Basic neuroscience “crash course”

BMM summer school
8/15/15

Disclaimers

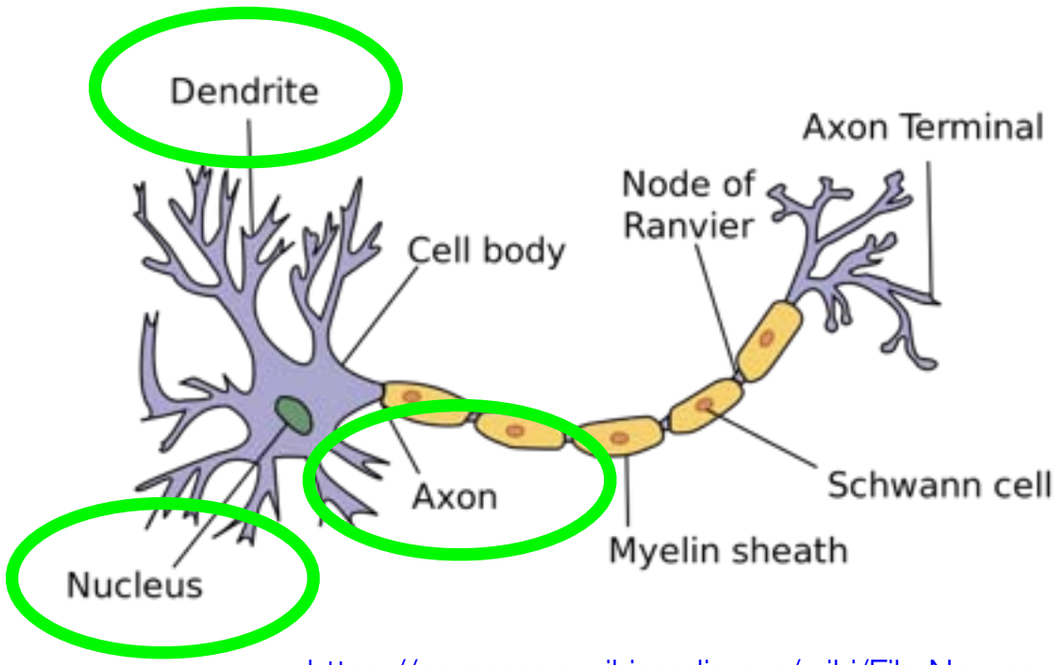
- Very basic
- CBMM/vision-centric

Outline

- Neurons
  - Resting potential (ion concentrations/channels)
  - Action potential & PSPs
- Basic brain anatomy
  - Inferior, superior, ventral, dorsal
  - Occipital, temporal, parietal, frontral lobes
  - Grey/white matter
- Neural recordings - EPhys, EEG/MEG, fMRI
- Visual system
  - Hierarchy: V1—> IT
  - Receptive fields
  - Computational models

Neurons

- Soma (cell body), dendrites, axons
- Synapses



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https://en.wikipedia.org/wiki/Synapse

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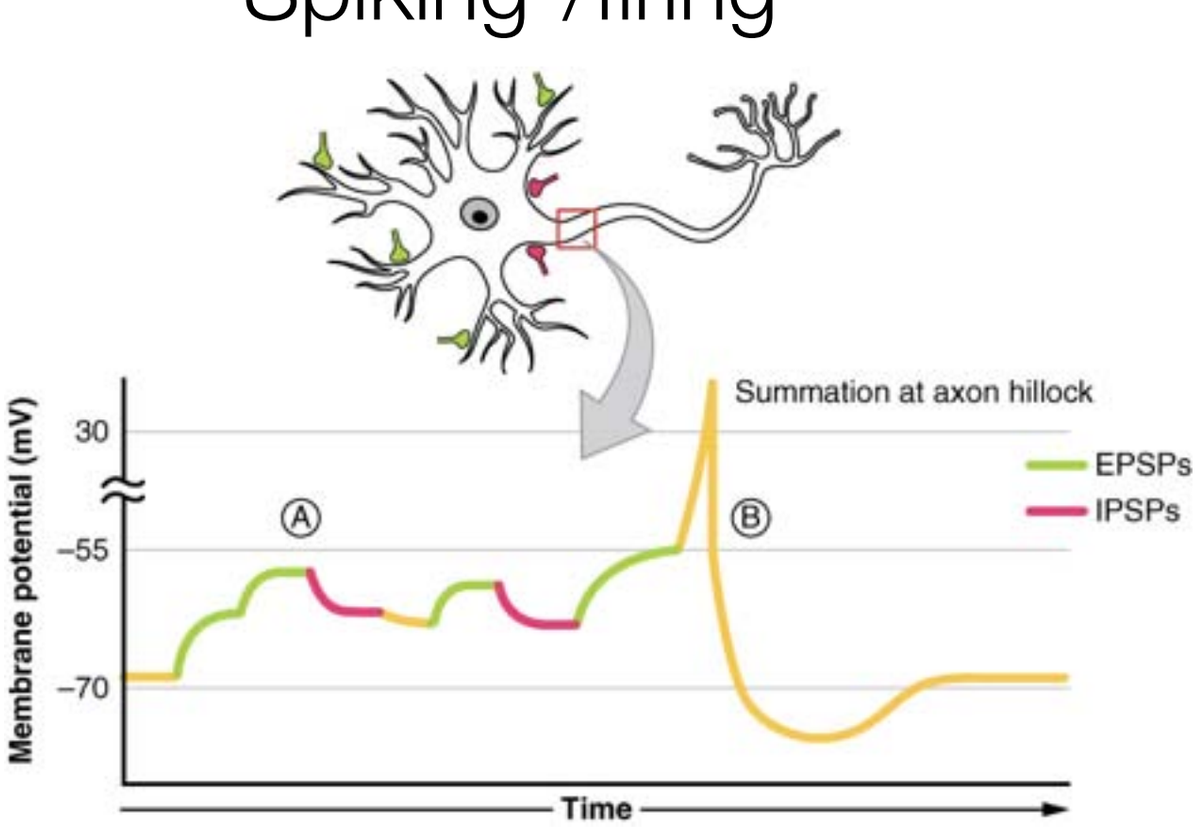
Neuron

