRAIN

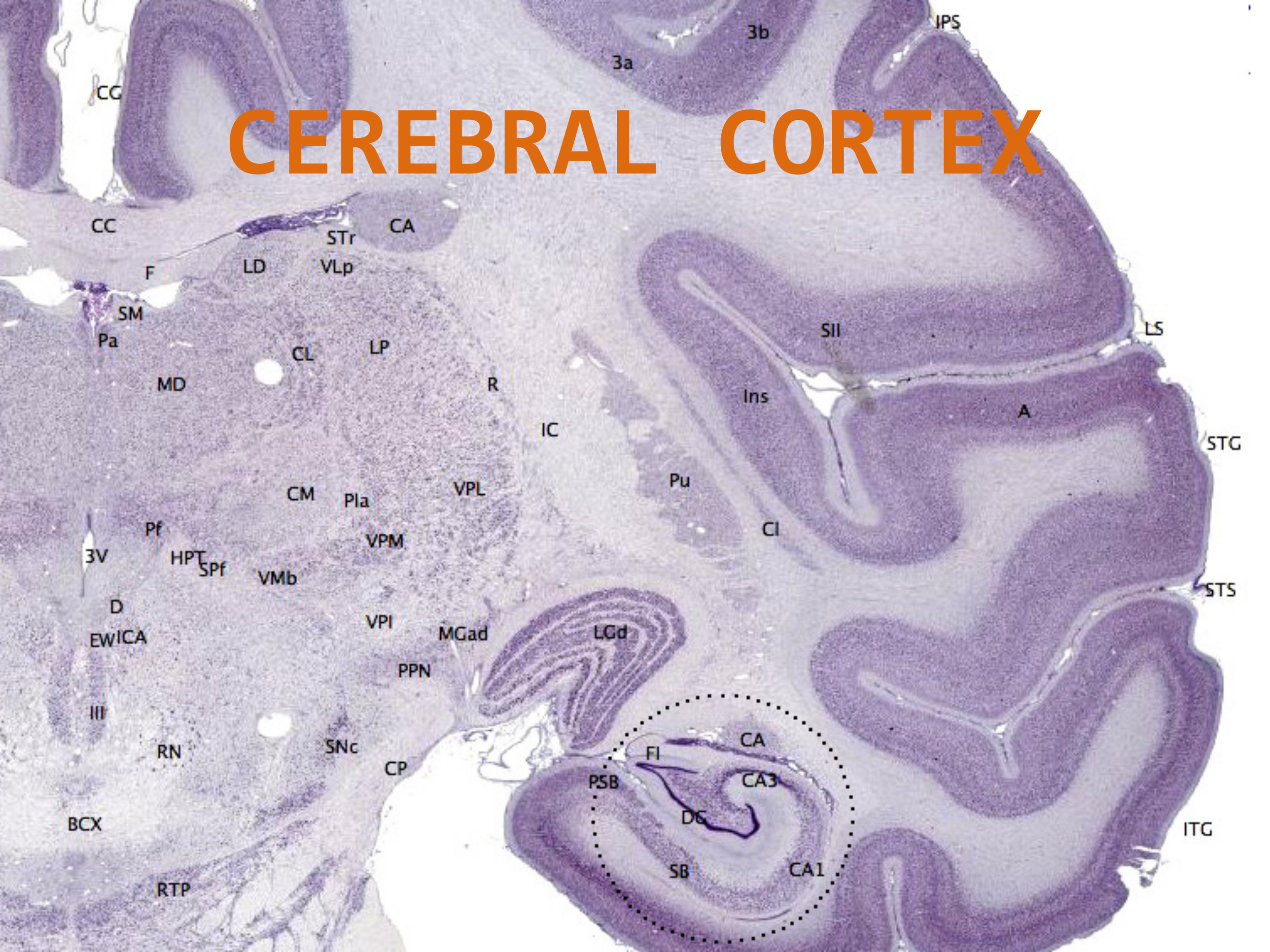
* ~85 billion neurons

* 12-15 billion in telencephalon

* ~70 billion in cerebellum

Herculano-Houzel, S. (2009)

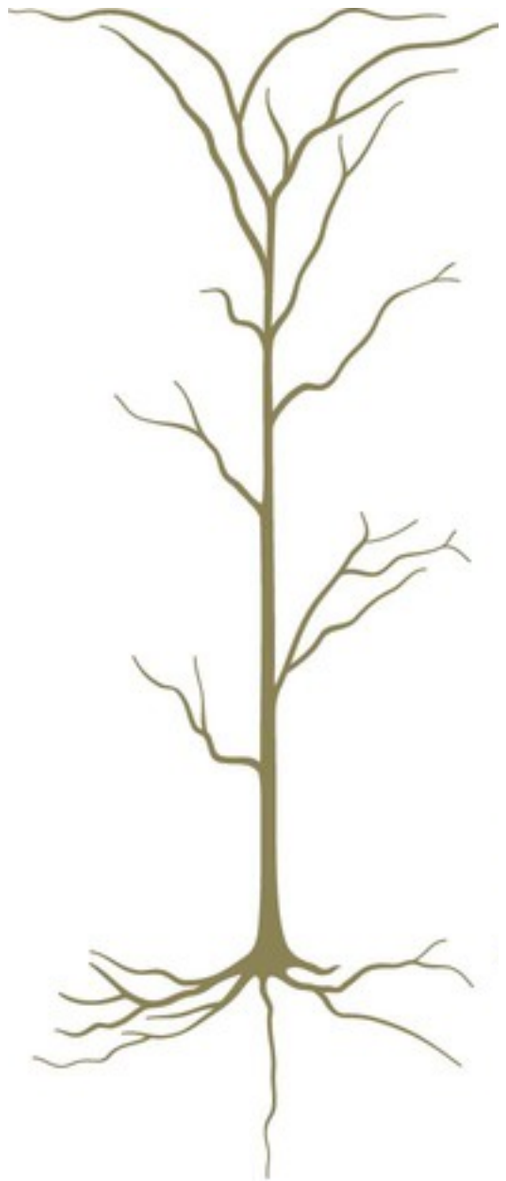
CEREBRAL CORTEX



NEURONS

* **Neurons** are cells that are specialized for rapidly processing and communicating information

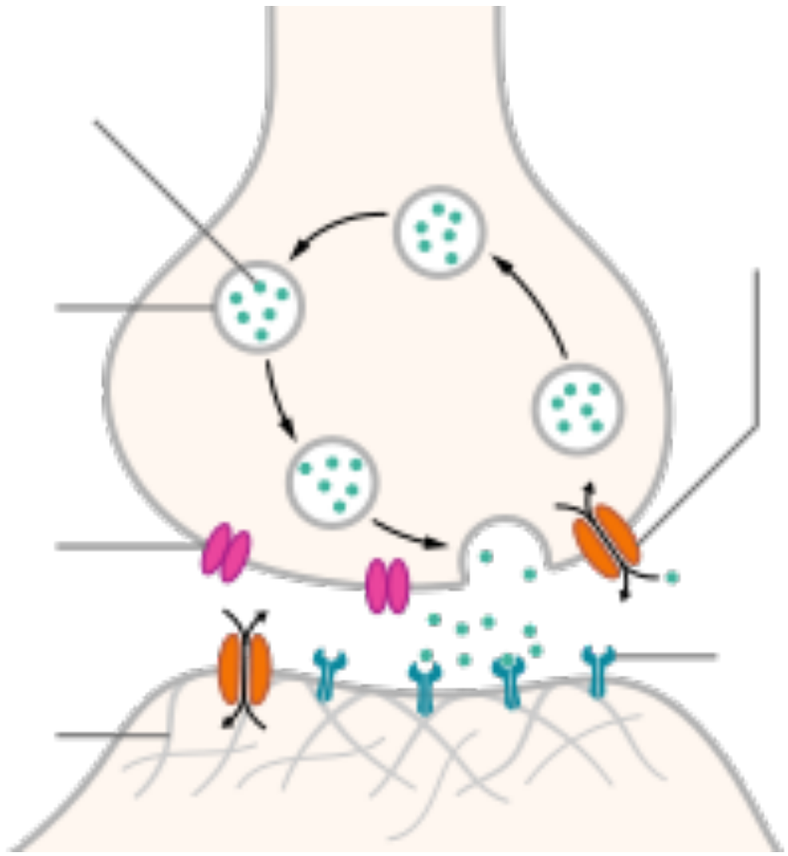
* In cortex, neural activity is **binary**: on (**spiking**) or off



