NEUROSCIENCE III
CORTEX

Prof. Alexander Huth
1/30/2020

LAST TIME

* synaptic plasticity

* homeostasis

* hebbian learning & how to fix it

TODAY

* cortex

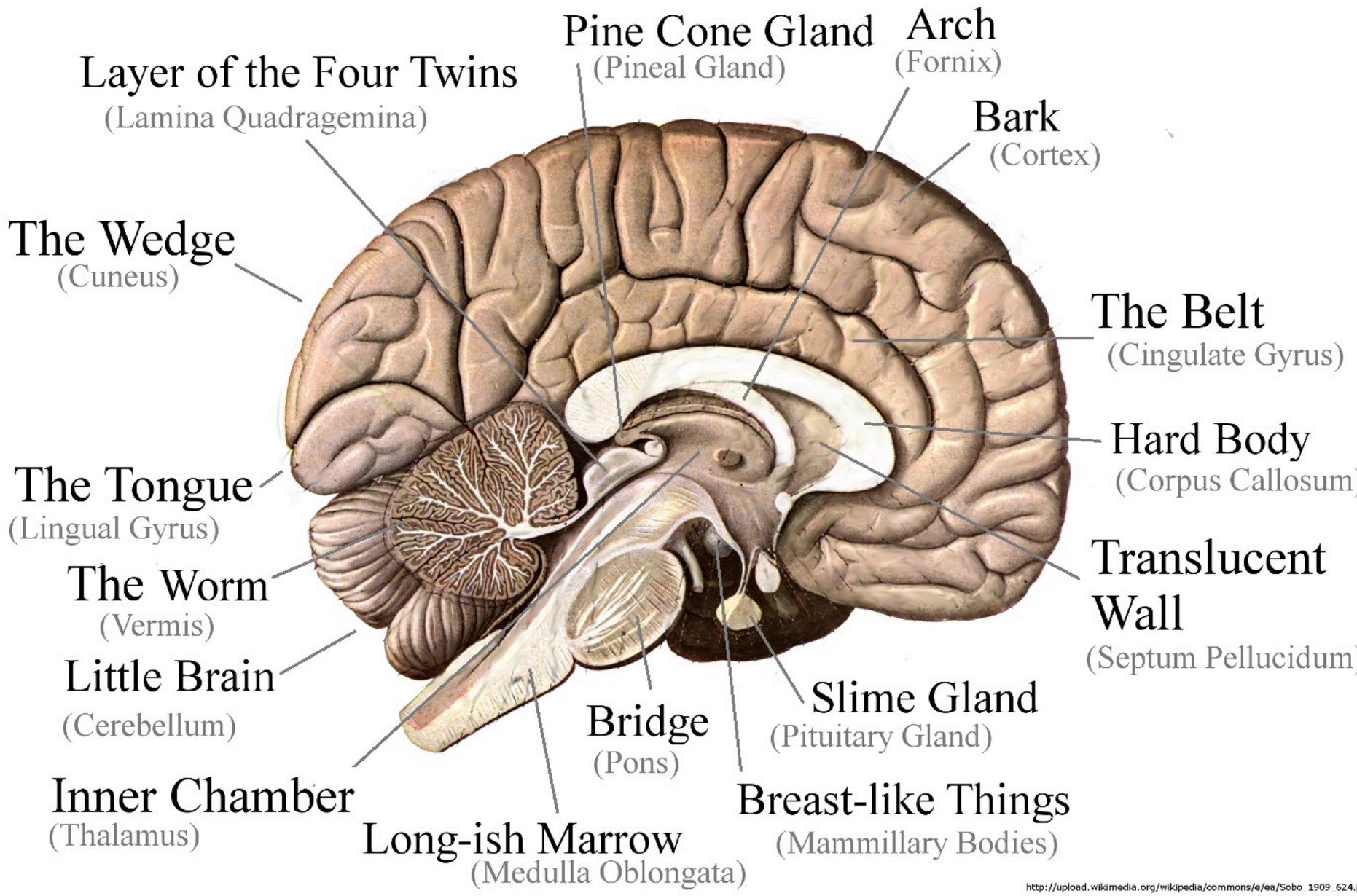
* cortical cell types

* methods

  * lesions

  * neurophysiology

* cortical maps



http://upload.wikimedia.org/wikipedia/commons/e/ea/Sobo_1909_624.png

THE HUMAN BRAIN

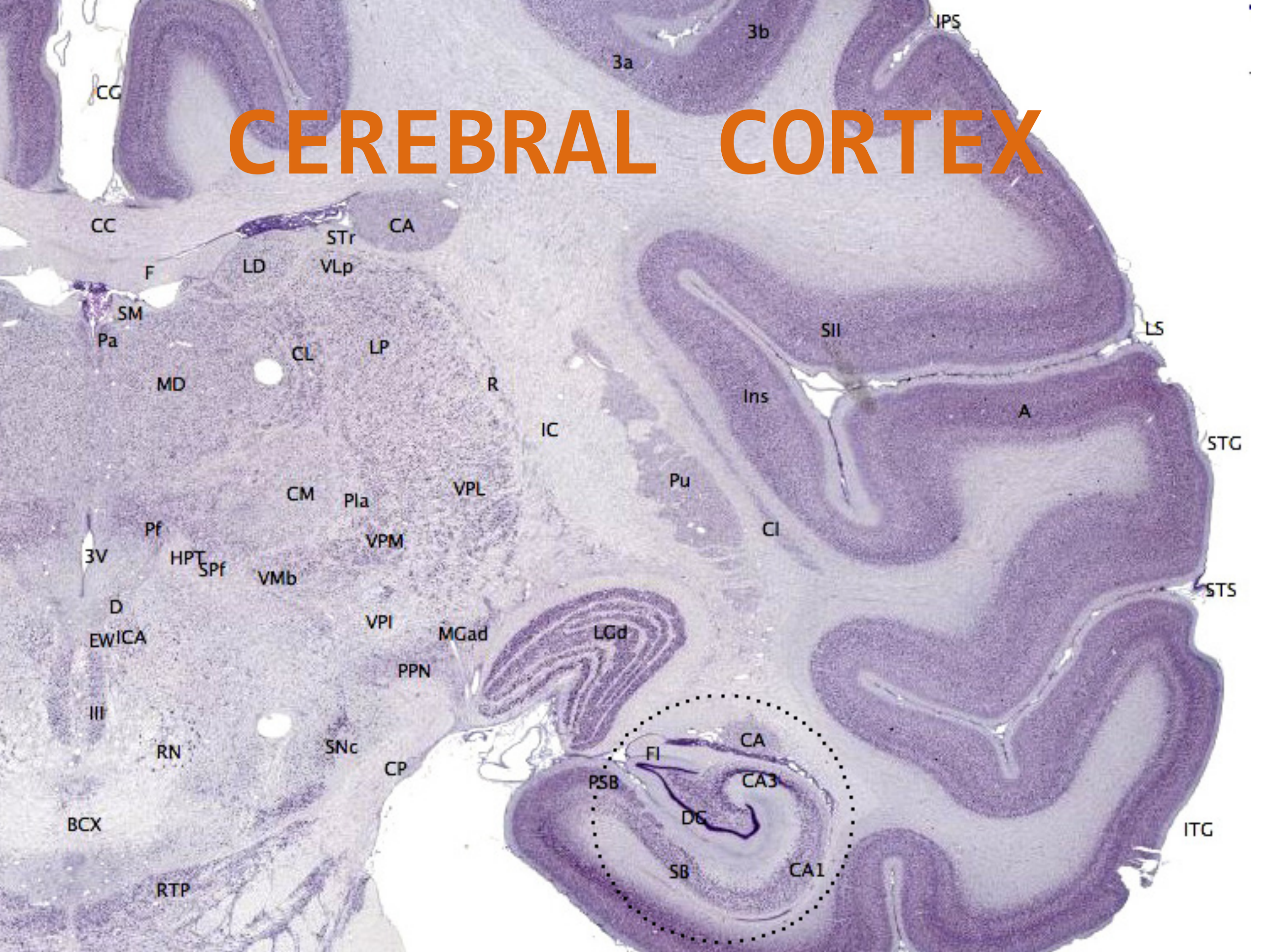
* ~85 billion neurons

* 12-15 billion in telencephalon

* ~70 billion in cerebellum

