Lecture 2: Neuroscience Basics.

Reading Assignments:

None

Class Web Site

http://iLab.usc.edu/classes/2001cs599/

Soon, you will find there:

- Lecture notes: user "iLab" and password "cool"
- Reading assignments
- Grades
- General announcements
- Project topics

Projects

Two categories:

- Implement a neuromorphic vision algorithm, using the language, platform, and approach of your choice,

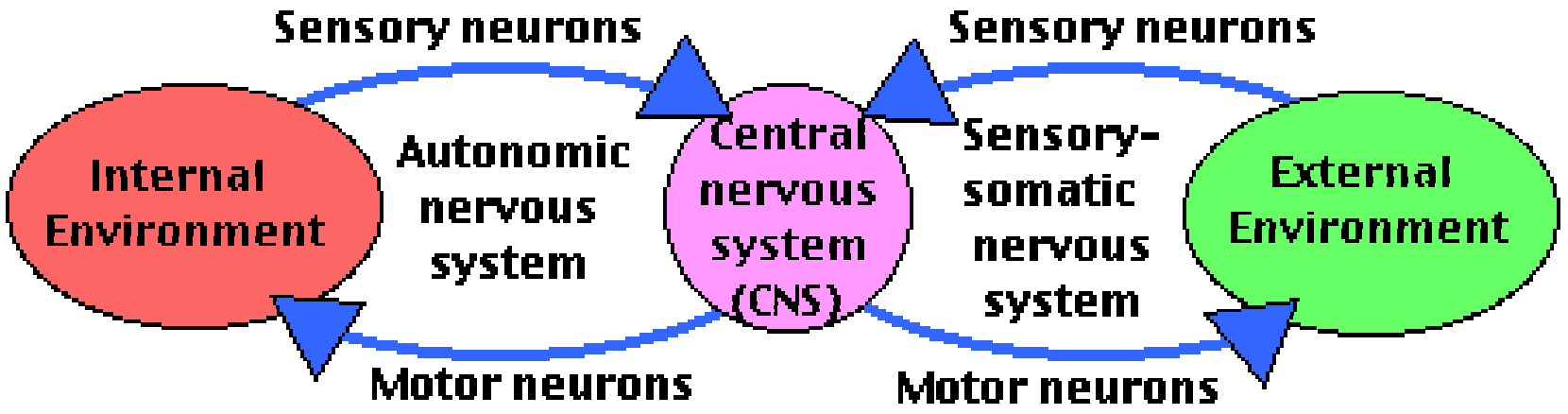
e.g., “an edge detector that sees illusory contours”

- Write a review article on a vision topic, including both computer vision and visual neuroscience state of the art in this domain, and making suggestions for further interactions and improvements,

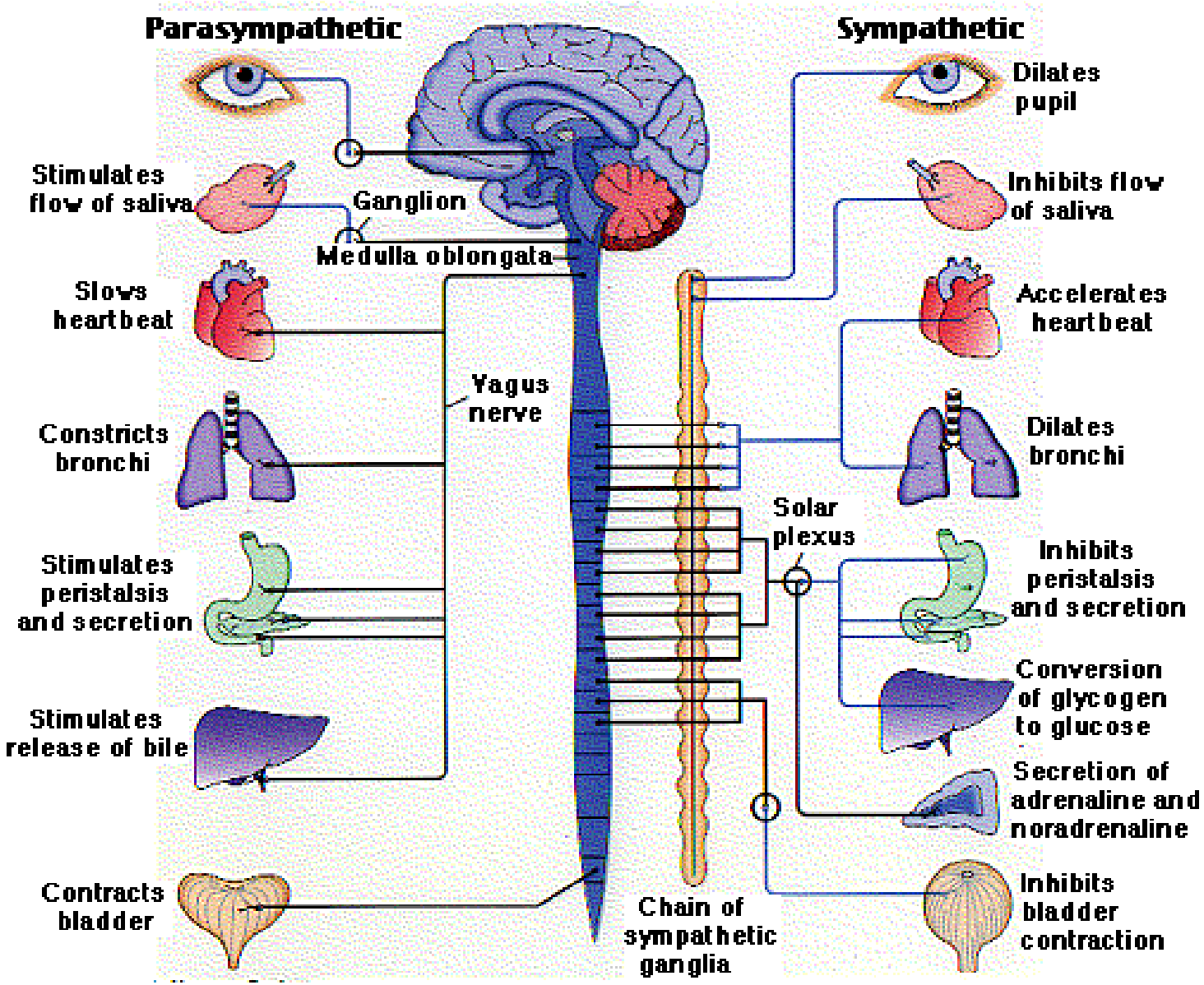
e.g., “human-computer interfaces”