NEURONS

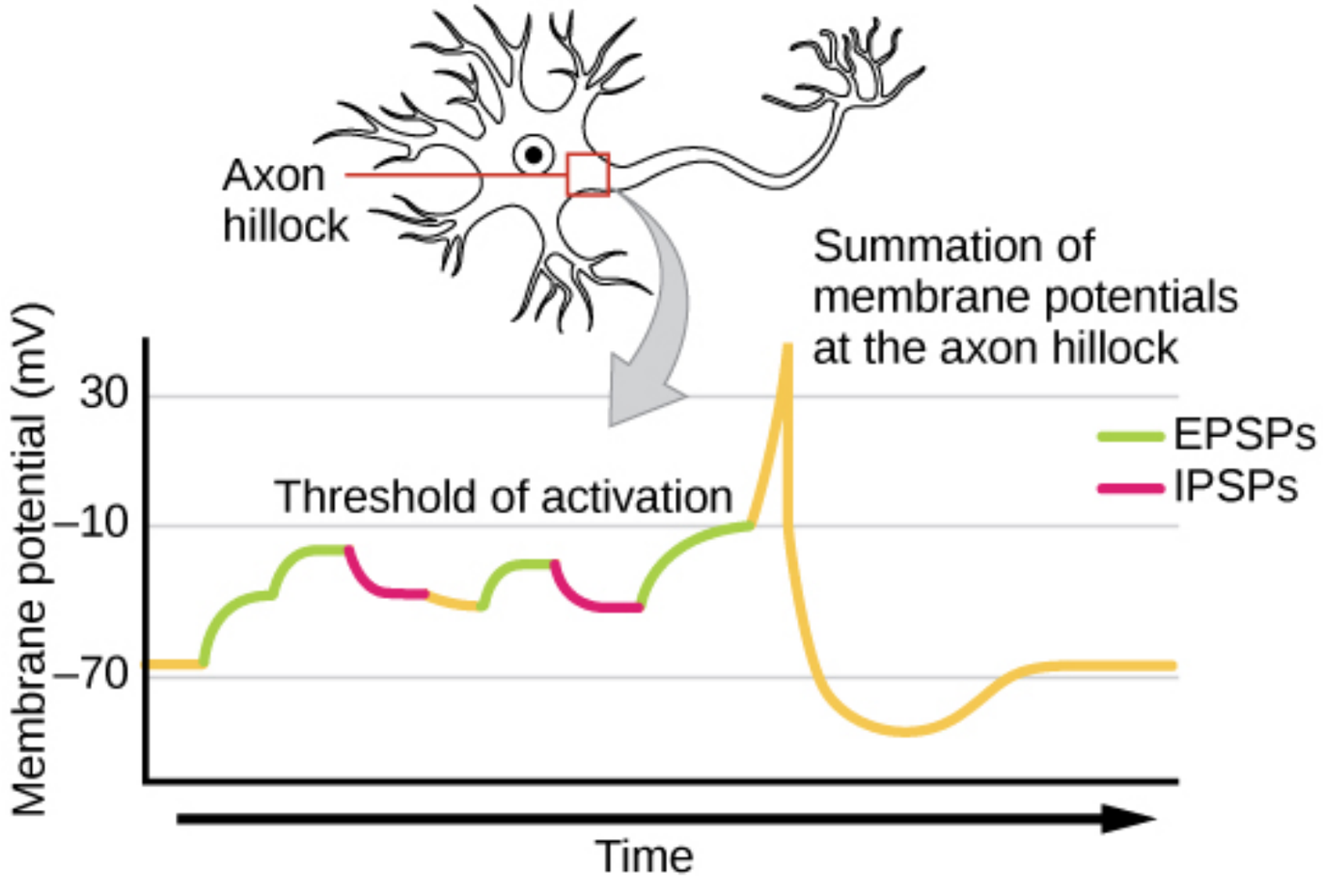
* Neurons form **synapses**: connections that carry information from one neuron to another

* Synapses can be **excitatory** or **inhibitory**



NEURONS

* A **spike** is generated when summed inputs reach a threshold value



NEURONS

* Synaptic weights are **plastic**

* **Hebbian Learning:**

  * *Neurons that fire together, wire together*

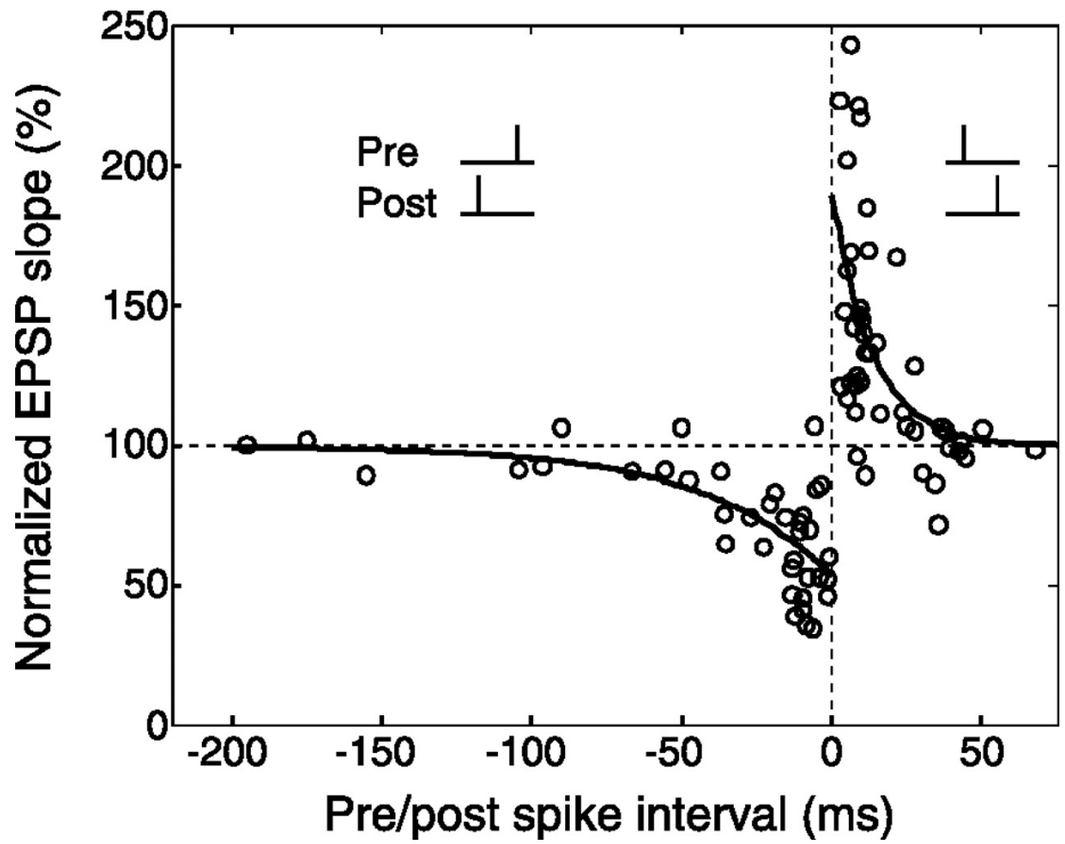
Donald Hebb
(1904-1985)

NEURONS

* Spike-timing dependent plasticity (STDP)

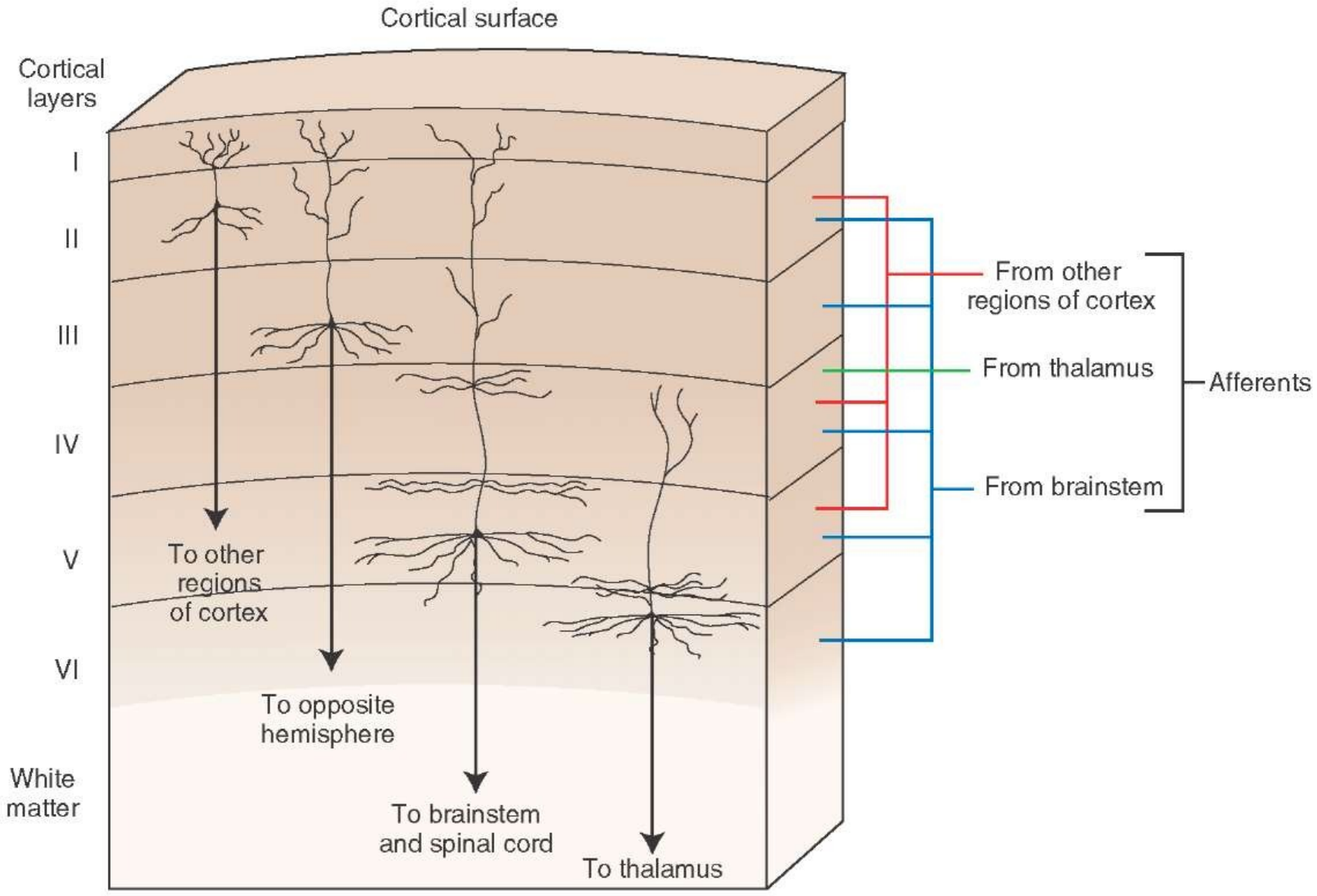
* Long-term potentiation (LTP)