- Ion channels and resting membrane potential
- Post-synaptic potential
- Action potentials
  - "Spiking"/firing



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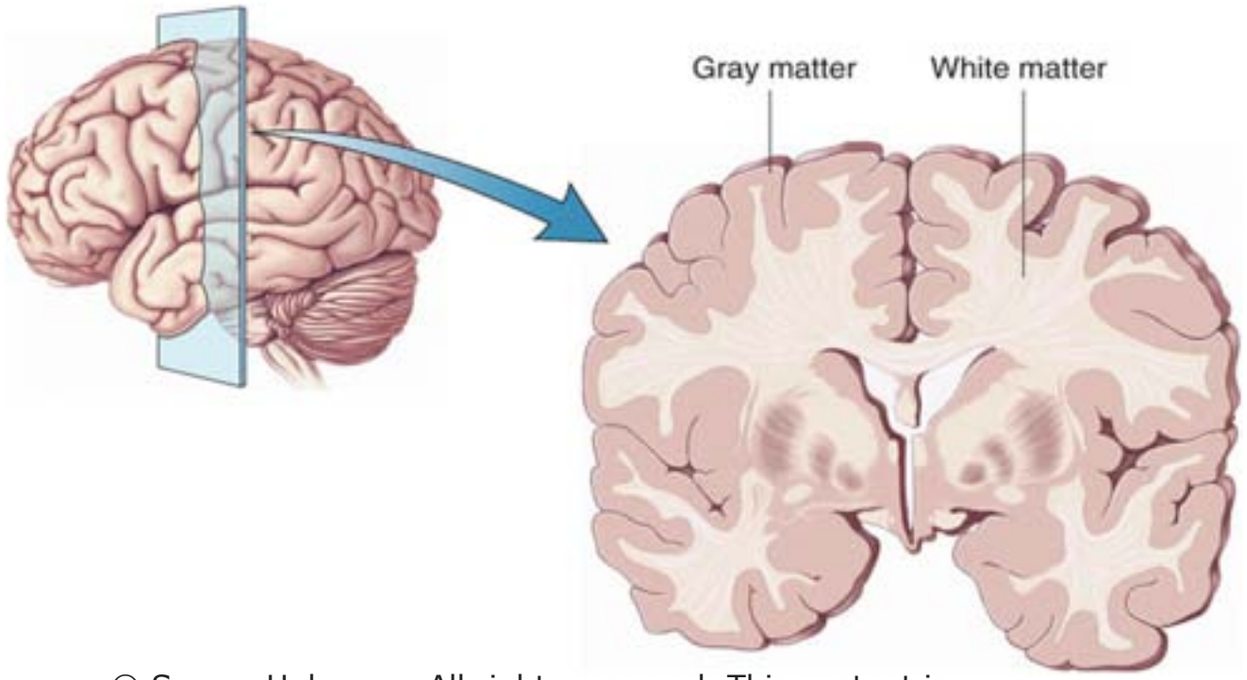
http://hyperphysics.phy-astr.gsu.edu/hbase/biology/actpot.html

https://commons.wikimedia.org/wiki/File:1224_Post_Synaptic_Potential_Summation.jpg