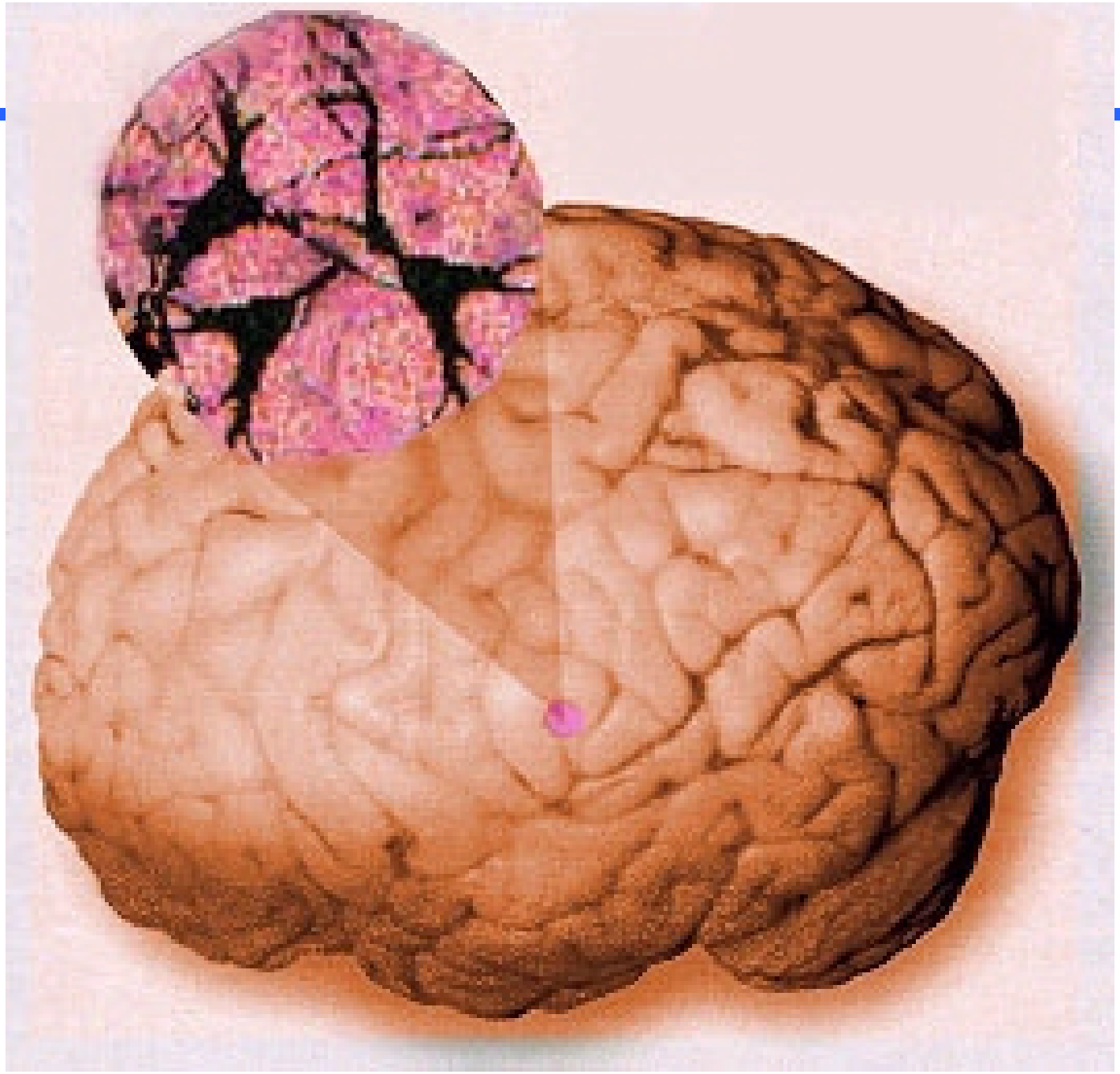
Central vs. Peripheral Nervous System

The brain is not the entire nervous systems; there is also the spinal cord, many peripheral "ganglia" (small clusters of neurons), and neurons extend connections to locations all over the body (e.g., sensory neurons, motor neurons).