* Long-term depression (LTD)



CEREBRAL CORTEX

* *Vaguely* stereotypical 6-layer structure



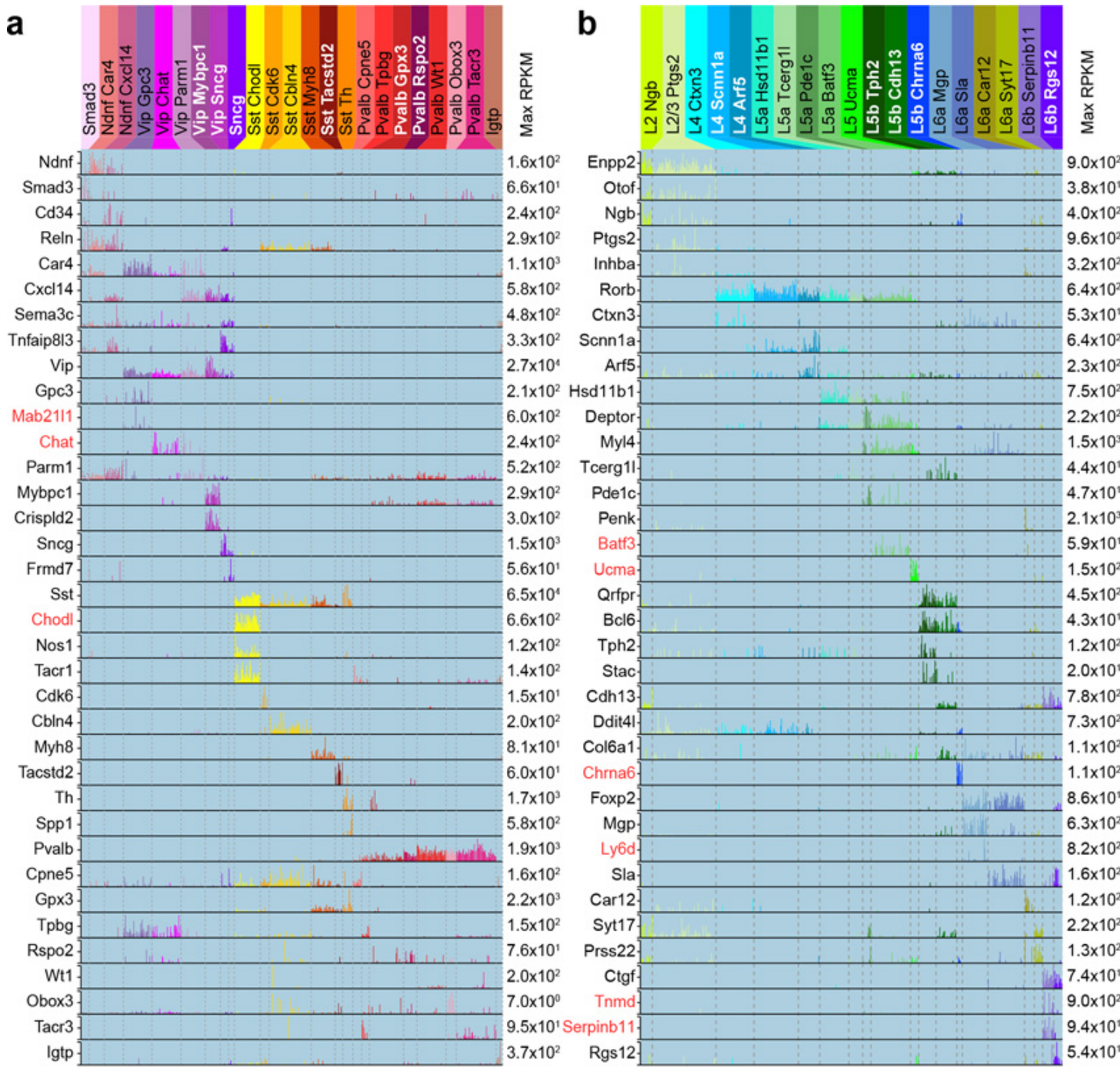
CEREBRAL CORTEX

* Traditional idea:
  * 1 type of excitatory cell (pyramidal), a few types of inhibitory cells (basket, chandelier, etc.)

CEREBRAL CORTEX

* Modern findings:

  * at least **23** excitatory types & **19** inhibitory types (in visual cortex alone!)



Tasic et al. (2016)

CEREBRAL CORTEX

* In short:

  * Cortex is complicated (much more so than neuroscientists thought a few years ago)

METHODS

* Build it

* Break it

* Measure it

LESIONS

* First scientific way to study human brain function

* Led to idea of **localization of function**

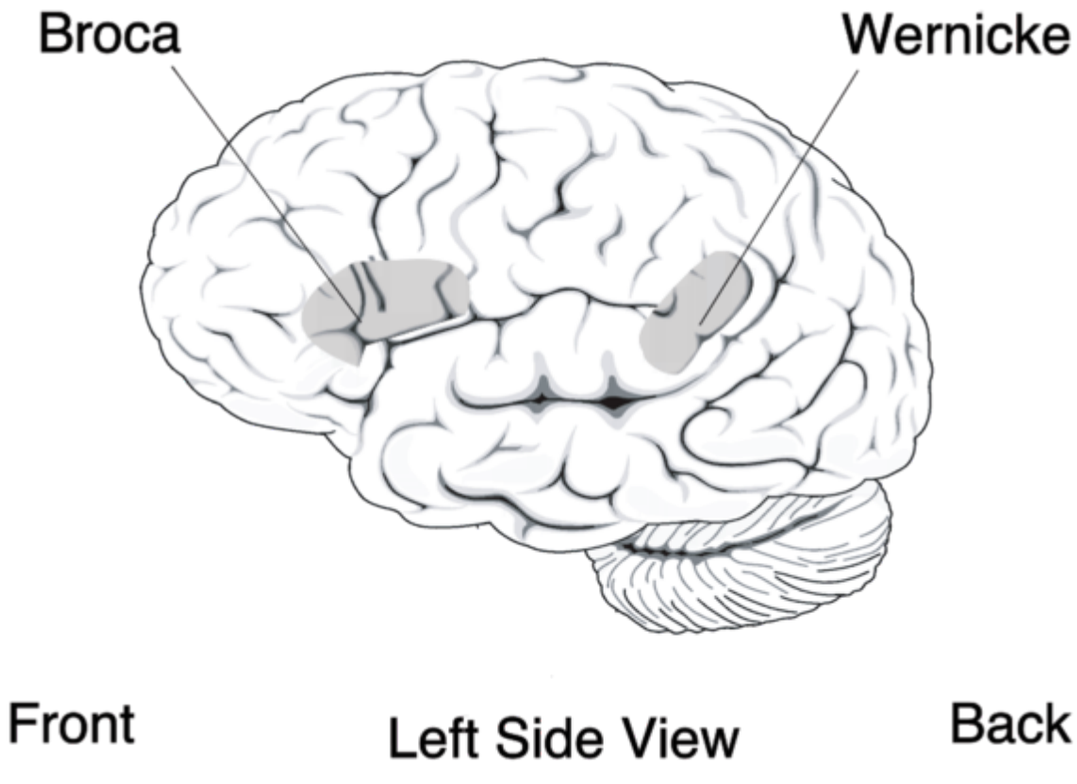
  * The brain is divided into parts or **areas**

  * What is the function of each area?