Basic brain anatomy



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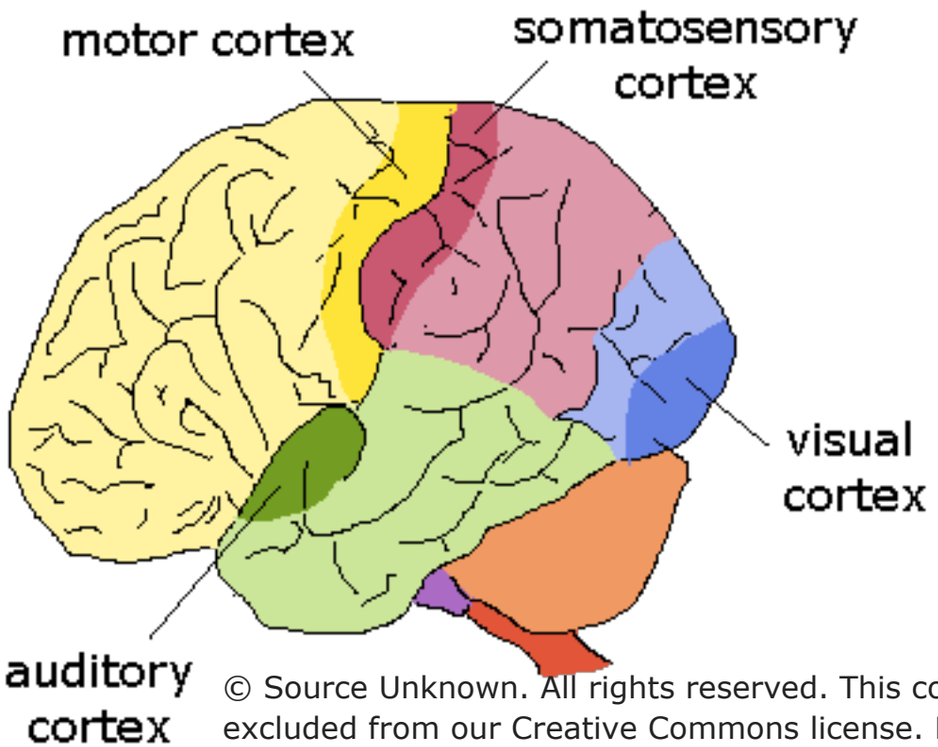

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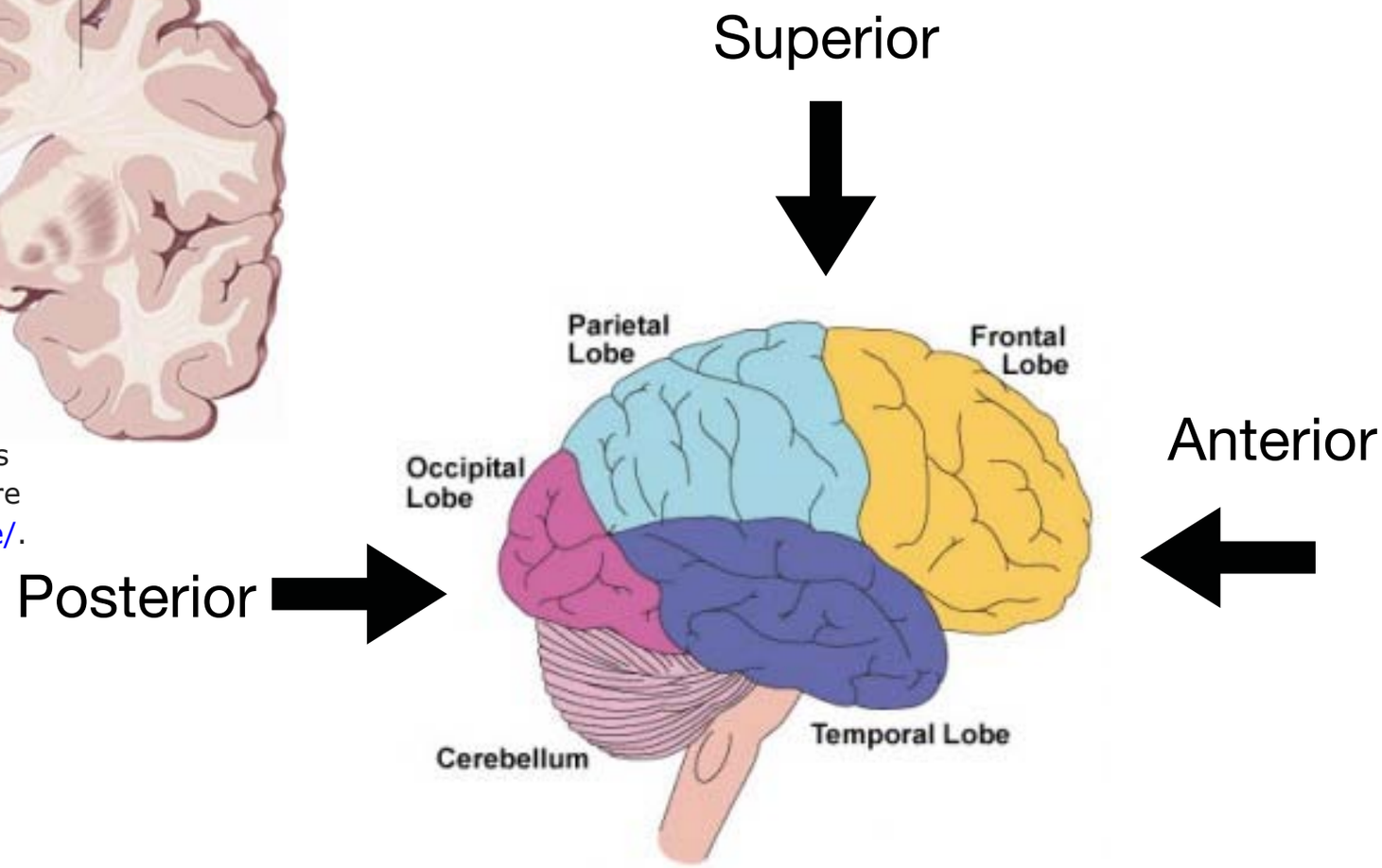