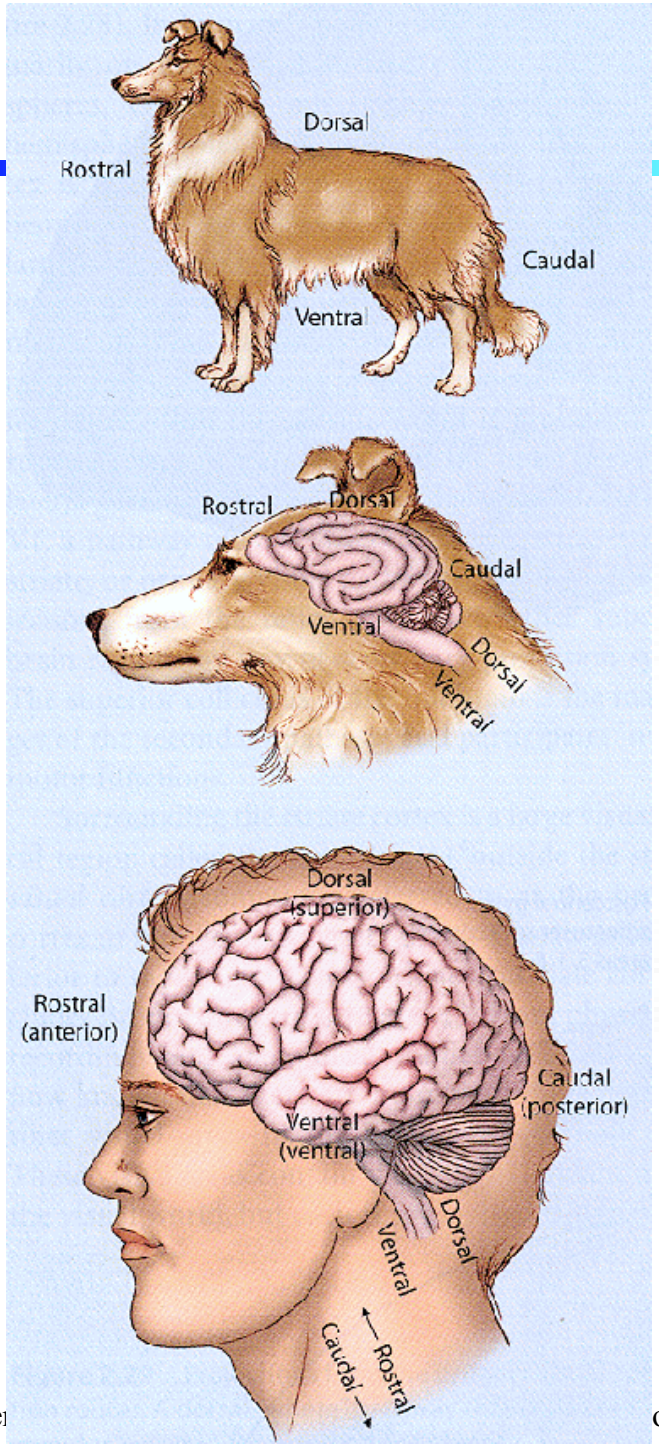


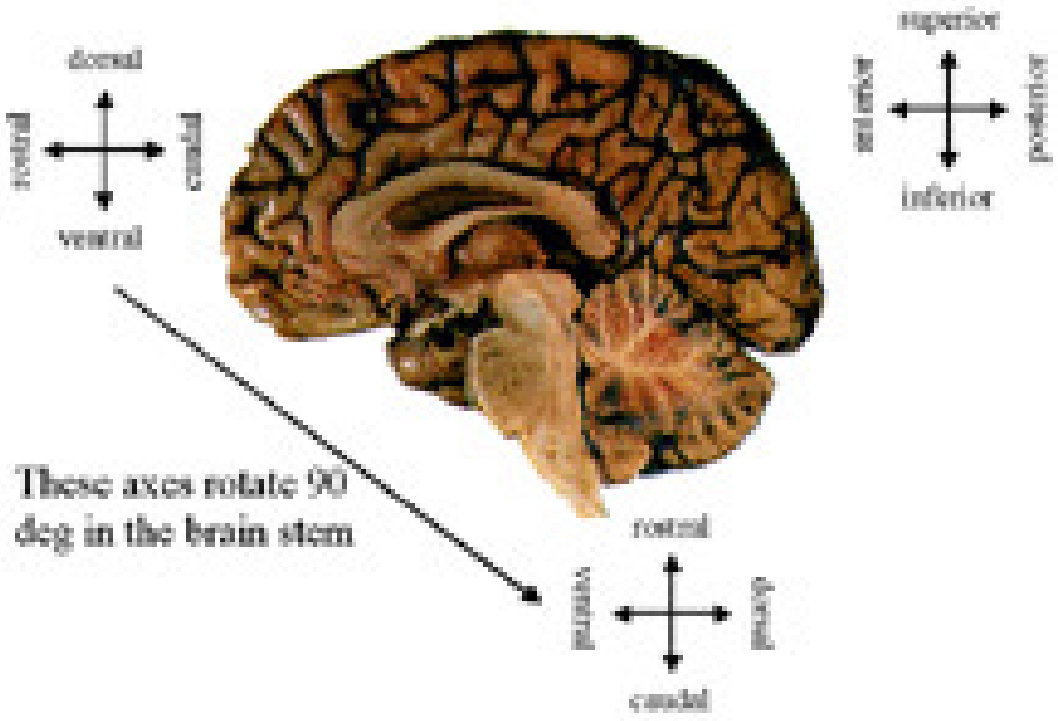
Autonomic Nervous System



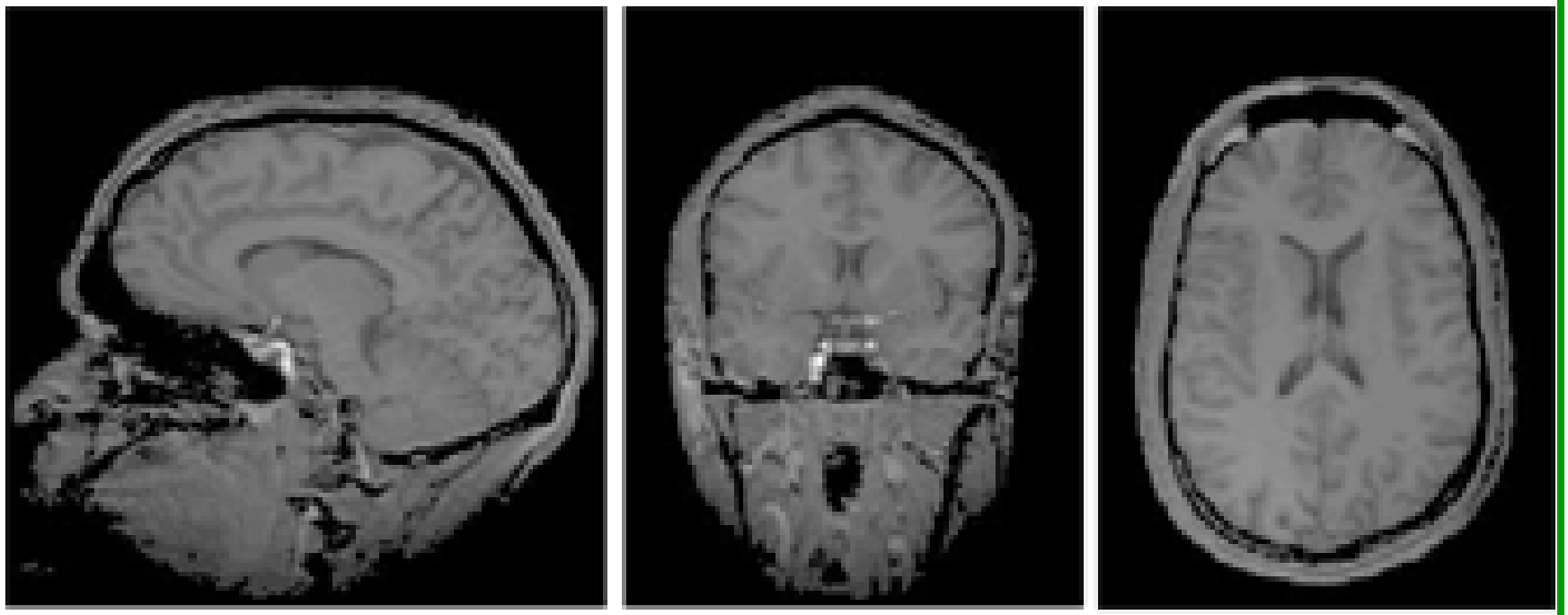