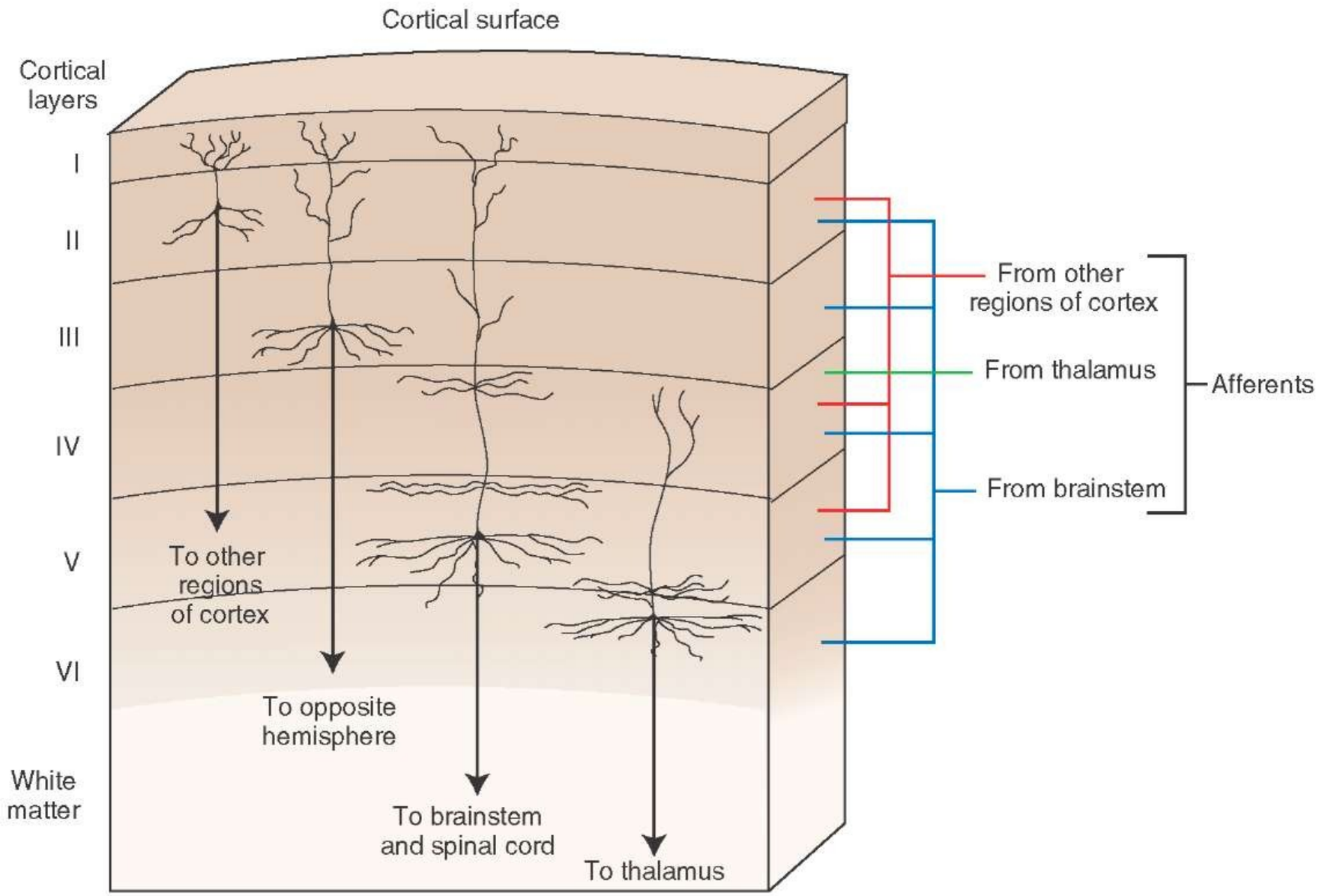
Herculano-Houzel, S. (2009)

CEREBRAL CORTEX



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

* How do we know about different cell types?

* Physiological properties

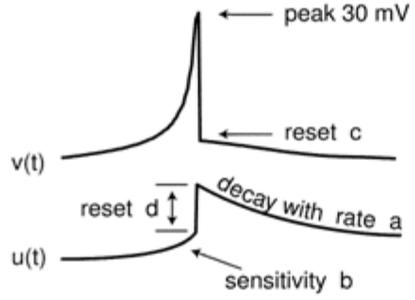
* Morphology (aka shape)

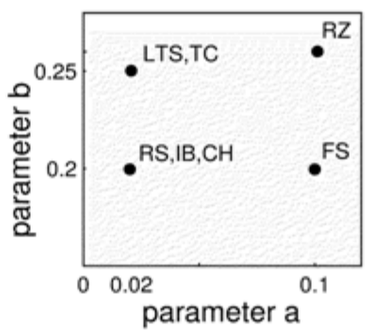
* …?

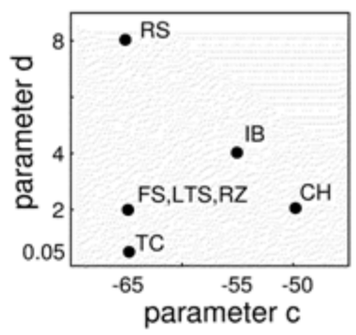
PHYSIOLOGICAL PROPERTIES

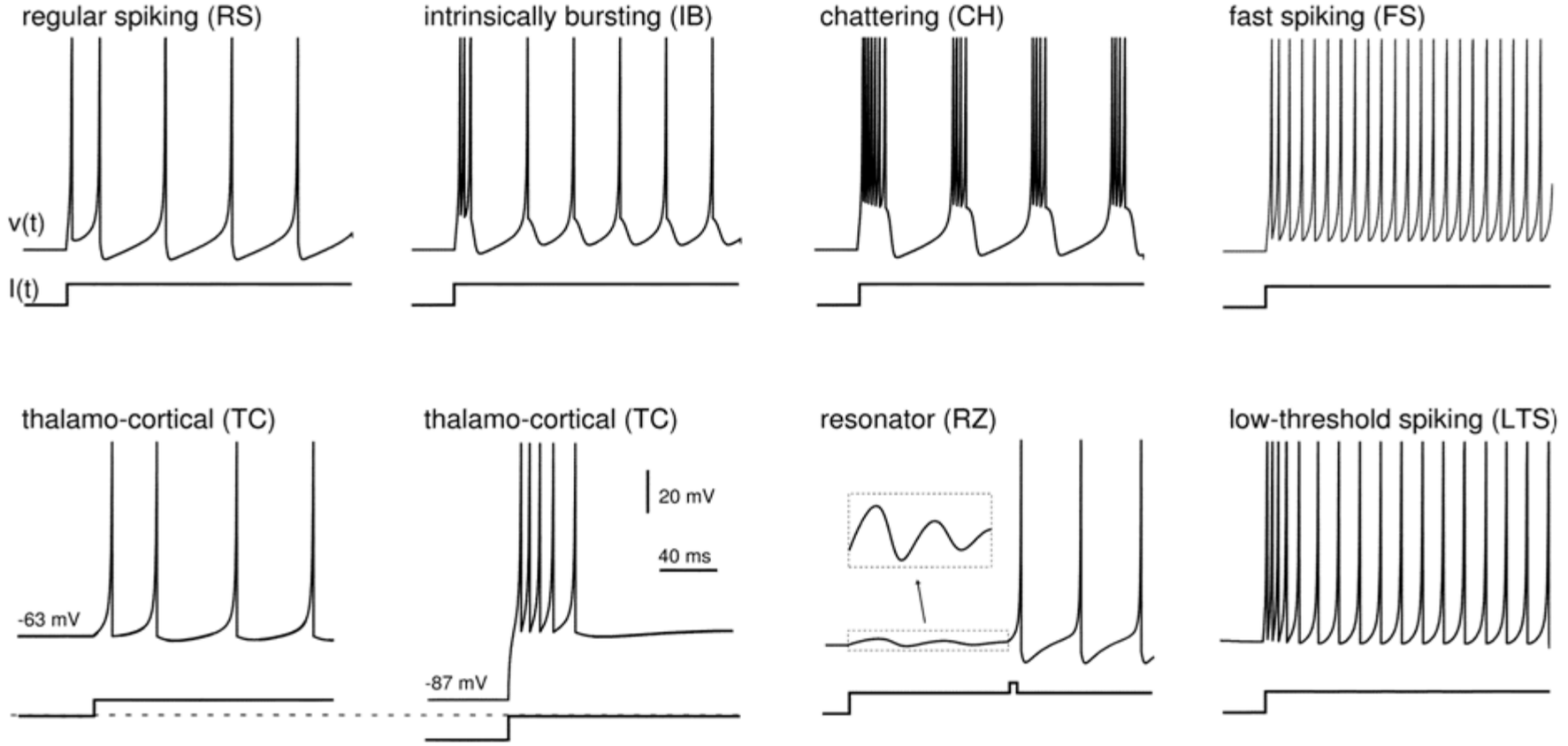
$$v' = 0.04v^2 + 5v + 140 - u + I$$
$$u' = a(bv - u)$$