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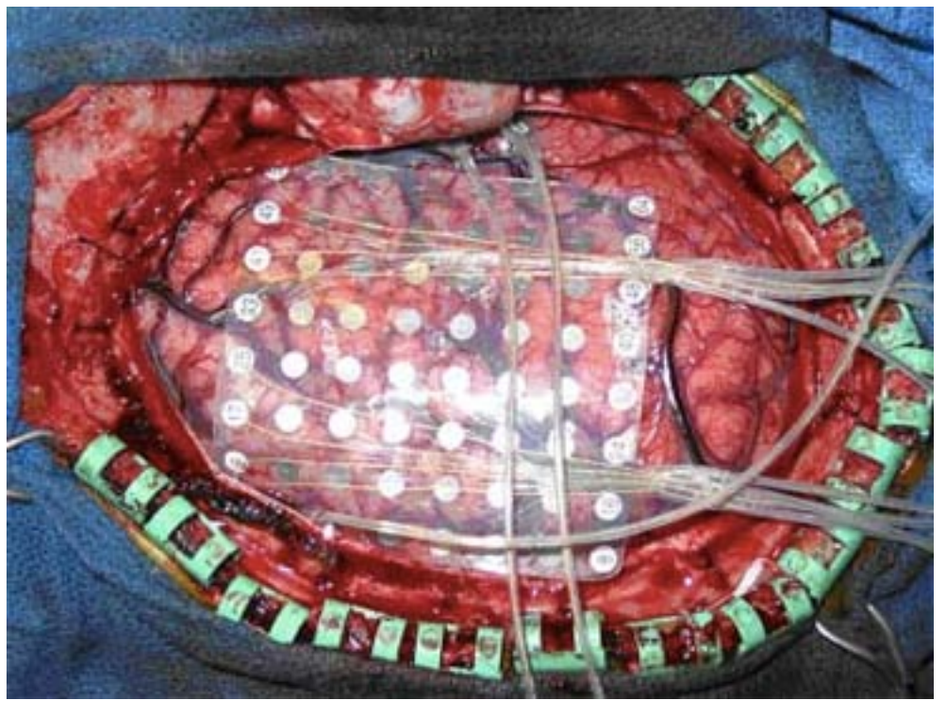
Invasive neural recordings

- Electrophysiology
  - Single unit (intra or extracellularly)
  - Multi-unit/local field potentials
- Electrocorticography (ECoG)



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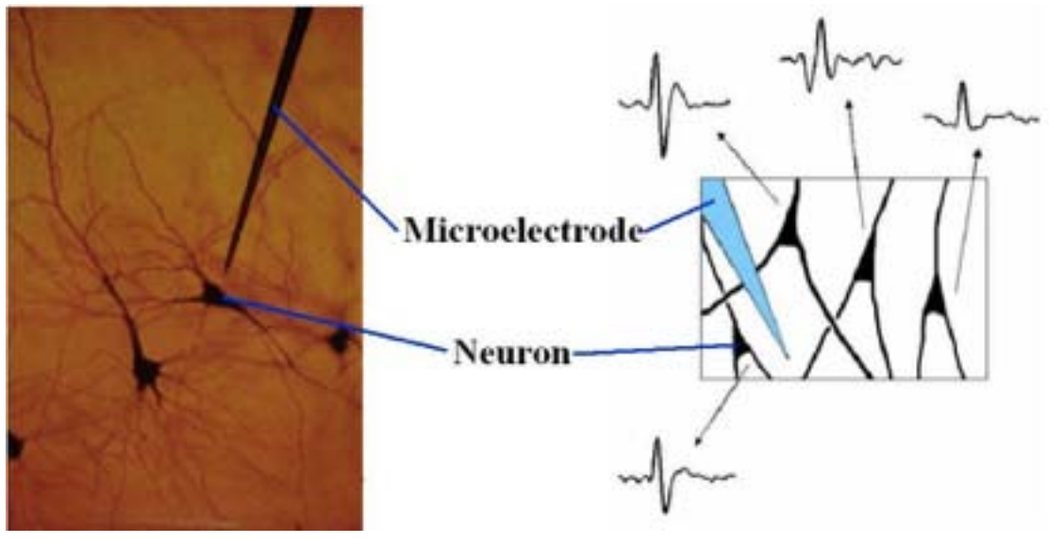