Axes in the brain



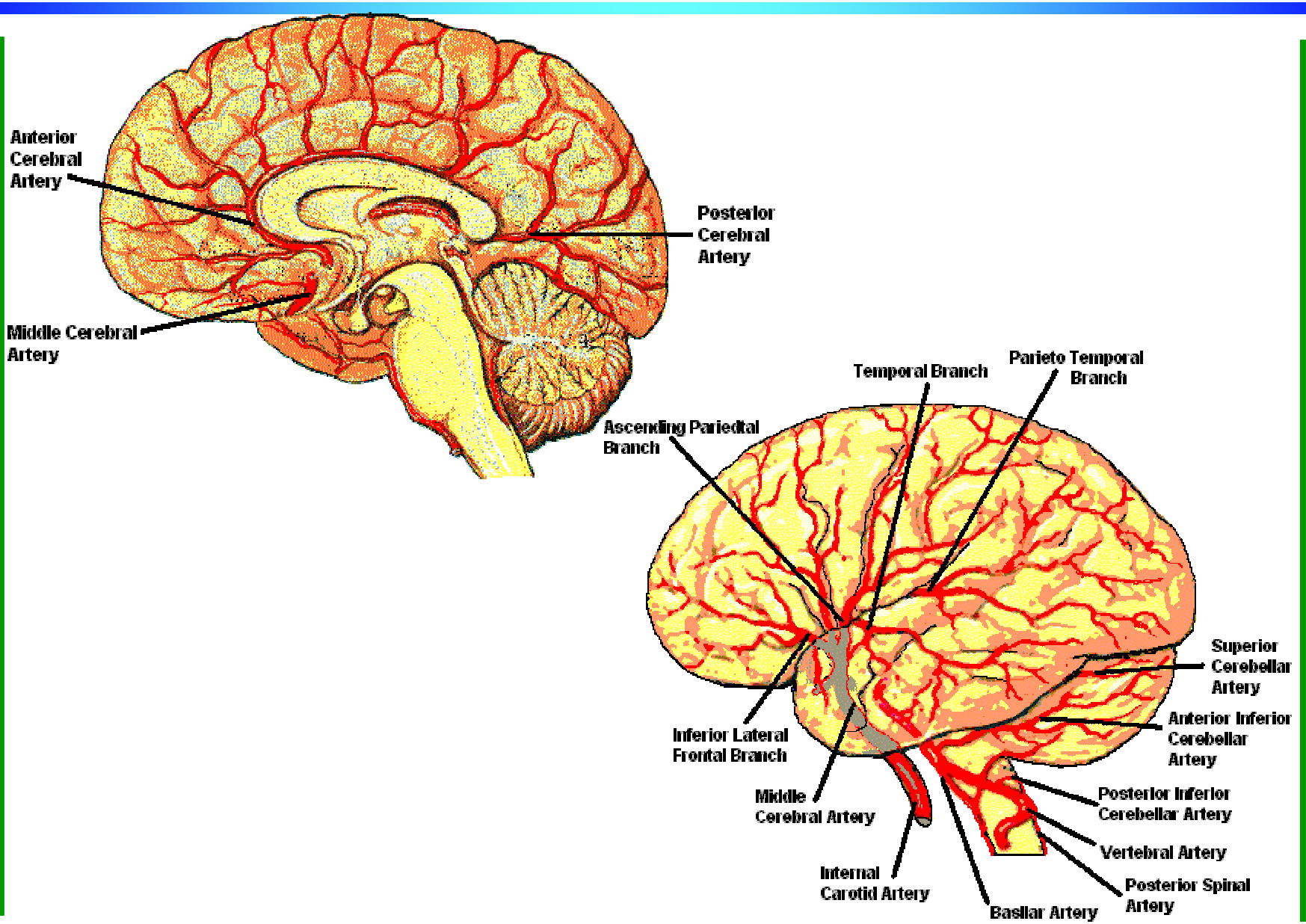


Medical Orientation Terms for Slices



sagittal coronal axial (horizontal)