LESIONS

* Broca’s aphasia: the inability to **produce** fluent speech

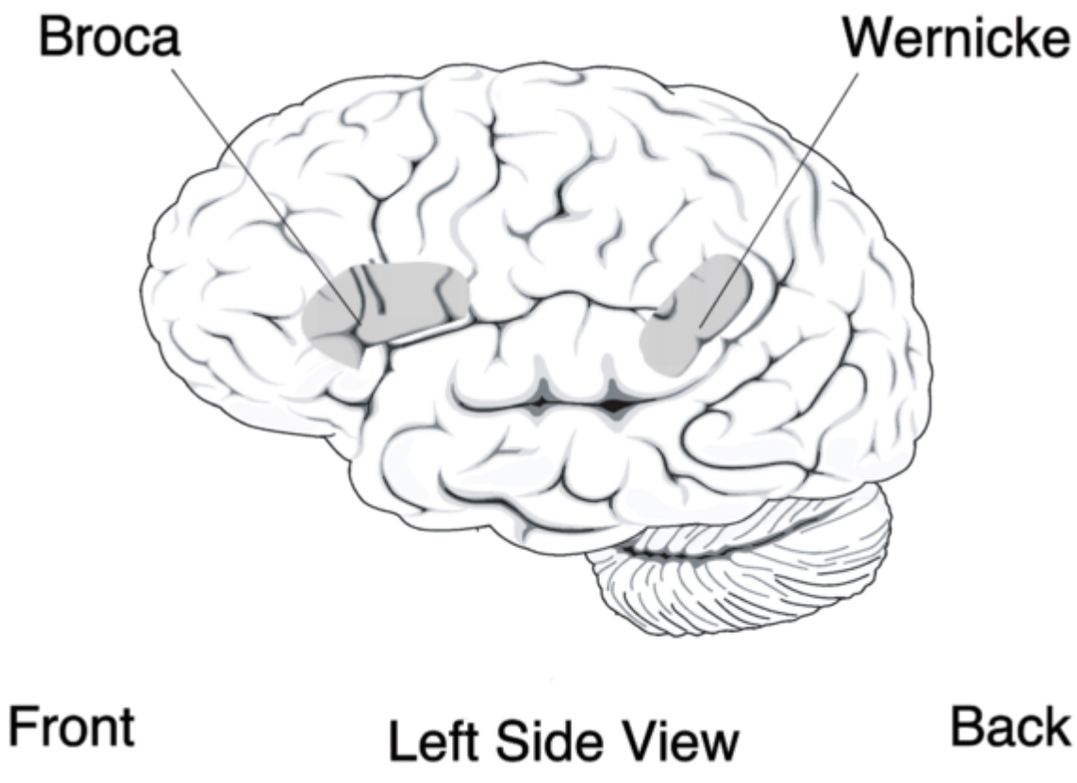
Paul Broca (1824-1880)



LESIONS

* Wernicke’s aphasia: the inability to **understand** speech

Carl Wernicke (1848-1905)



LESIONS

* In non-human neuroscience:
  * Tools like **optogenetics** enable fast, reversible inactivation of specific cell types in specific areas

* Exciting and effective

METHODS

* Build it

* Break it

* Measure it

MEASURE WHAT?

* Anatomy

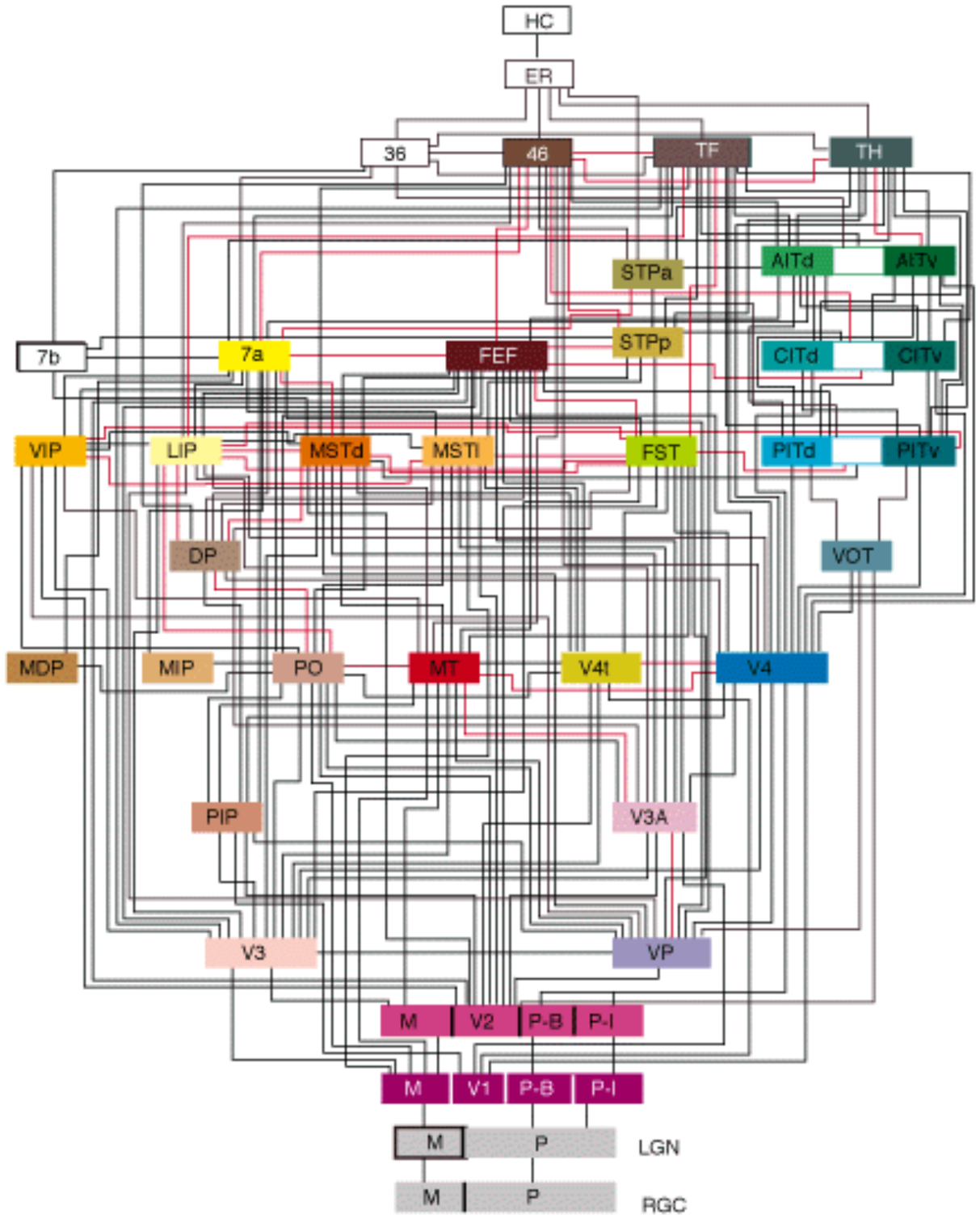
* Connectivity

* Function

CONNECTIVITY

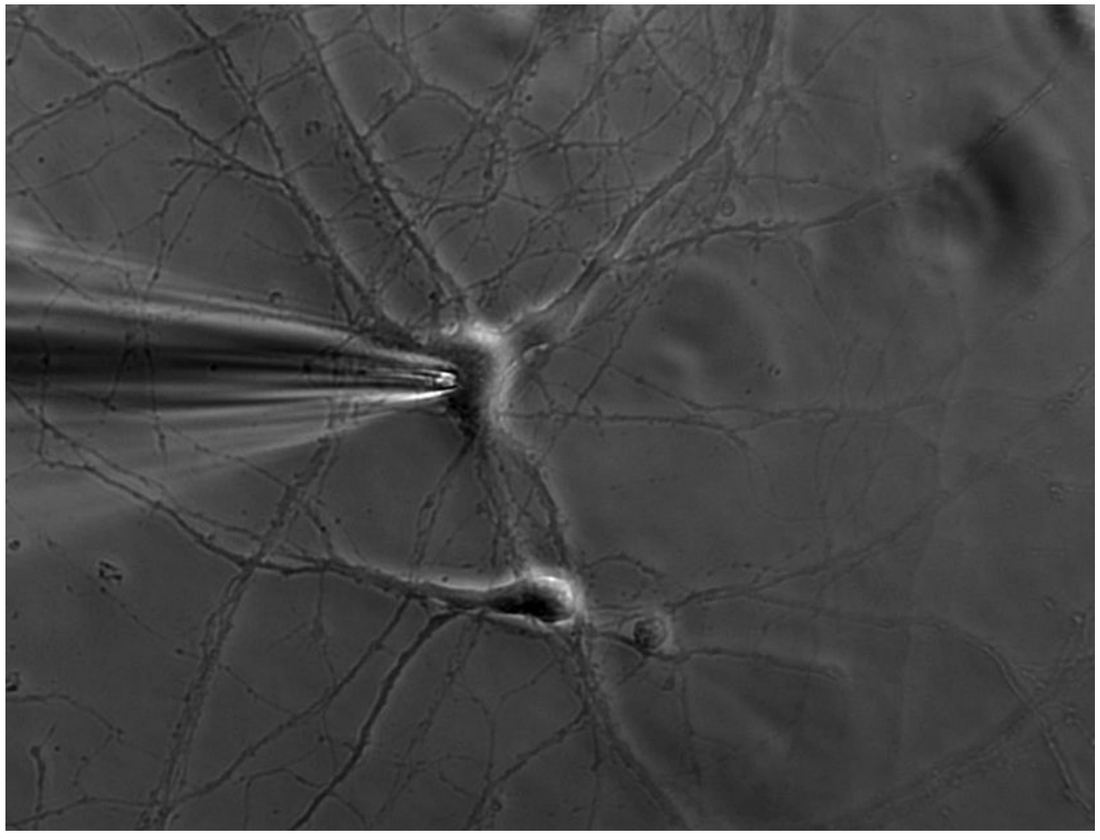
* **Connectivity** of areas in macaque visual cortex