if v = 30 mV,
then v ← c, u ← u + d



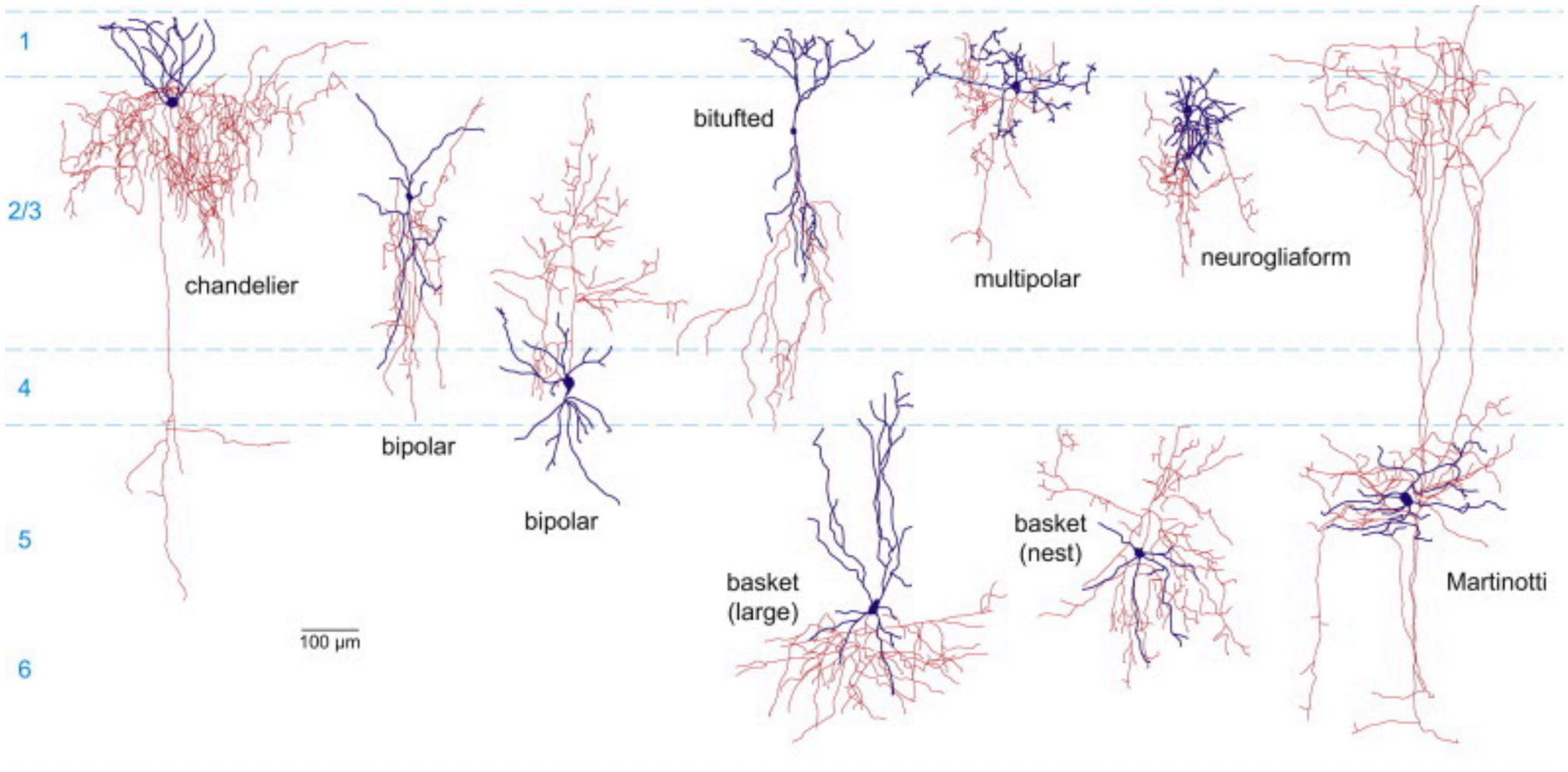






Izhikevich (2003) Simple model of spiking neurons

MORPHOLOGY



dendrite **axon**

The Mouse Nervous System (2012)

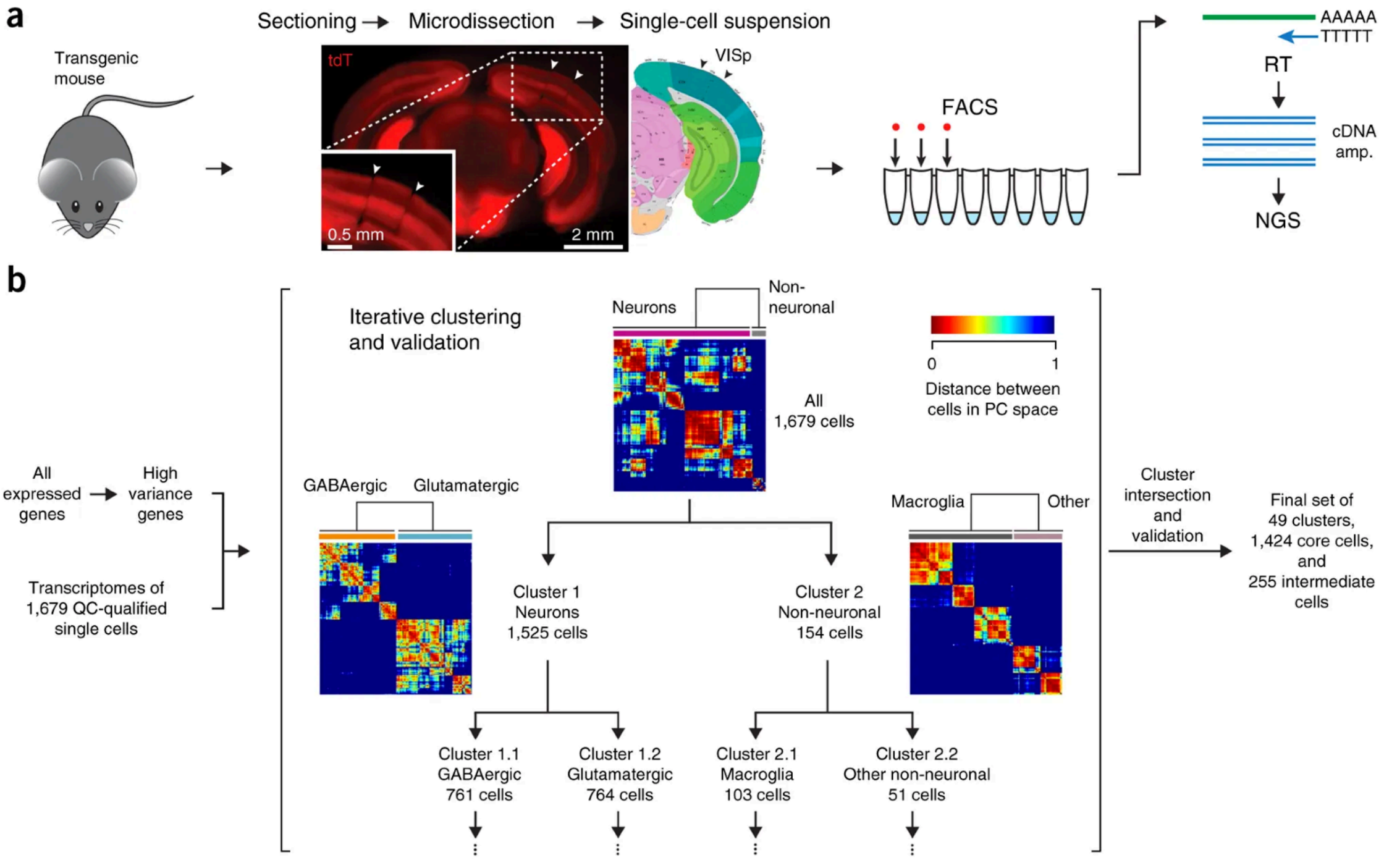
TRANSCRIPTOMICS

* ~Every cell in your body has the **same DNA**

* But different cells **express** different genes, leading to the production of different **proteins**

* We can see which genes are being expressed in a cell by ~sequencing all the messenger RNA (**mRNA**) in the cell