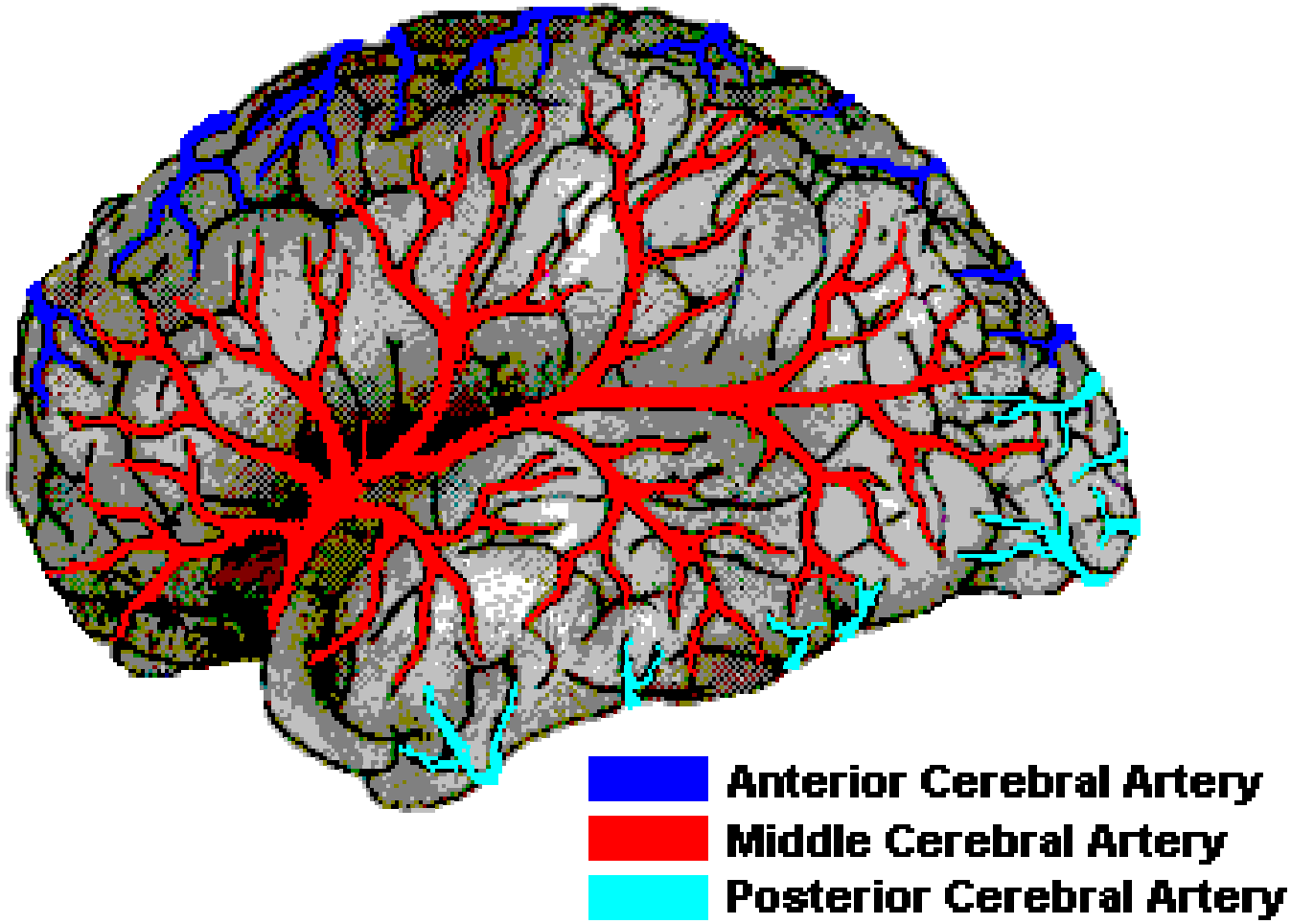
Main Arterial Supply to the Brain



Arterial Supply is Segmented

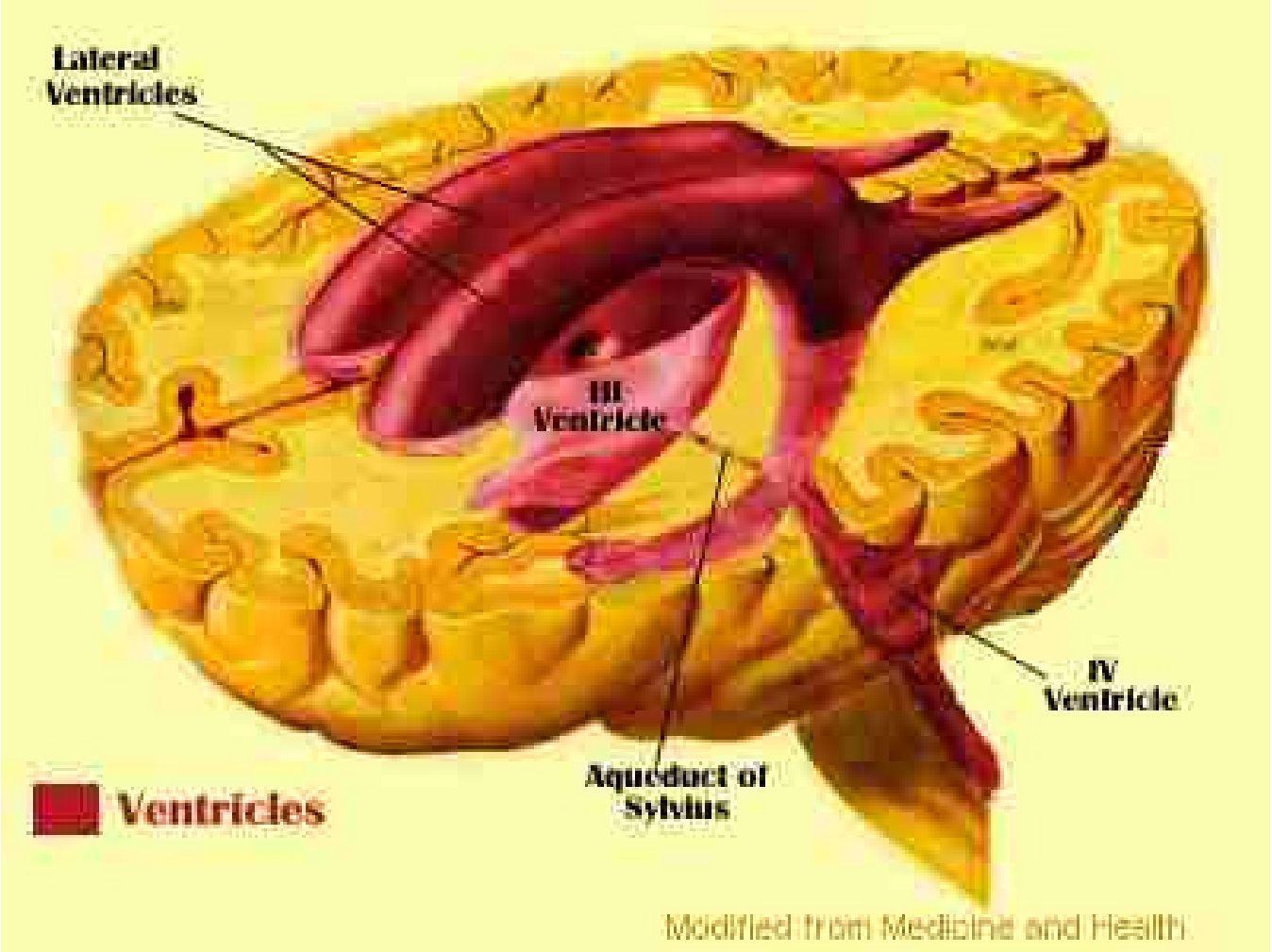
Occlusion/damage to one artery will affect specific brain regions.

Important to remember for patient studies.