* Felleman & Van Essen (1991)

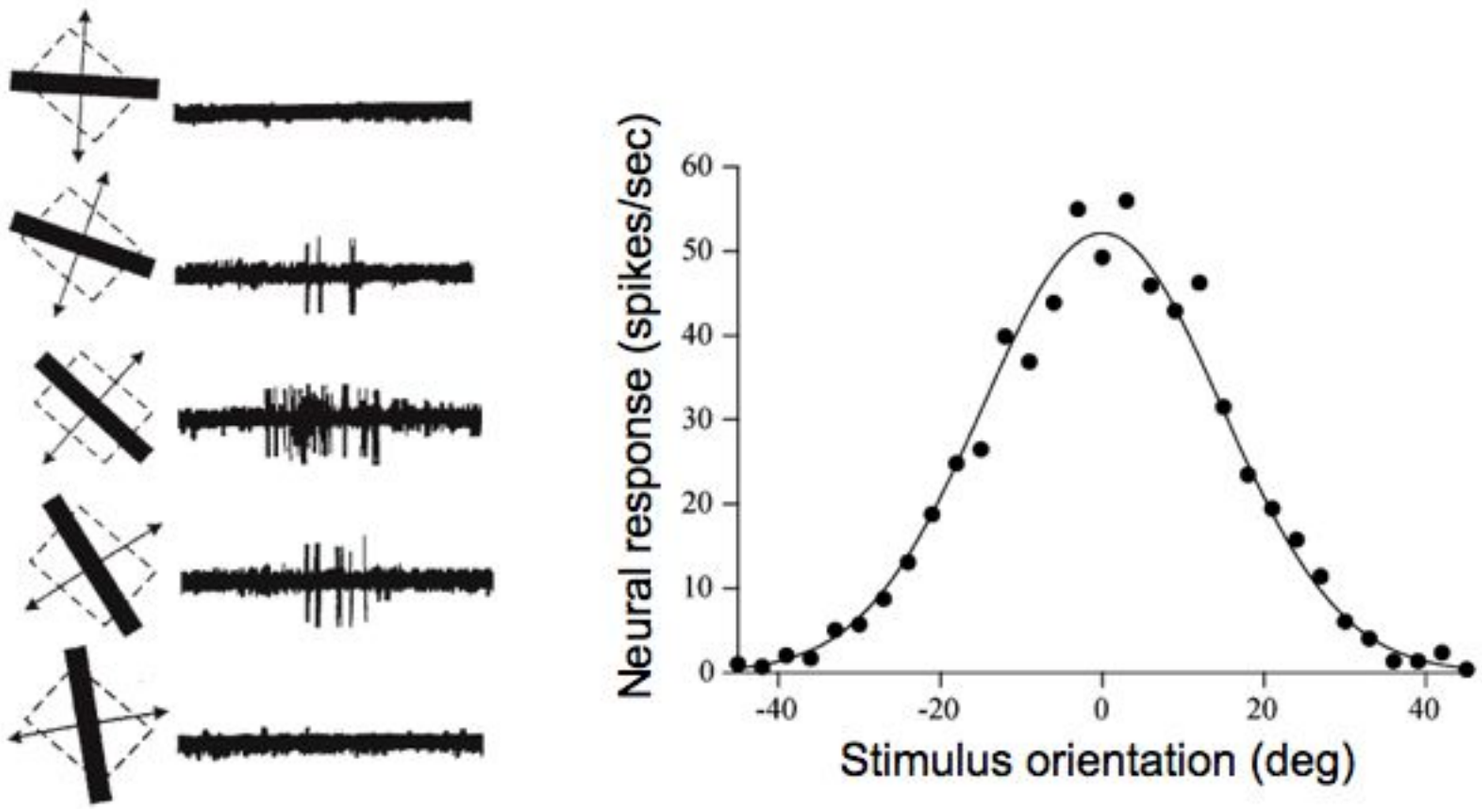


NEUROPHYSIOLOGY

* It’s possible to measure the activity of a single neuron using an **electrode**



NEUROPHYSIOLOGY



Hubel & Wiesel, 1968

NEUROPHYSIOLOGY

* Individual neurons can be characterized as having **receptive fields**

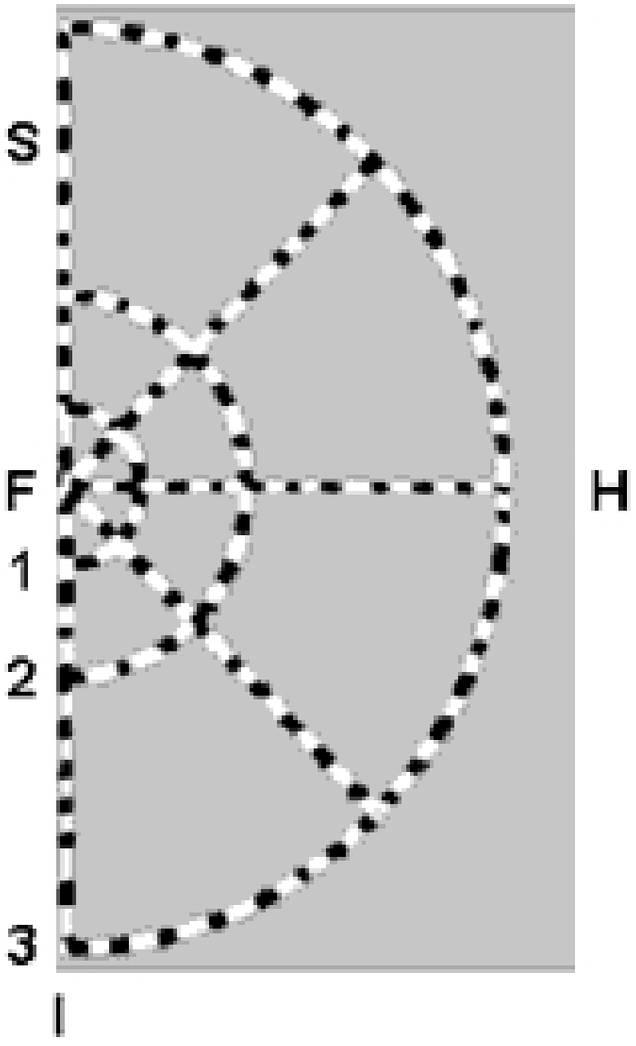
* A receptive field is the **stimulus subspace** that **elicits activity** in a neuron