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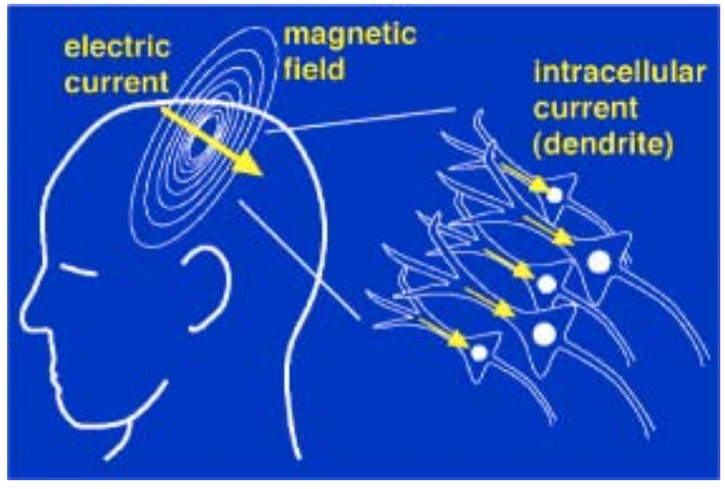
http://newton.umsl.edu/tsytsarev_files/Lecture02.htm

Neuroimaging

- Magnetoencephalography (MEG)/ Electroencephalography (EEG)
- functional MRI



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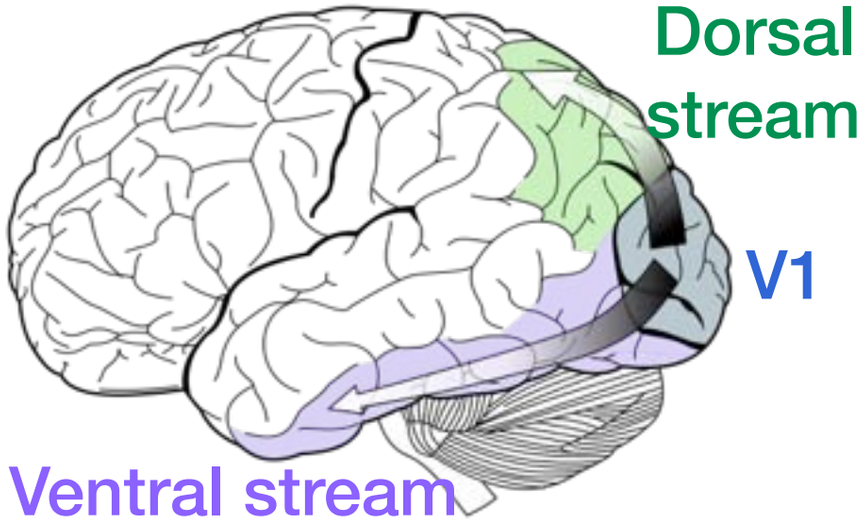
Courtesy of McGovern Institute for Brain Science, MIT.

Comparing neural recordings

- Electrophysiology recordings - high spatiotemporal resolution, limited brain coverage
- fMRI - high spatial resolution data, broad coverage, low temporal resolution
- EEG/MEG - high temporal resolution, broad coverage, low spatial information

Visual processing in the human brain

- Ventral Stream - “What” Pathway
- Dorsal Stream - “Where” Pathway



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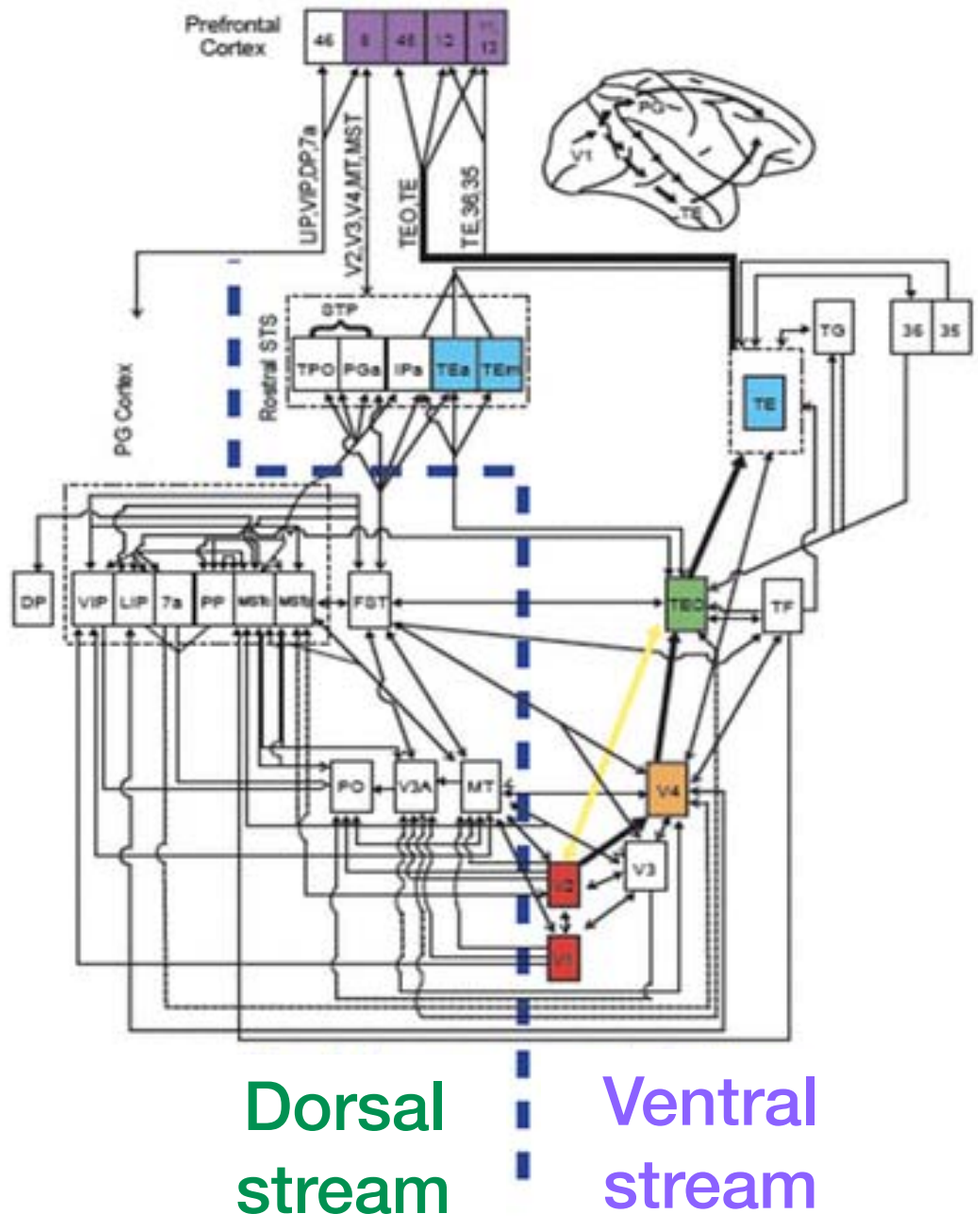