TRANSCRIPTOMICS

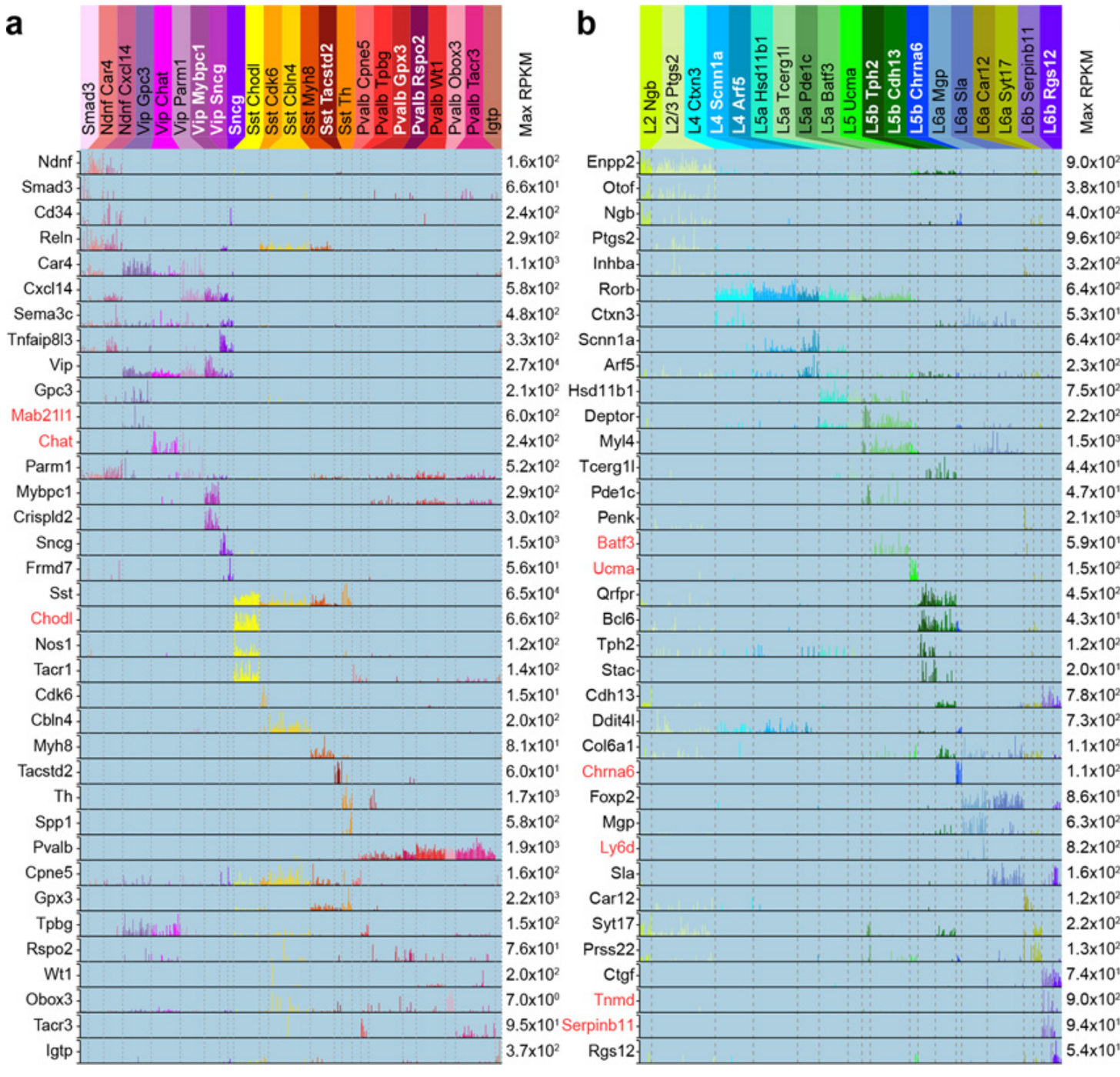


Tasic et al. (2016)

TRANSCRIPTOMICS

* Modern findings:

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



Tasic et al. (2016)

METHODS

* 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**

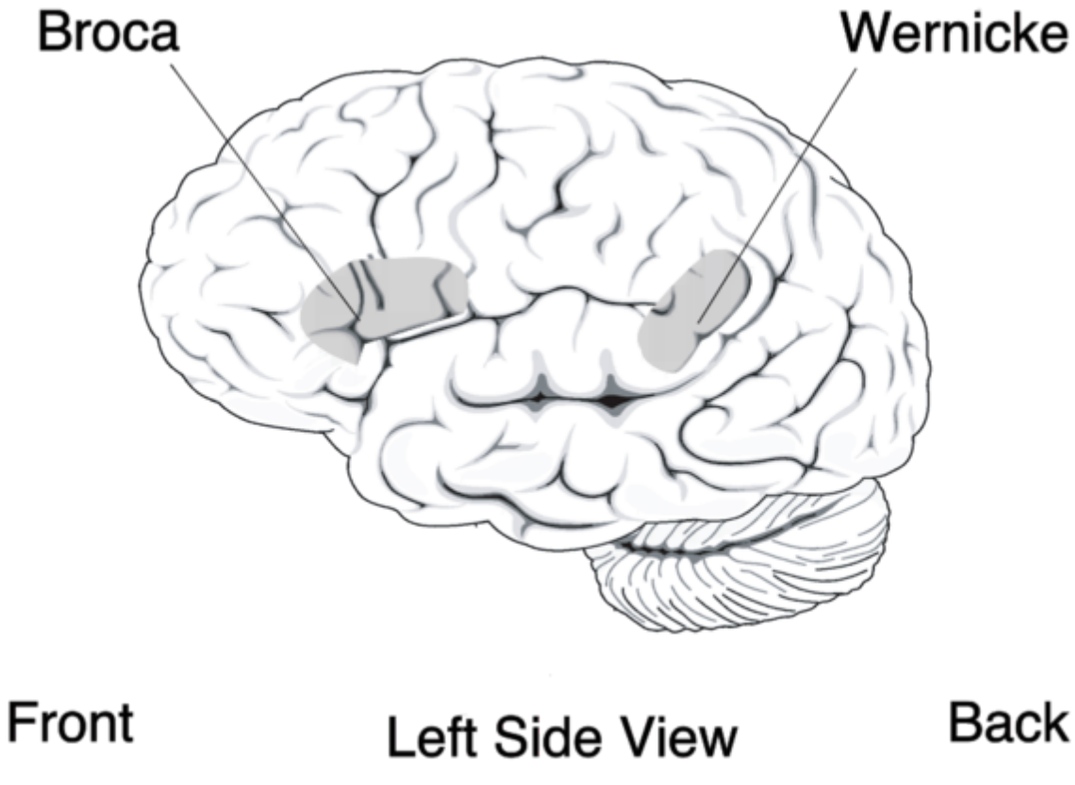
  * What is the function of each area?

LESIONS

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

Paul Broca (1824-1880)

Example: https://www.youtube.com/watch?v=JWC-cVQmEmY

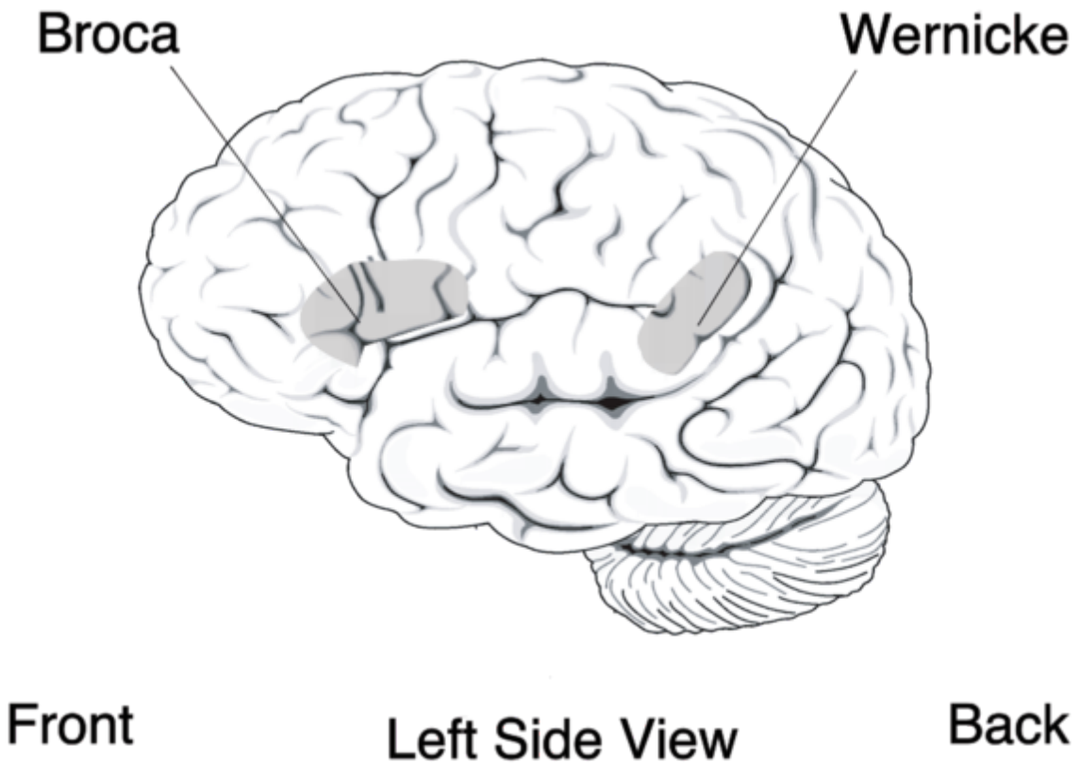


LESIONS

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

Carl Wernicke (1848-1905)