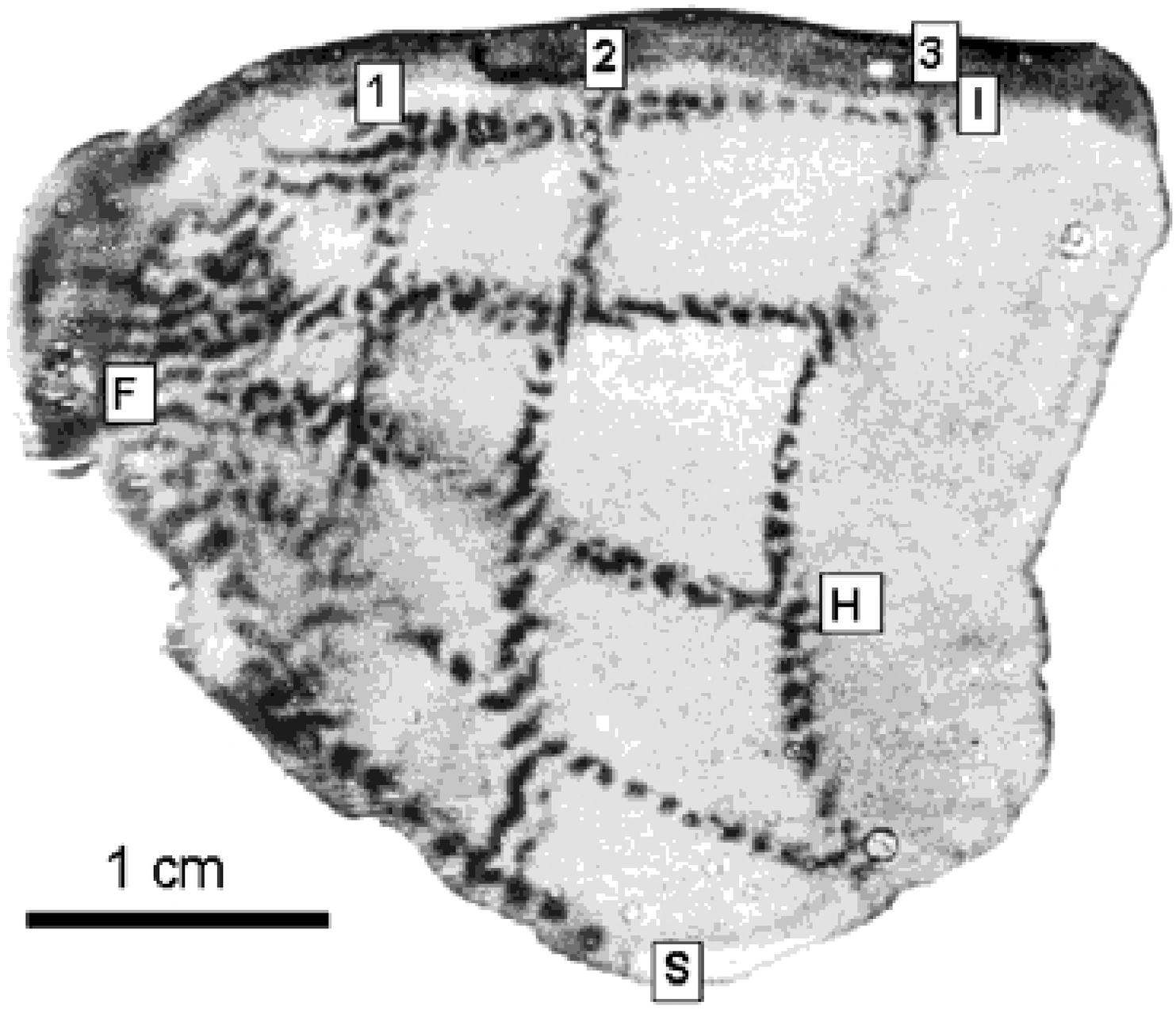
NEUROPHYSIOLOGY

* In cortex, many neurons are organized into **maps**

* *Nearby* neurons have *similar* receptive fields

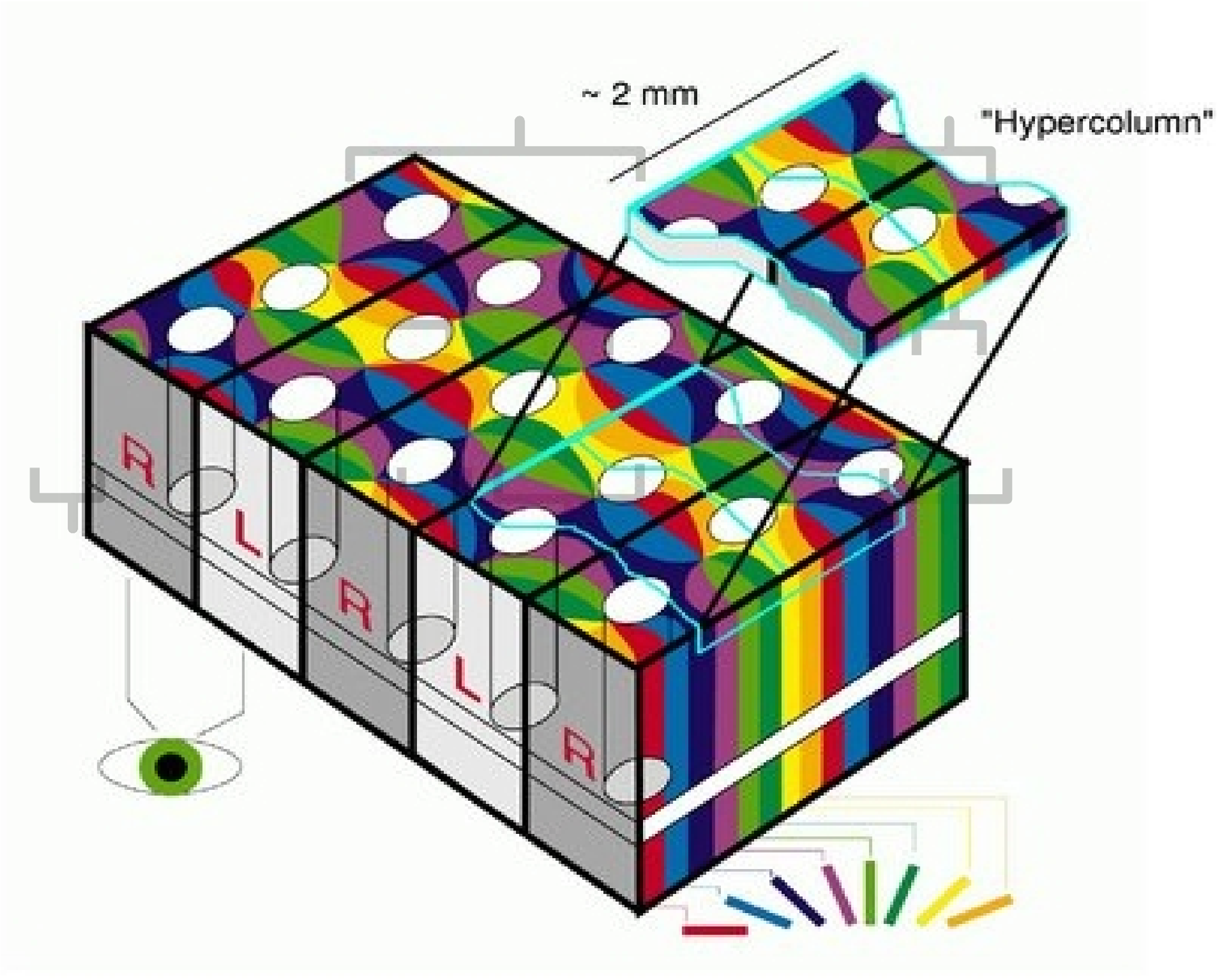
Retinotopic map in primary visual cortex