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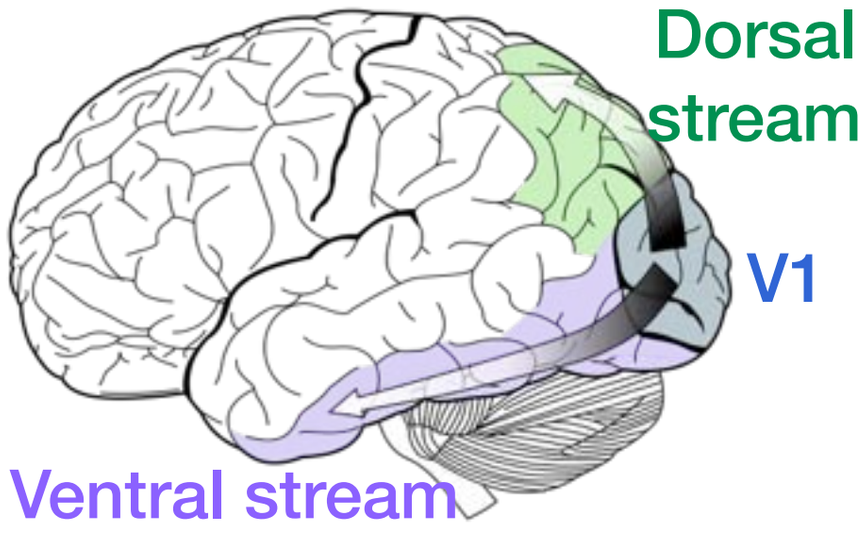
Ventral visual processing stream

- Many layers organized in a hierarchy
- First layer: primary visual cortex (V1) - cells respond to oriented lines and edges
- Top layer: inferior temporal cortex (IT) - cells respond to entire objects and are both selective and invariant