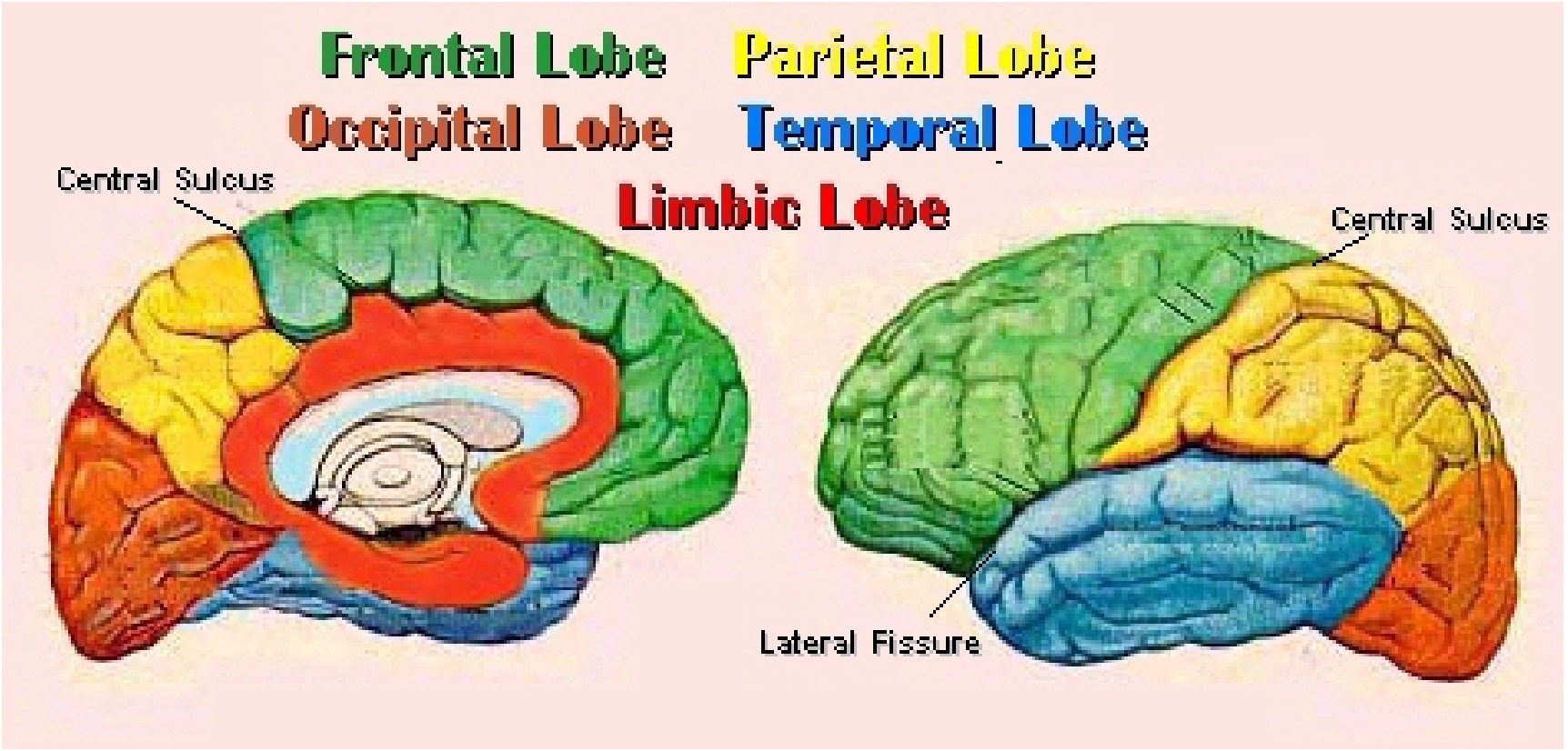


Ventricular System

Ventricules: Cavities filled with fluid inside and around the brain. One of their functions is to drain garbage out of the brain.