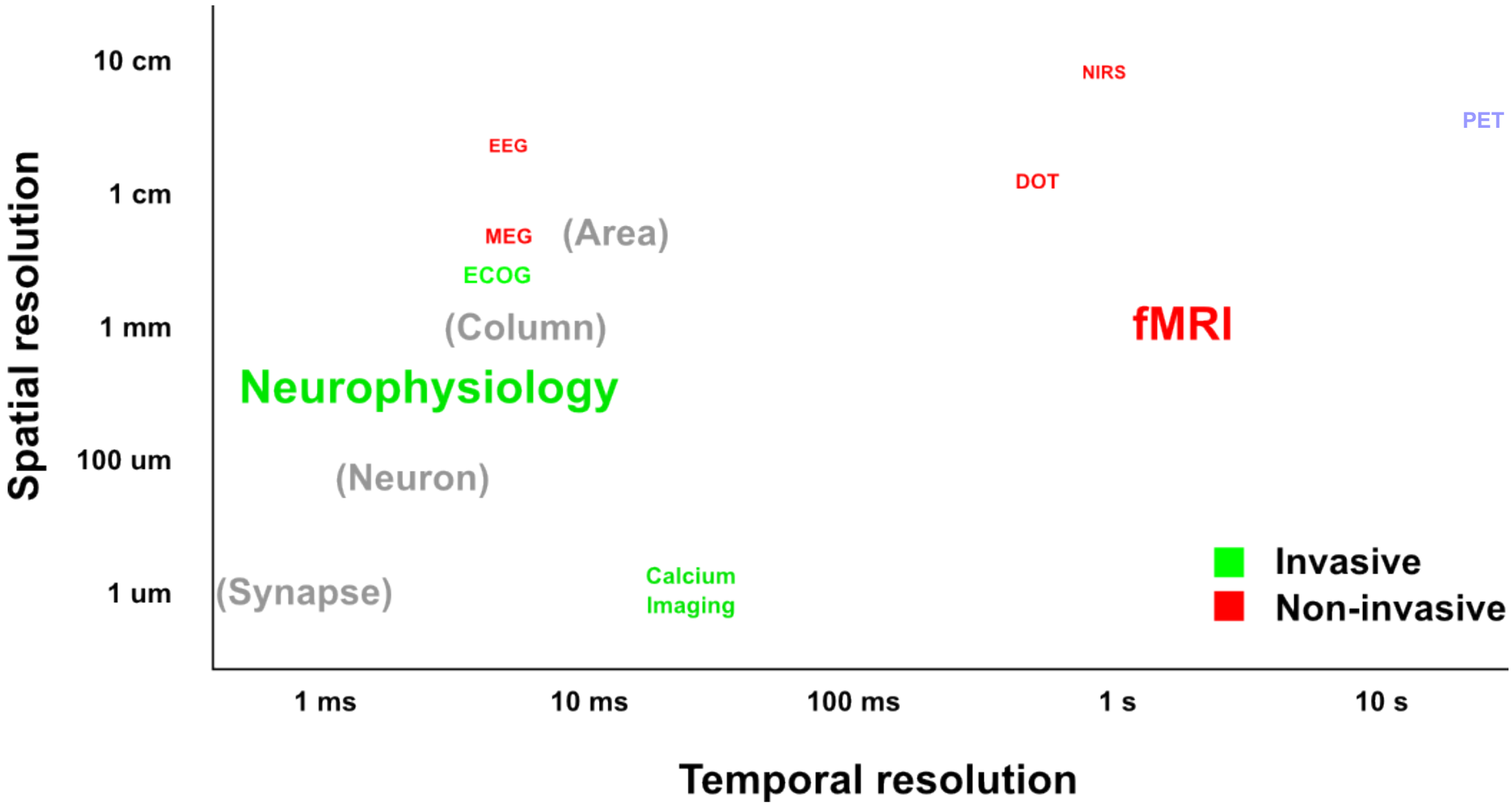


Tootell, Silverman, Switkes & DeValois, 1982

Many dimensions are coded at each position



Methods for recording brain activity



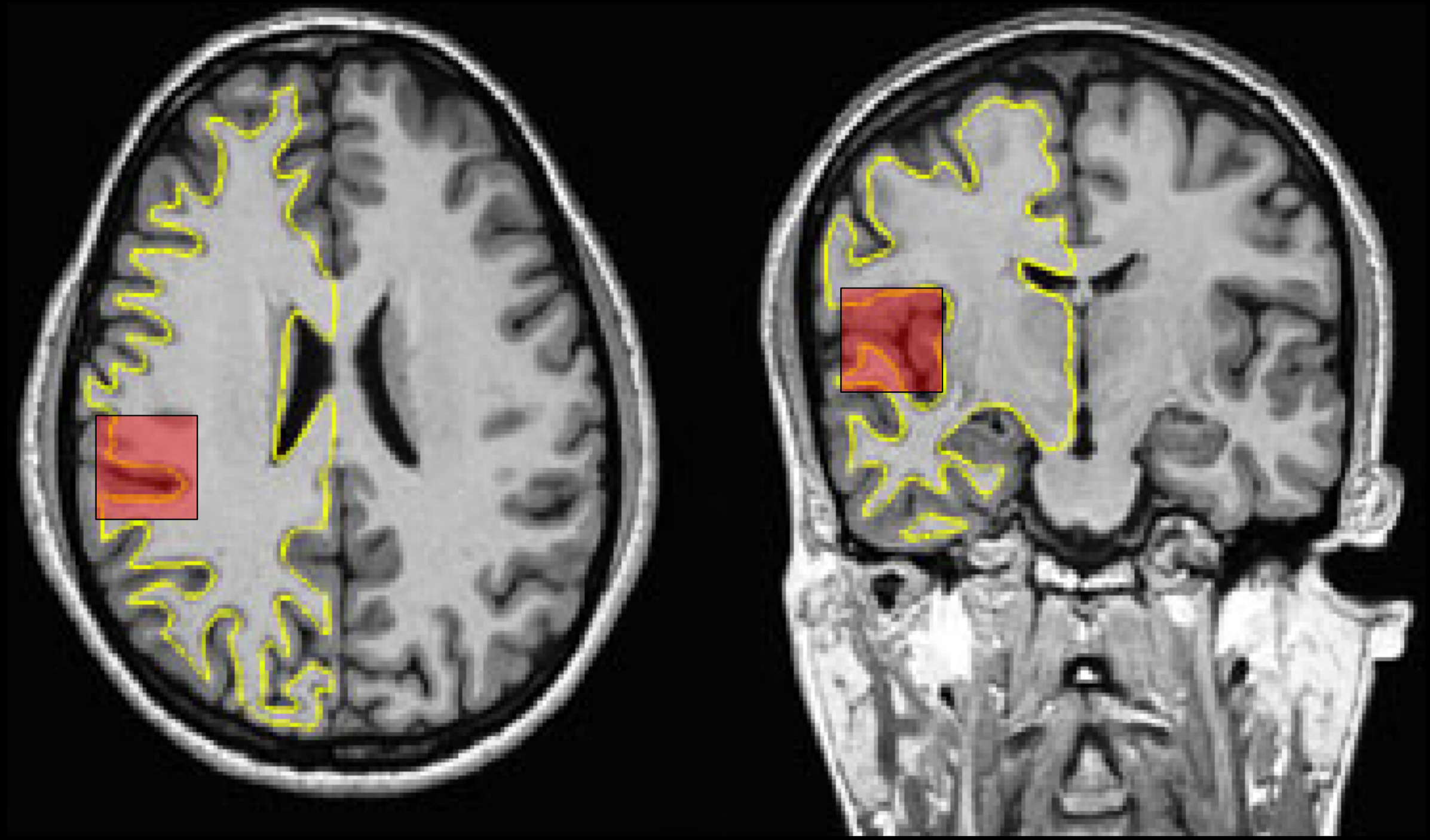
EEG: Electroencephalography

Tangemann et al. 2010

Cichocki et al. 2009

Advantages	Disadvantages
Relatively simple and cheap	Poor signal quality
Good temporal resolution	Poor spatial resolution (> 1 cm)
Measures neural activity	Neural activity measure is biased
Inherently 2D	

EEG has poor spatial resolution

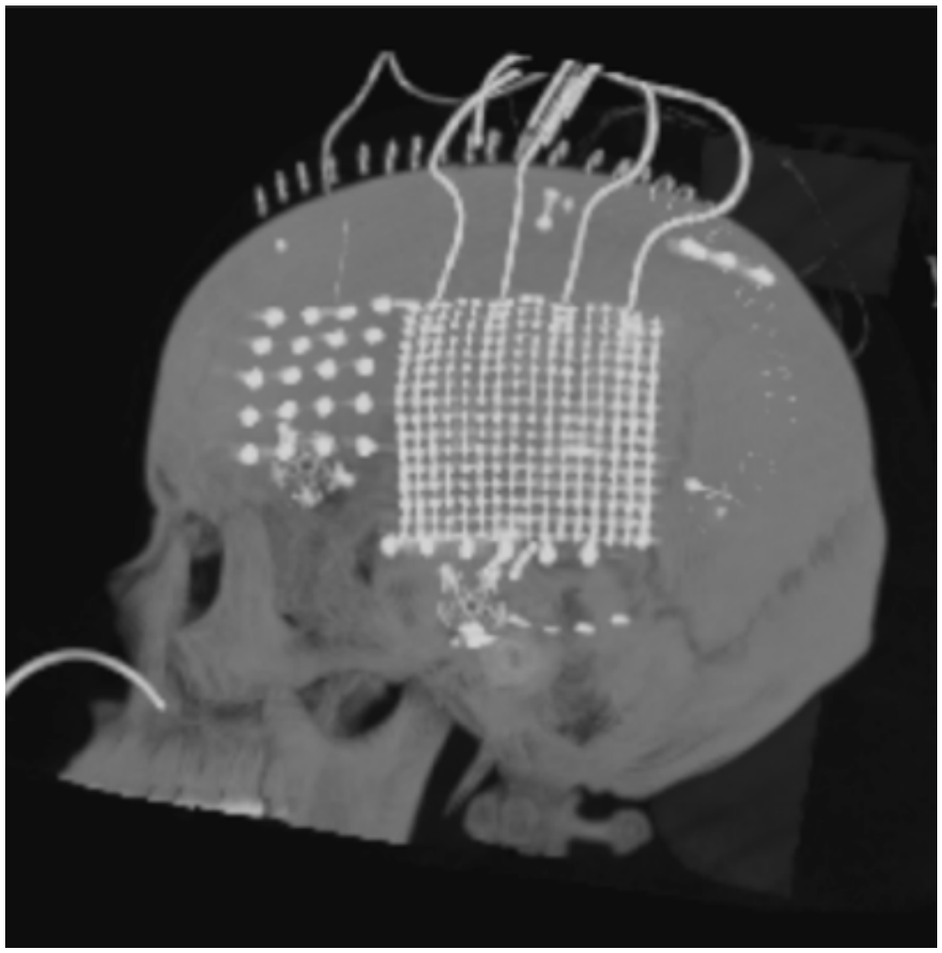


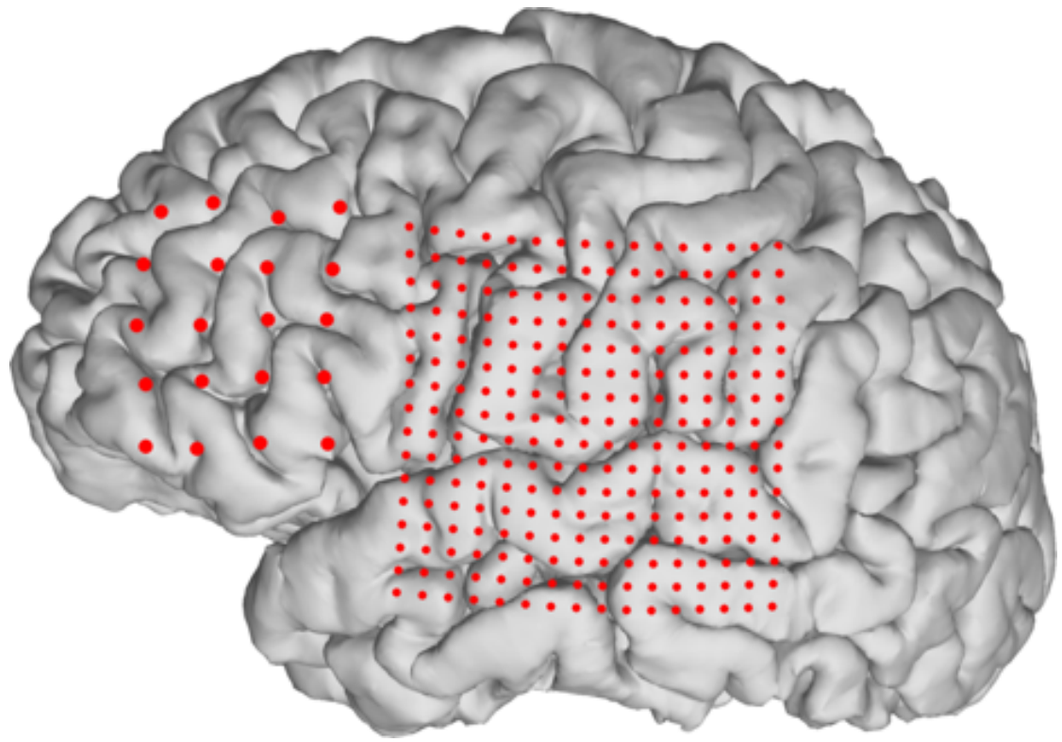
MEG: Magnetoencephalography

Roberts et al., 2008

Advantages	Disadvantages
Better signal quality than EEG	Expensive, requires gnomes
Good temporal resolution	Poor spatial resolution (~ 8 mm?)
Measures neural activity	Neural activity measure is biased
Inherently 2D	