Example: https://www.youtube.com/watch?v=3oef68YabD0

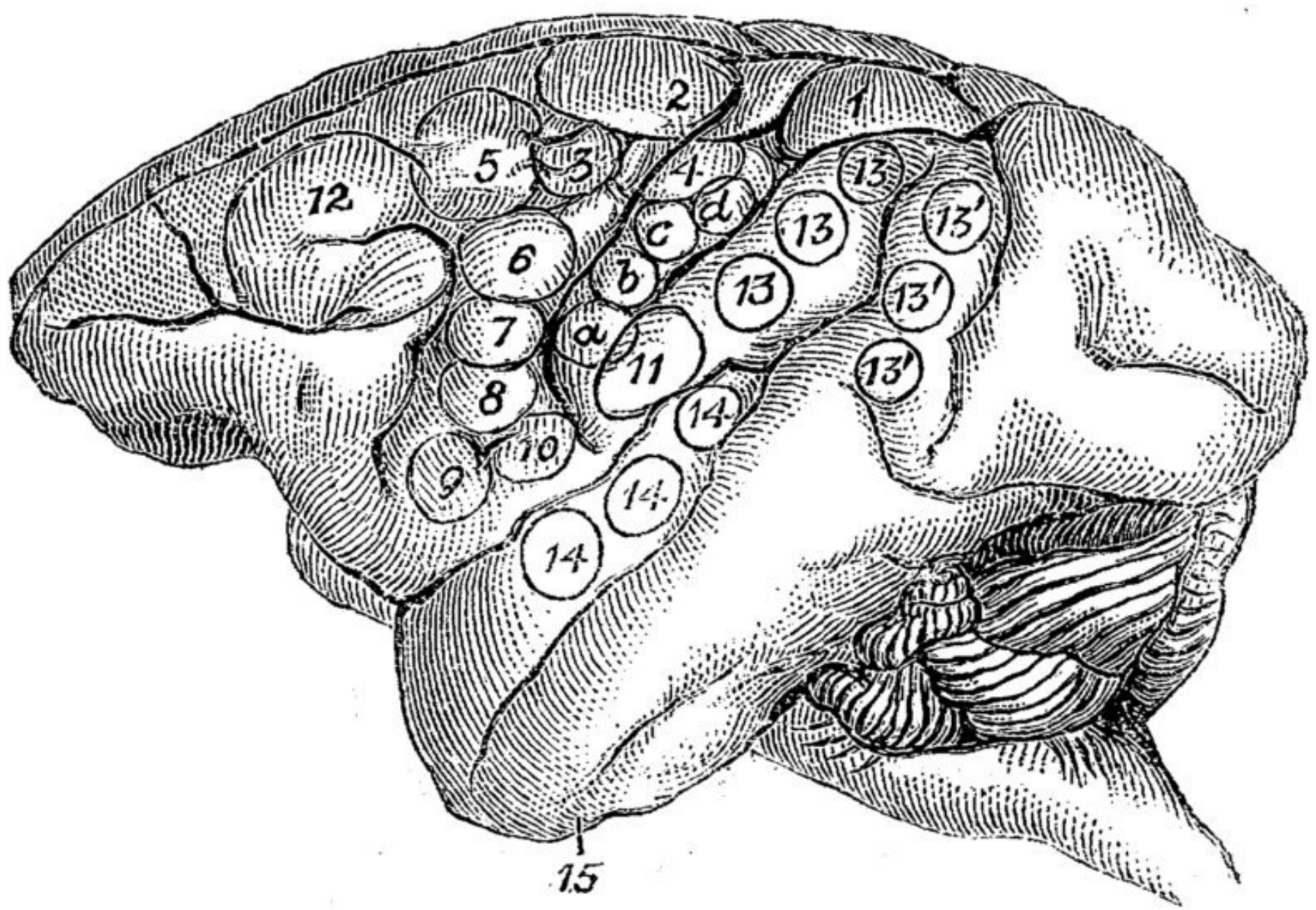


LESIONS

* In non-human neuroscience:
  * Tools like **optogenetics** enable fast, reversible inactivation (or activation) of specific cell types (defined genetically) in specific areas

* Exciting and effective

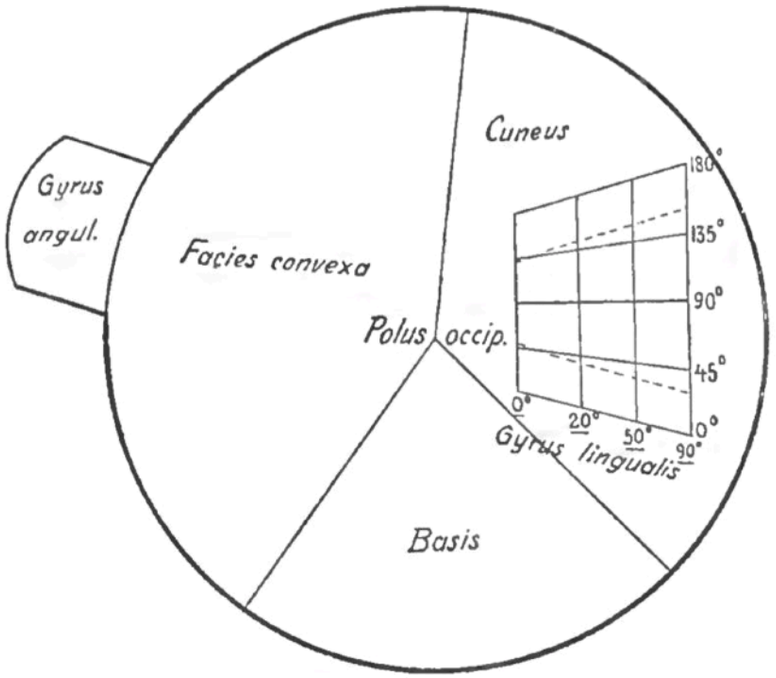
SOMATOTOPIC MAPS



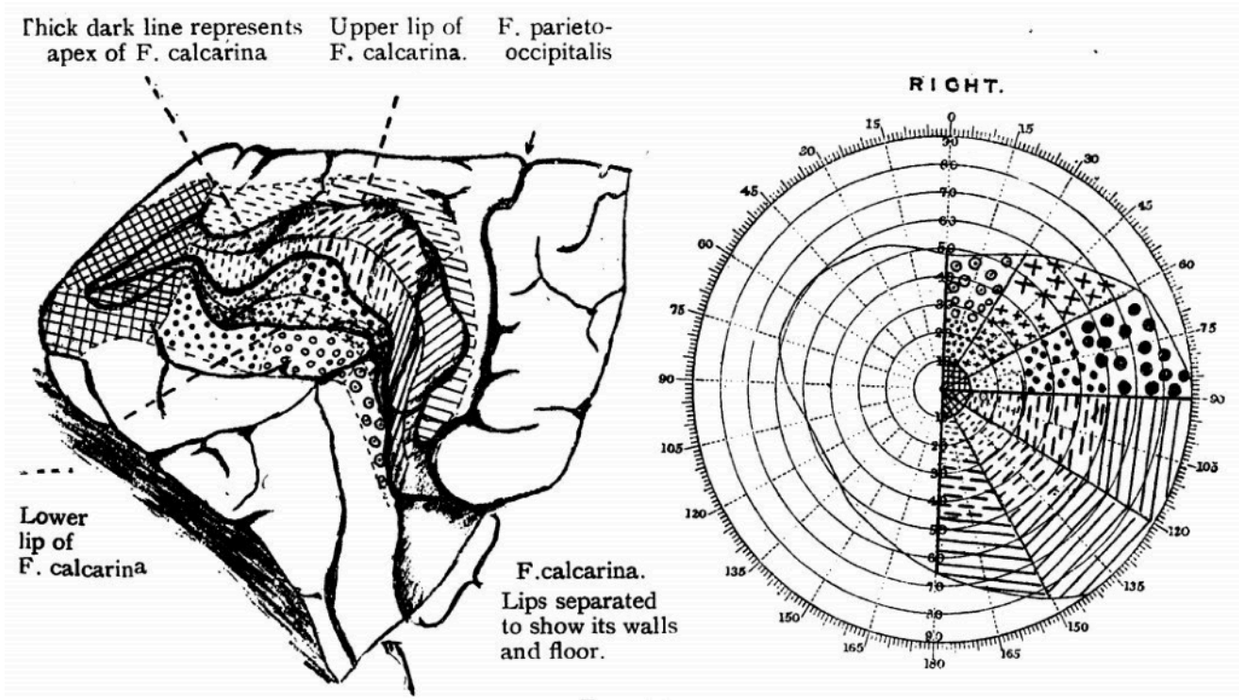
David Ferrier, 1886

RETINOTOPIC MAPS

Fig. 39.
Flächentreue Darstellung der linken Haupt- und Nebensehsphäre.



Tatsuji Inouye, 1909



Gordon Holmes, 1918

RETINOTOPIC MAPS

* https://gallantlab.org/pycortex/retinotopy_demo/

LESIONS

* In non-human neuroscience:

  * Surgical lesions (irreversible)

  * Muscimol (GABA agonist)

  * Cooling (!)

LESIONS

* In non-human neuroscience:
  * **Optogenetics** enables fast, reversible inactivation (or activation) of specific cell types (defined genetically) in specific areas

* Exciting and effective

METHODS

* Break it

* **Measure it**

MEASURE WHAT?