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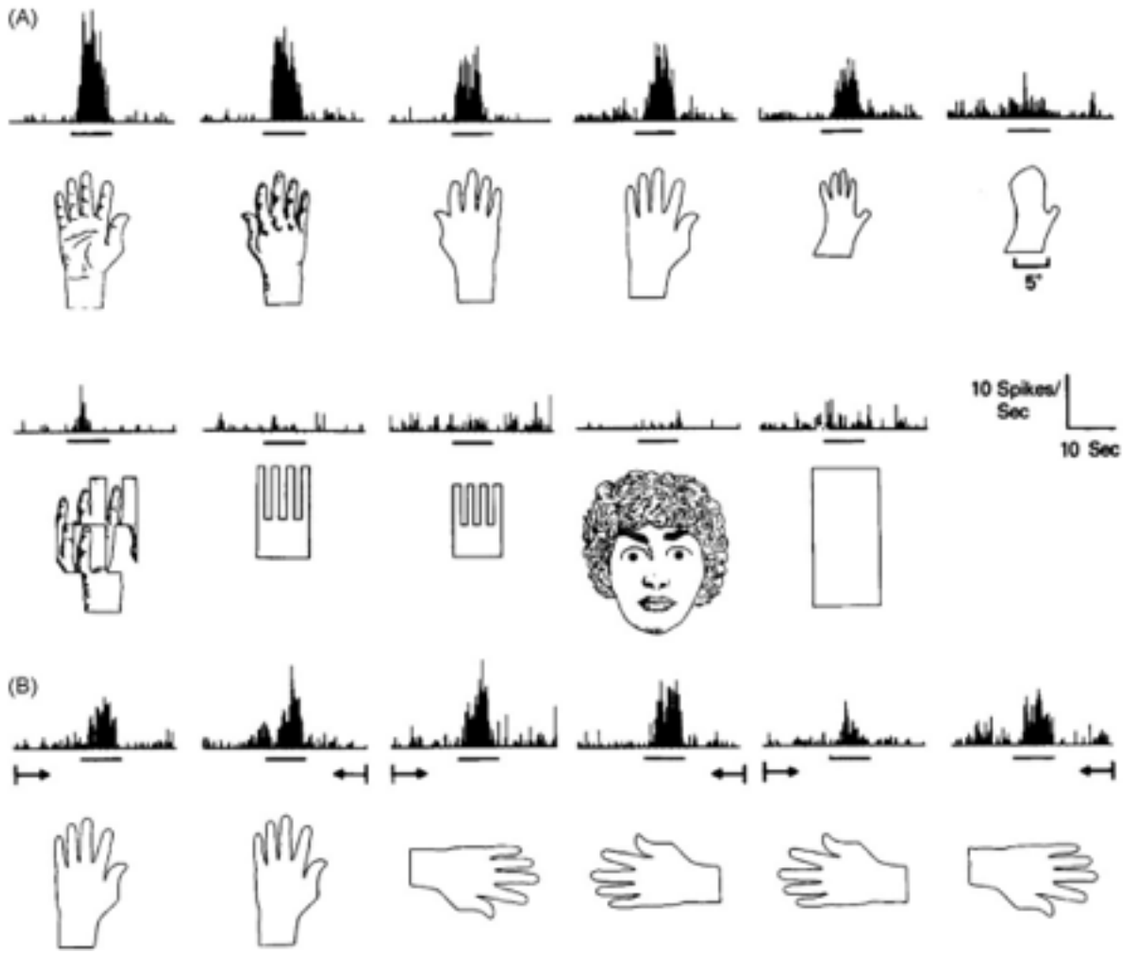
Inferior temporal cortex

- Hubel and Wiesel
- https://www.youtube.com/watch?v=Cw5PKV9Rj3o

Inferior temporal cortex



Single neuron studies of inferior temporal cortex
Gross

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Source: Gross, Charles G. "Single neuron studies of inferior temporal cortex." Neuropsychologia 46, no. 3 (2008): 841-852.

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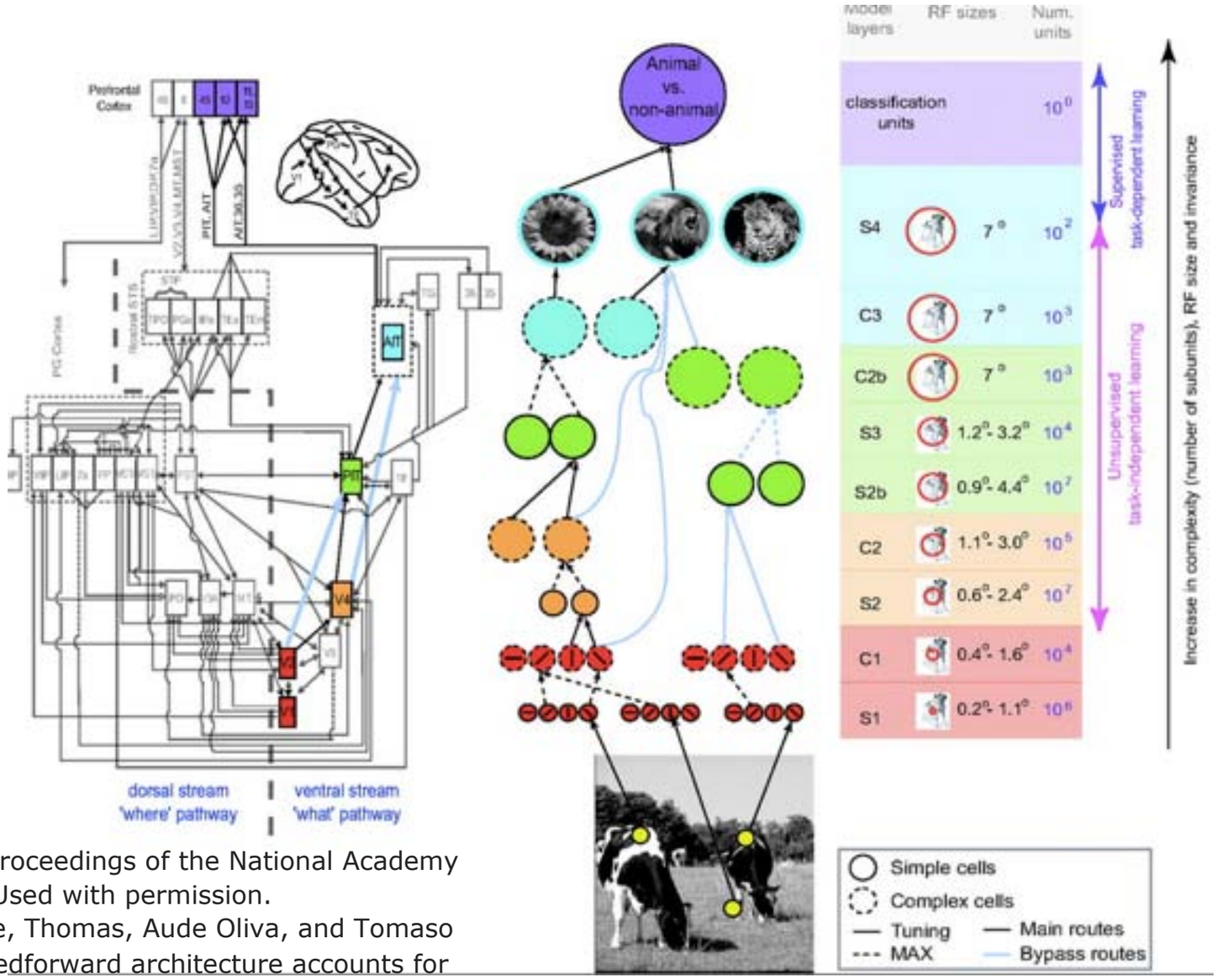
Source: Figure 2 from Hung, Chou P., Gabriel Kreiman, Tomaso Poggio, and James J. DiCarlo. "Fast readout of object identity from macaque inferior temporal cortex." Science 310, no. 5749 (2005): 863-866.