ECoG: Electrocorticography

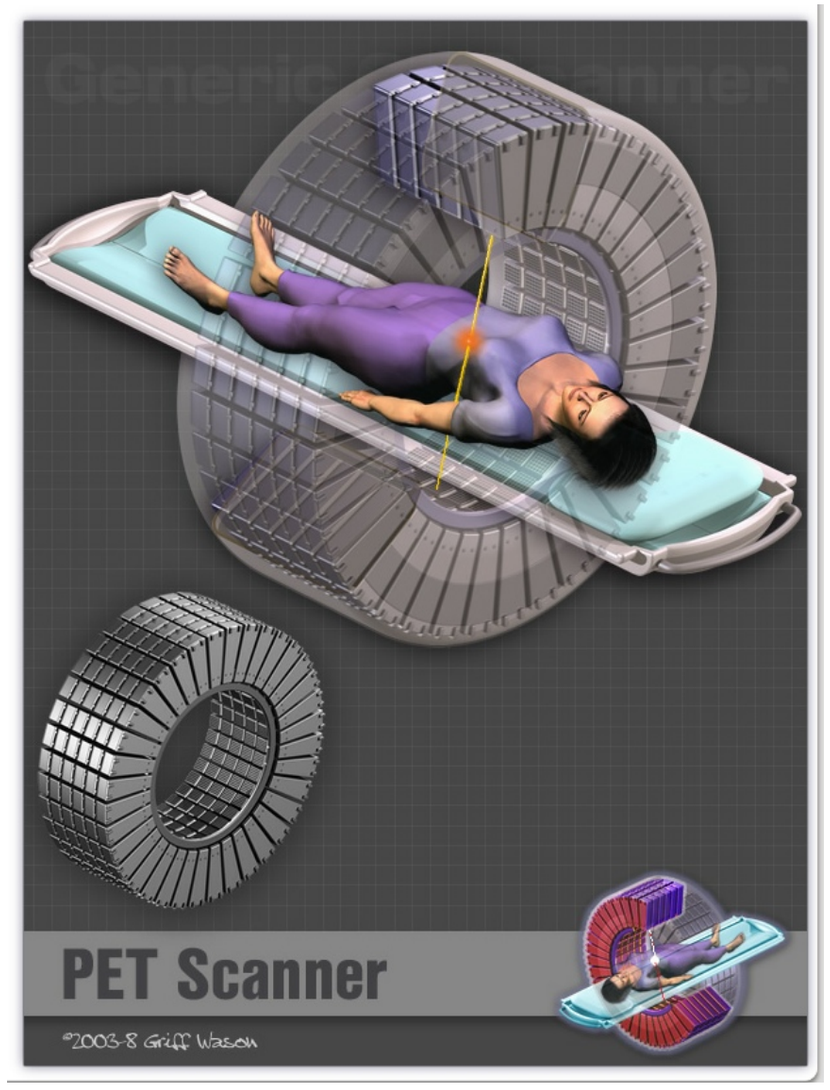




images c/o Liberty Hamilton, Chang Lab UCSF 2016

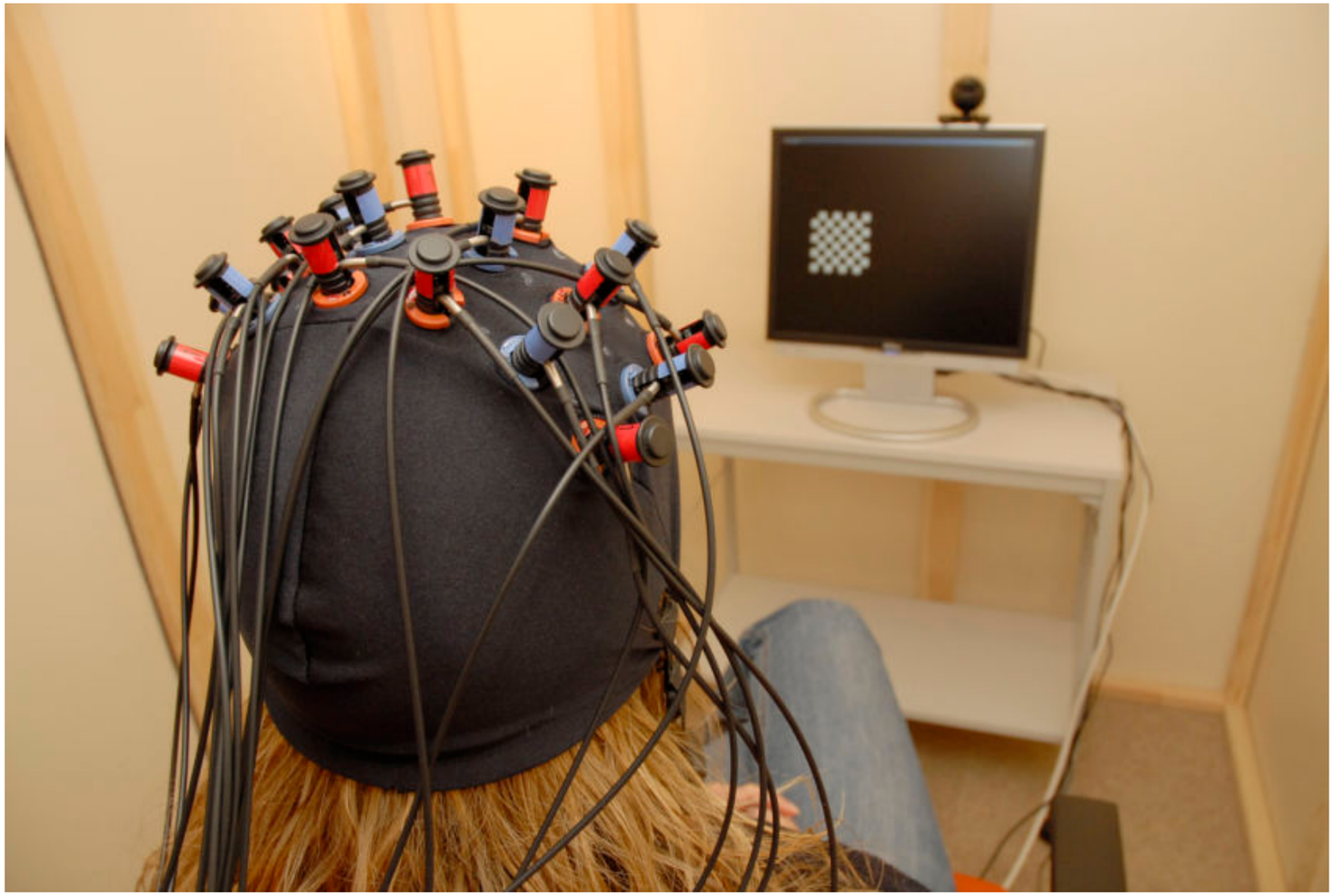
Advantages	Disadvantages
Relatively good signal quality	Invasive, requires craniotomy
Good temporal resolution	Poor spatial resolution (~ 8 mm)
Measures neural activity	Neural activity measure is biased
Inherently 2D	

PET: Positron emission tomography



Advantages	Disadvantages
Relatively simple and cheap	Poor signal quality
Good temporal resolution	Poor spatial resolution (> 1 cm)
Tomographic (2D slice)	Probably really bad for you

NIRS: Near-infrared spectroscopy



Neuper & Pfurtscheller, 2010

Advantages	Disadvantages
Relatively simple and cheap	Poor signal quality
Inherently 2D	Bad spatial resolution (> 3 cm)
	Doesn't measure neural activity

FMRI: Functional Magnetic Resonance Imaging

Advantages	Disadvantages
Good spatial resolution (~ 3 mm)	Very expensive & complicated
Inherently 3D	Poor temporal resolution (> 1 s)
	Does not measure neural activity

There are no great methods for measuring maps in the human brain.

THAT'S IT!

* For Thursday (9/7):
  * Read Marr excerpt (see github)

* Next time we'll talk about
  EXPERIMENTAL DESIGN