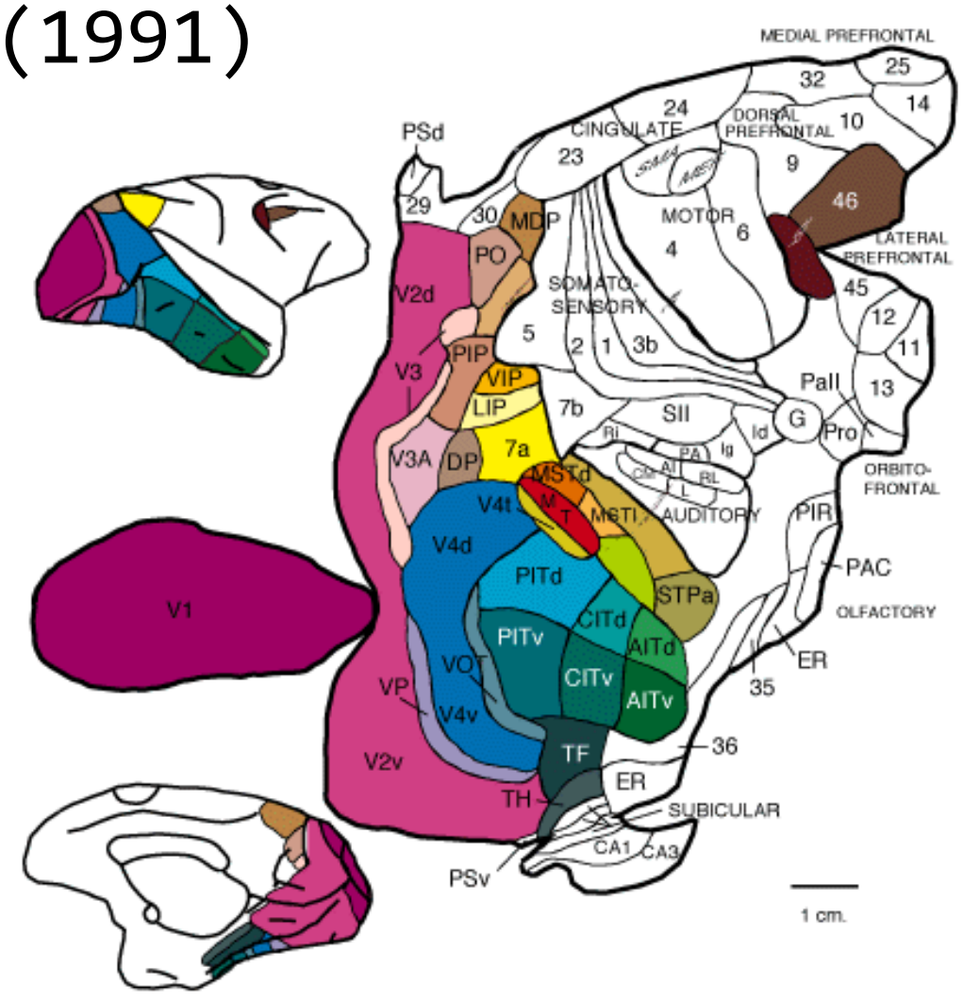
* Anatomy

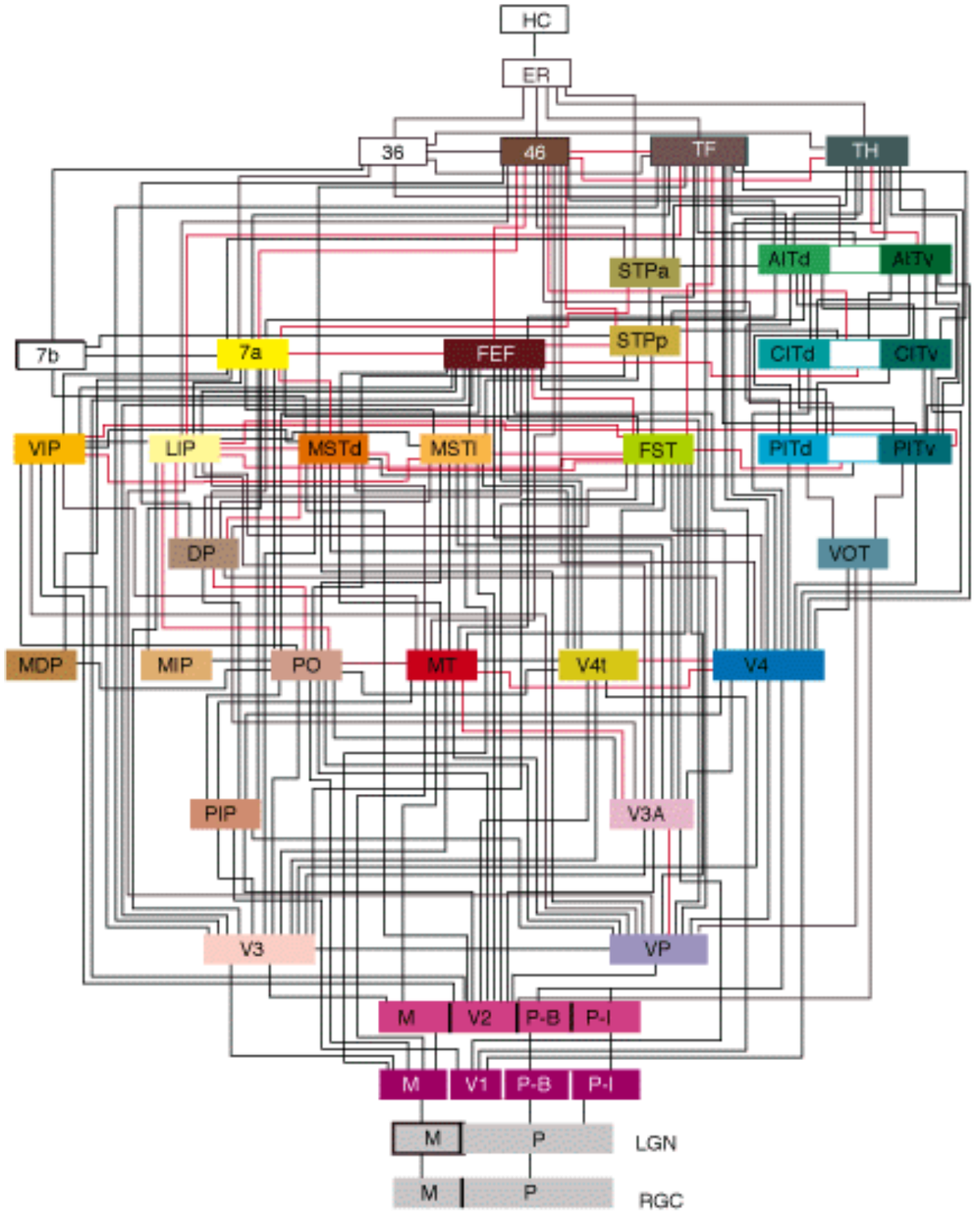
* Connectivity

* Function

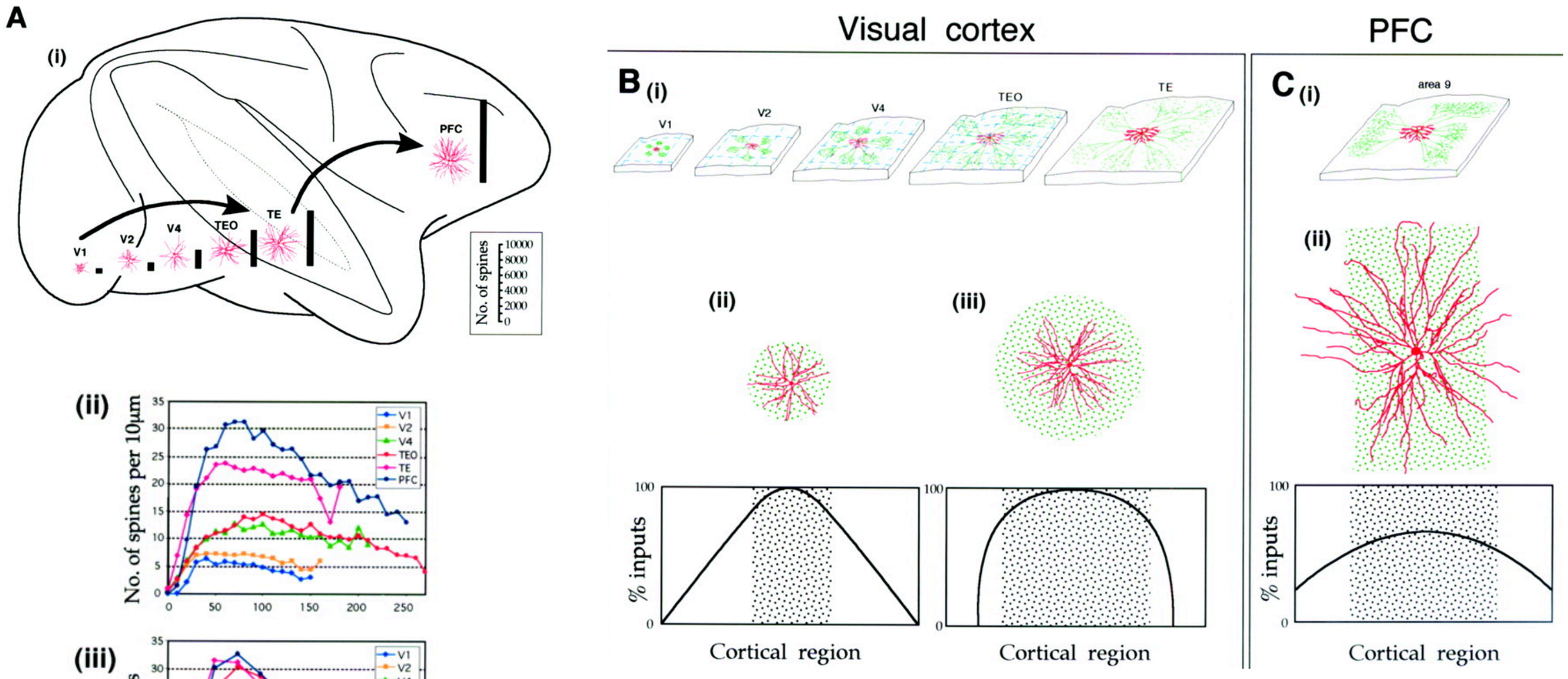
CONNECTIVITY

* **Connectivity** of areas in macaque visual cortex
* Felleman & Van Essen (1991)