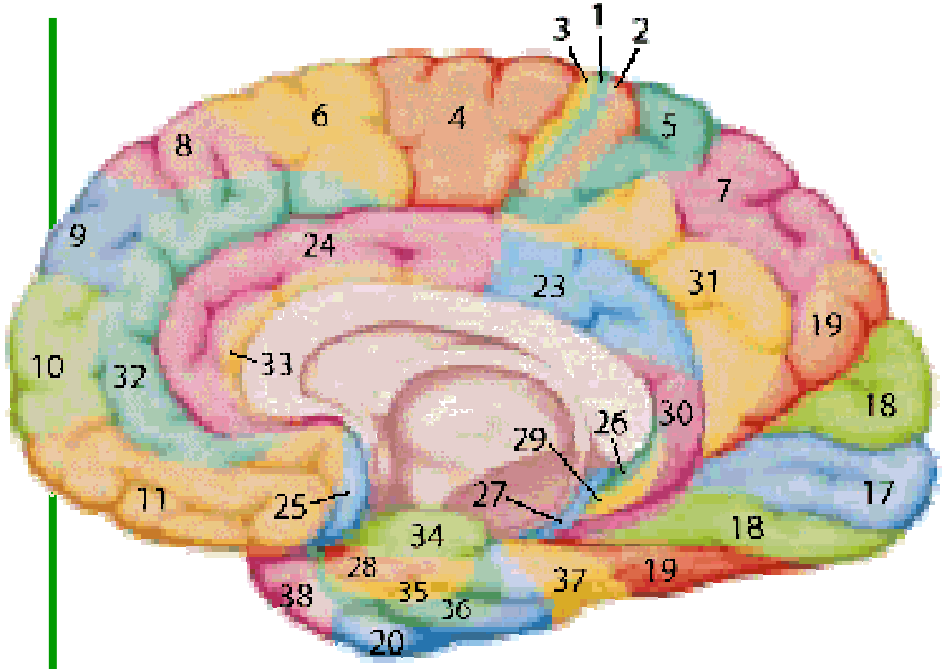
Cortical Lobes

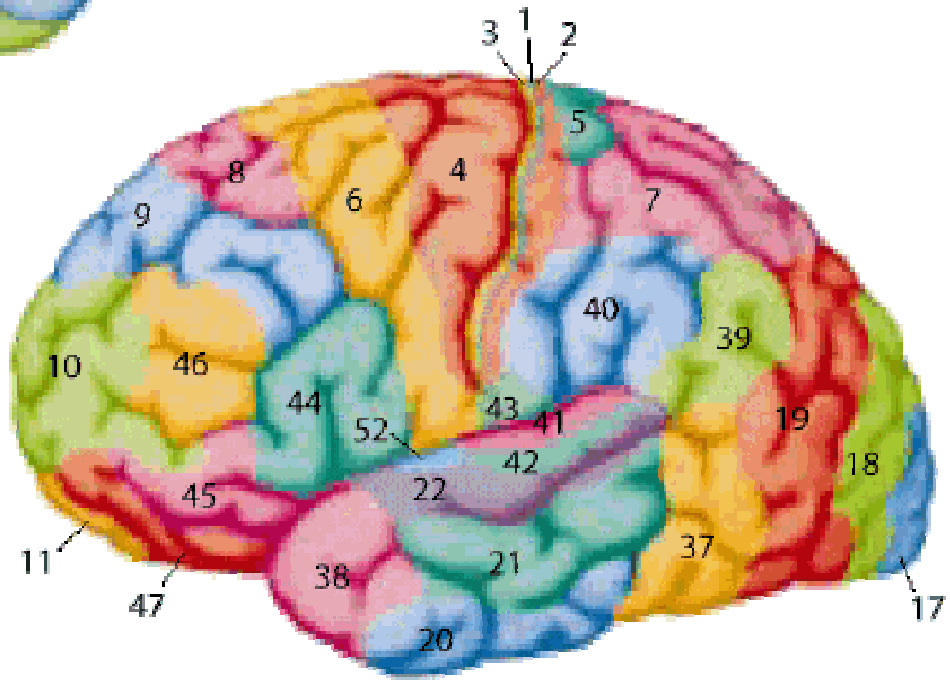


Sulcus ("fissure" if very large): Grooves in folded cortex
Gyrus: cortex between two sulci

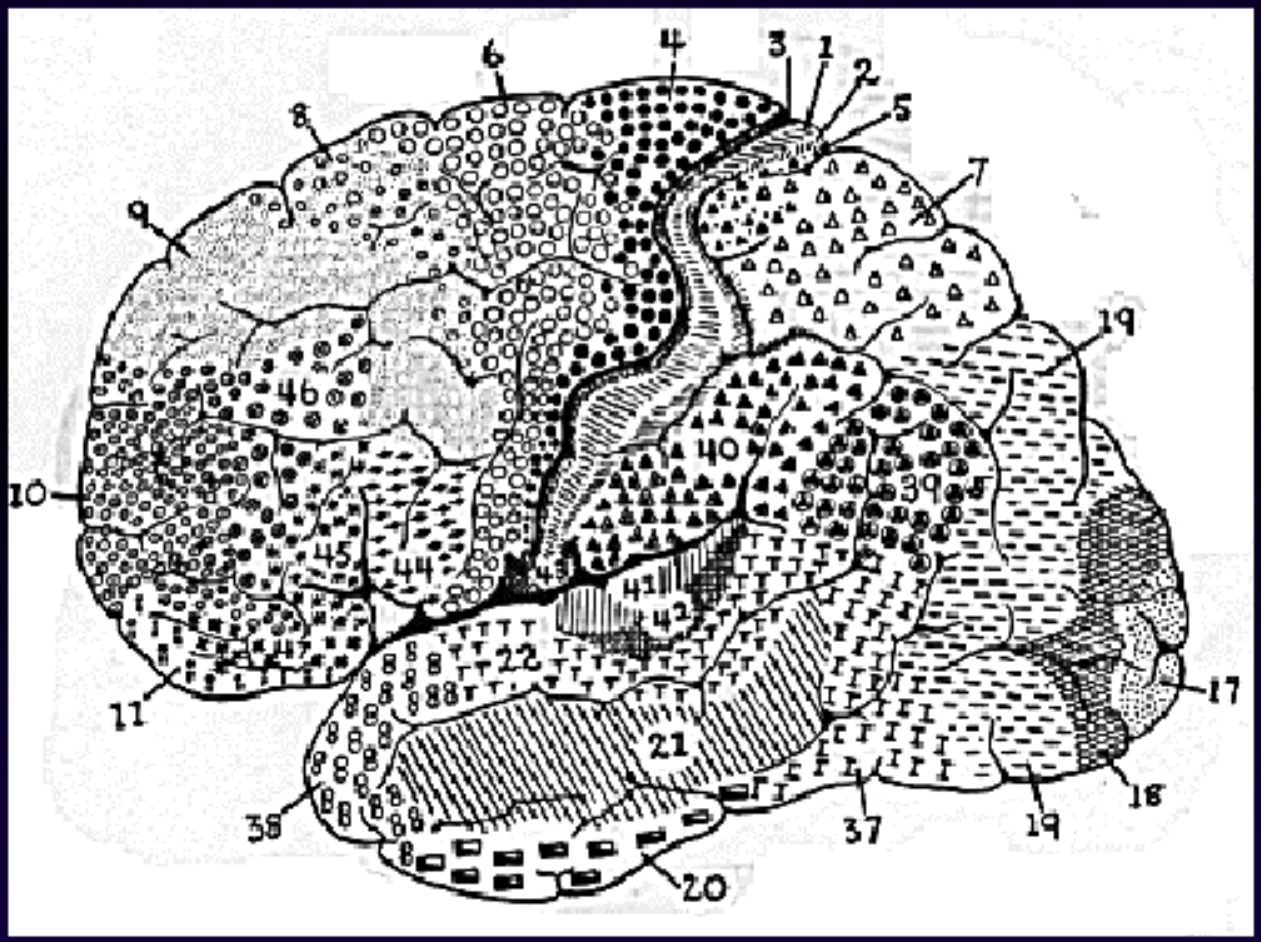
1 sulcus, many sulci; 1 gyrus, many gyri