Visual hierarchy



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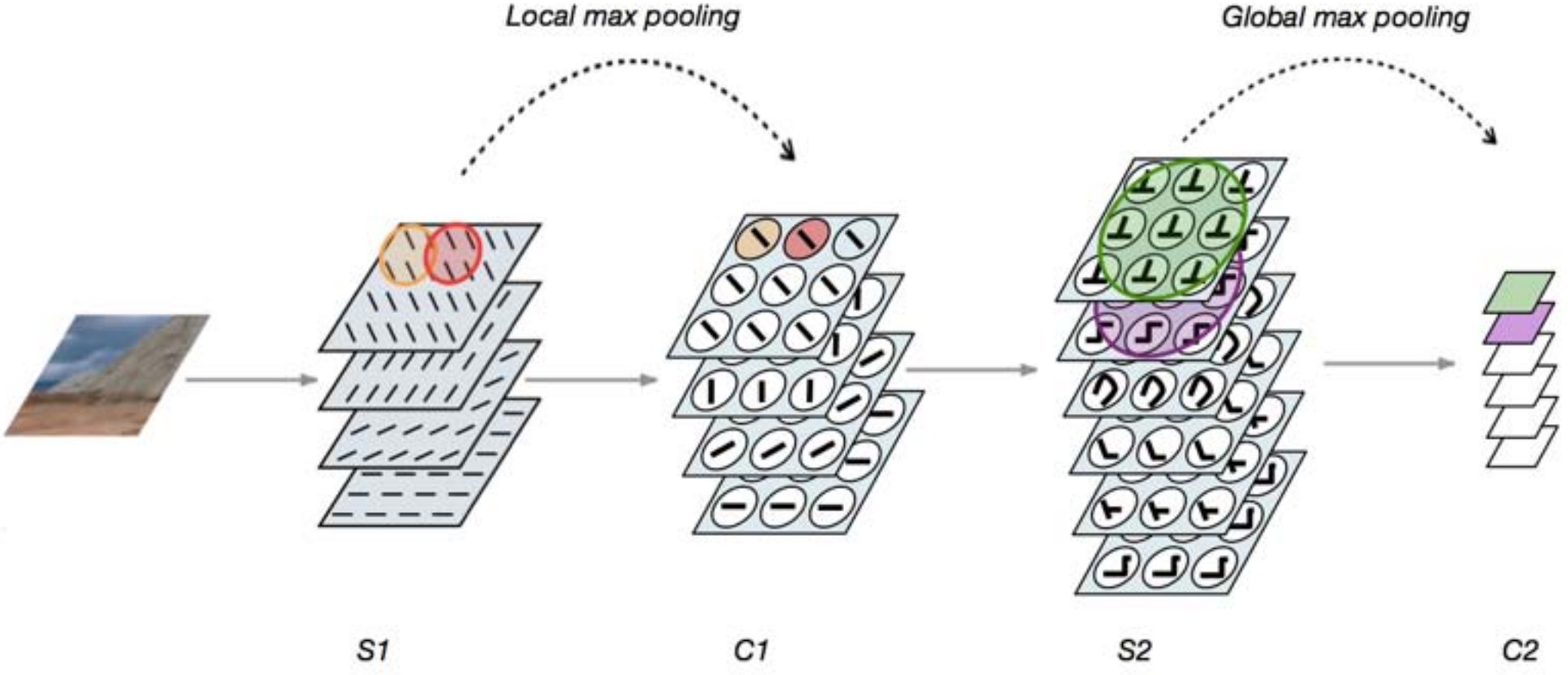
Hierarchical feedforward models

- Inspired by Hubel and Wiesel's findings in visual cortex
  - HMAX (Serre 2007, Riesenhuber 1999), CNNs (Krizhevsky 2012)
- Simple cells - template matching, build selectivity
- Complex cells - pooling, build invariance



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Resource: Brains, Minds and Machines Summer Course

Tomaso Poggio and Gabriel Kreiman

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