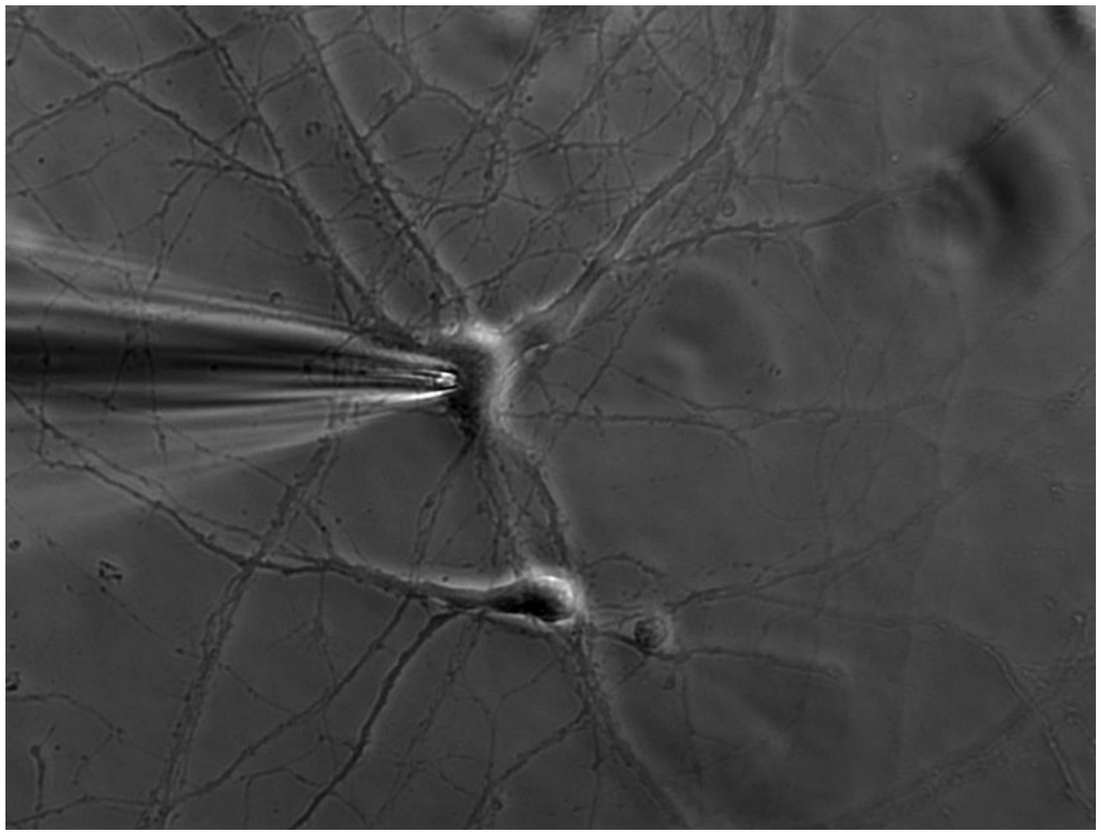
(MORPHOLOGY AGAIN)



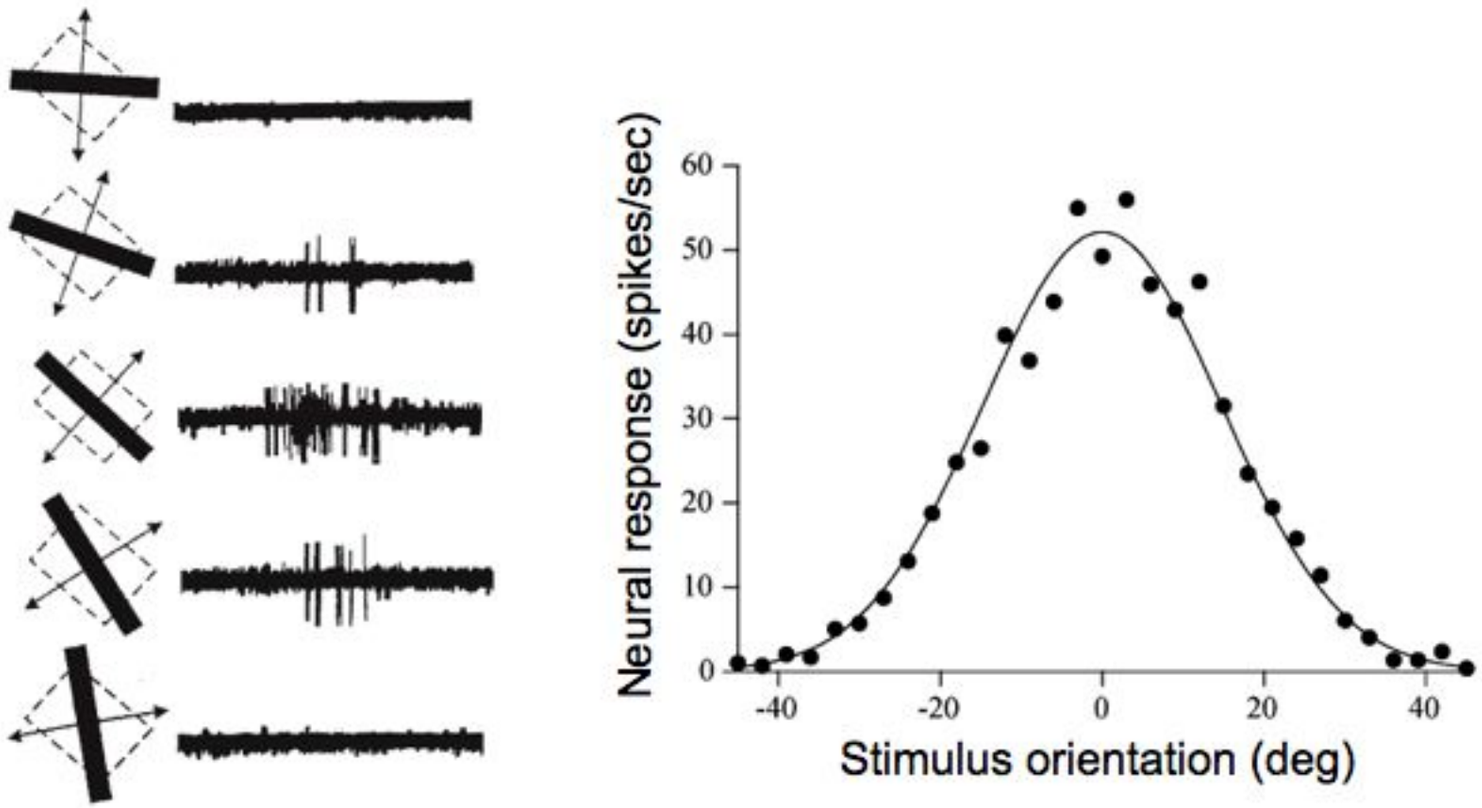
Elston (2003)

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**

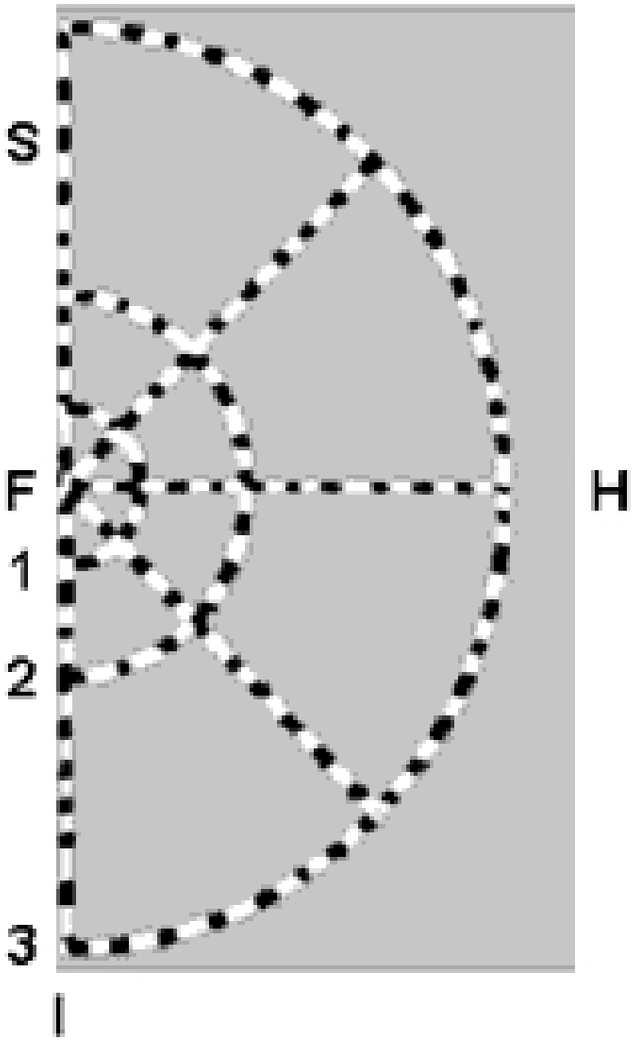
* A receptive field is the **stimulus subspace** that **elicits activity** in a neuron

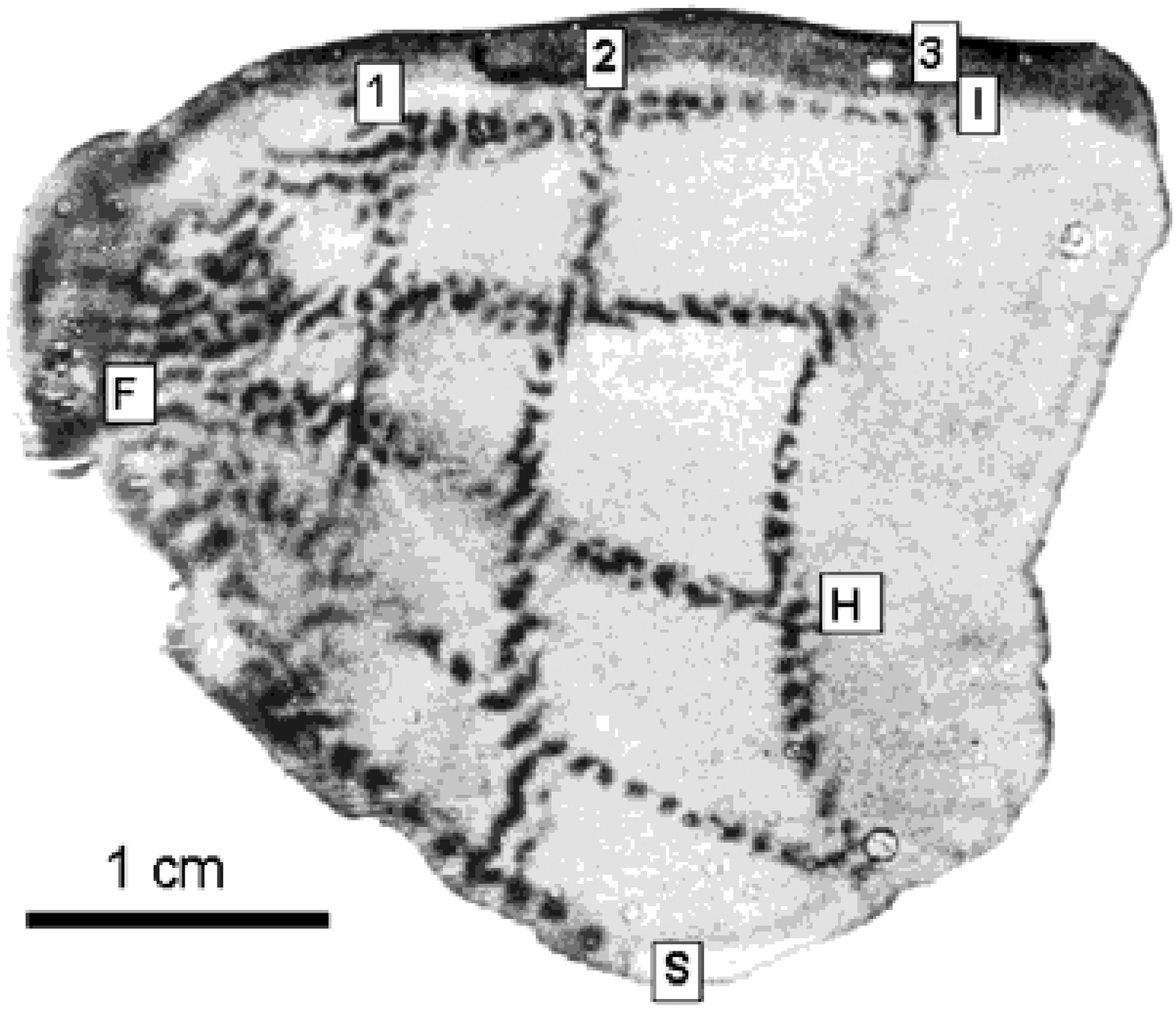
NEUROPHYSIOLOGY

* Neurophysiology can also be used to reveal **cortical maps**

* *Nearby* neurons have *similar* receptive fields

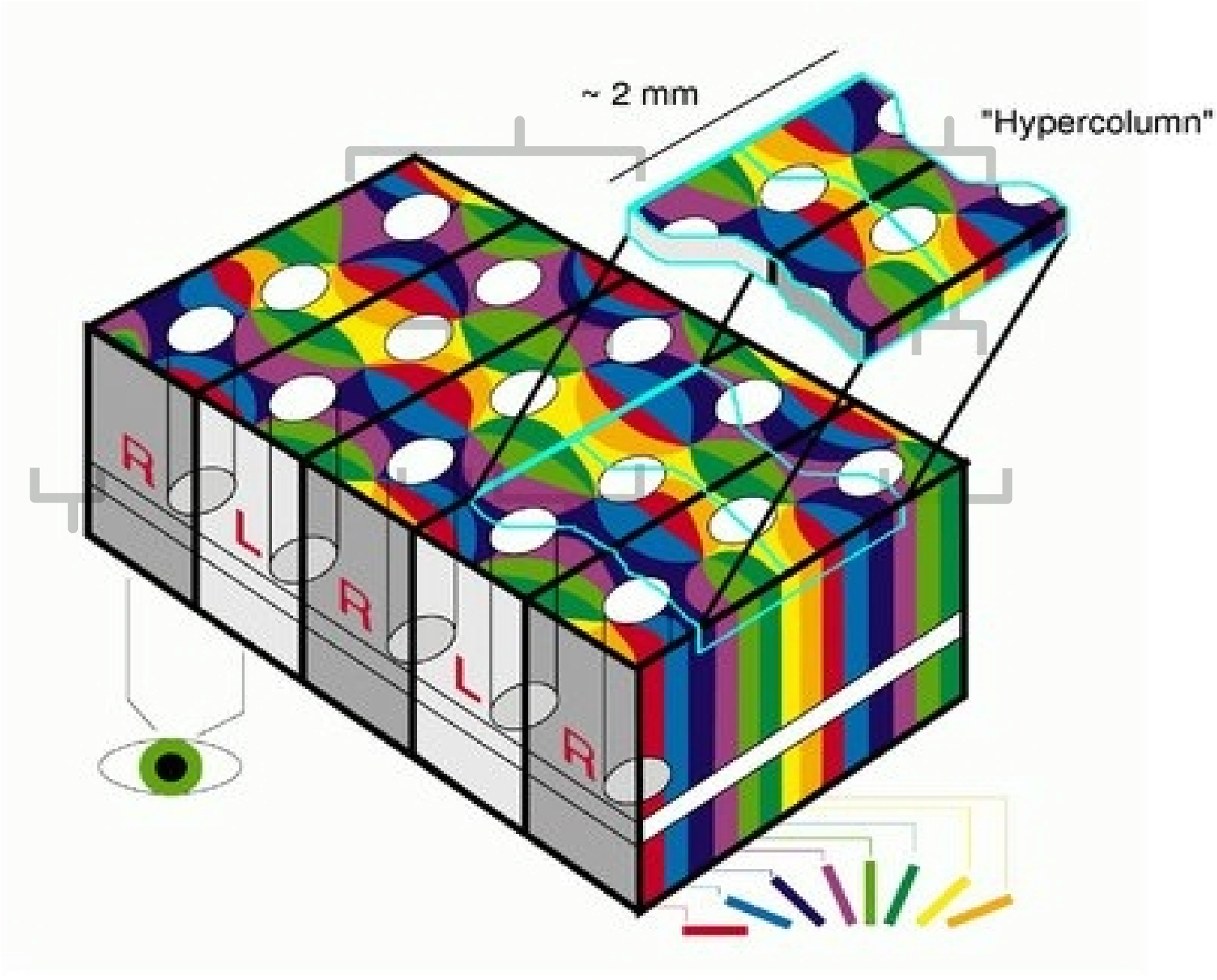
Retinotopic map in primary visual cortex





Tootell, Silverman, Switkes & DeValois, 1982

Many dimensions are coded at each position



TODAY

* cortex

* cortical cell types

* methods

  * lesions

  * neurophysiology

* cortical maps

NEXT TIME

* neuroscience methods & limitations