Brodmann Areas



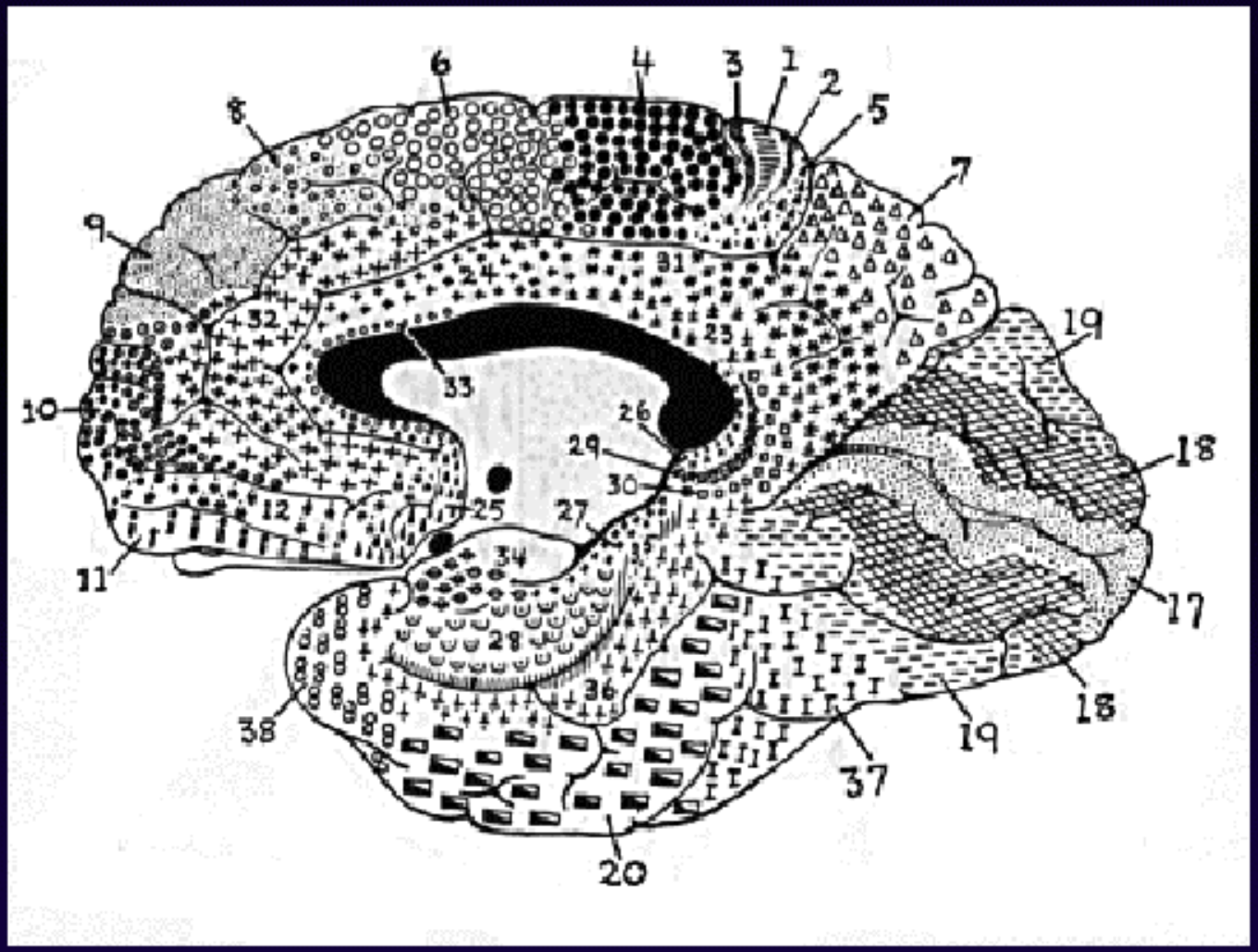


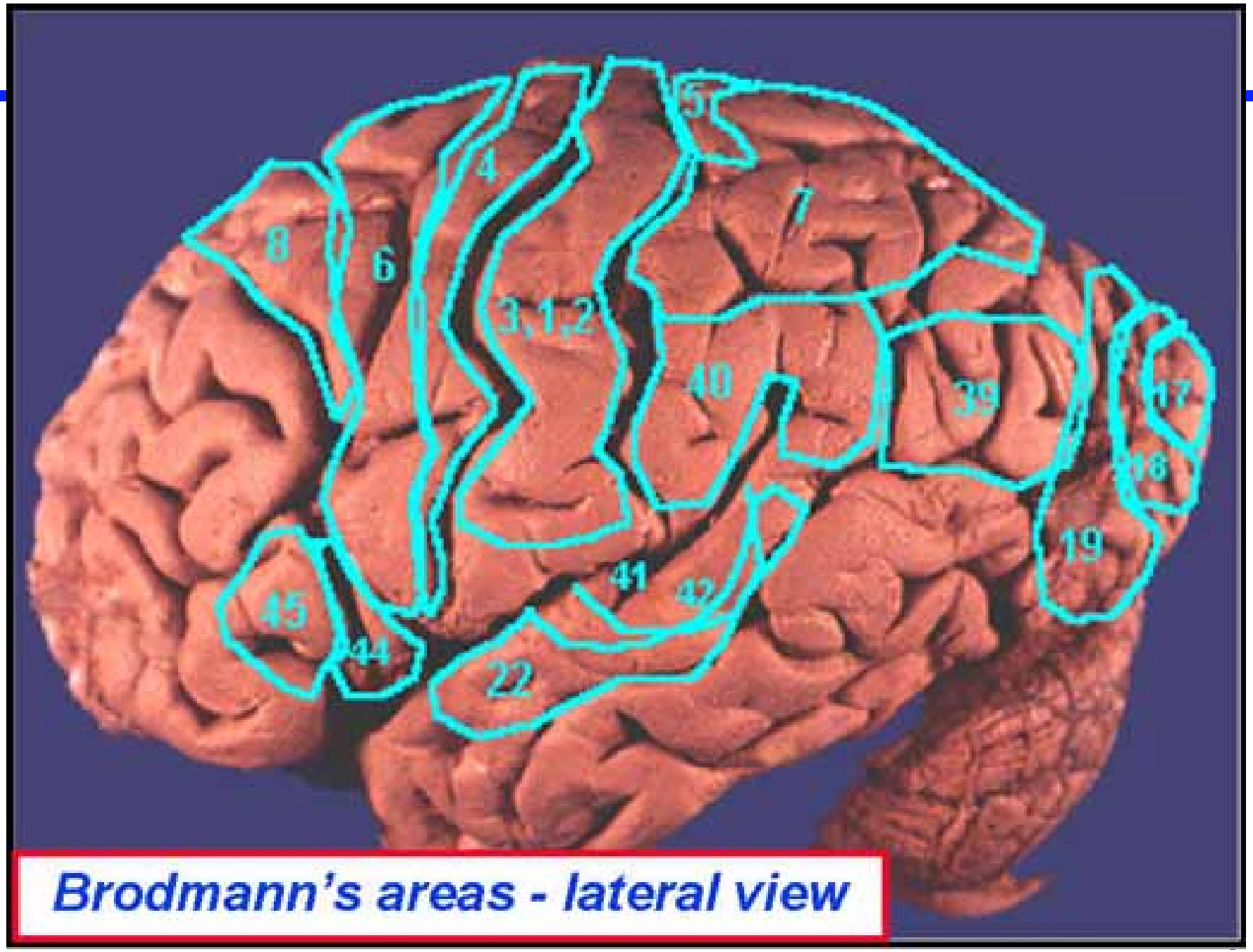
Brodmann's cytoarchitectural map of Cortical Areas

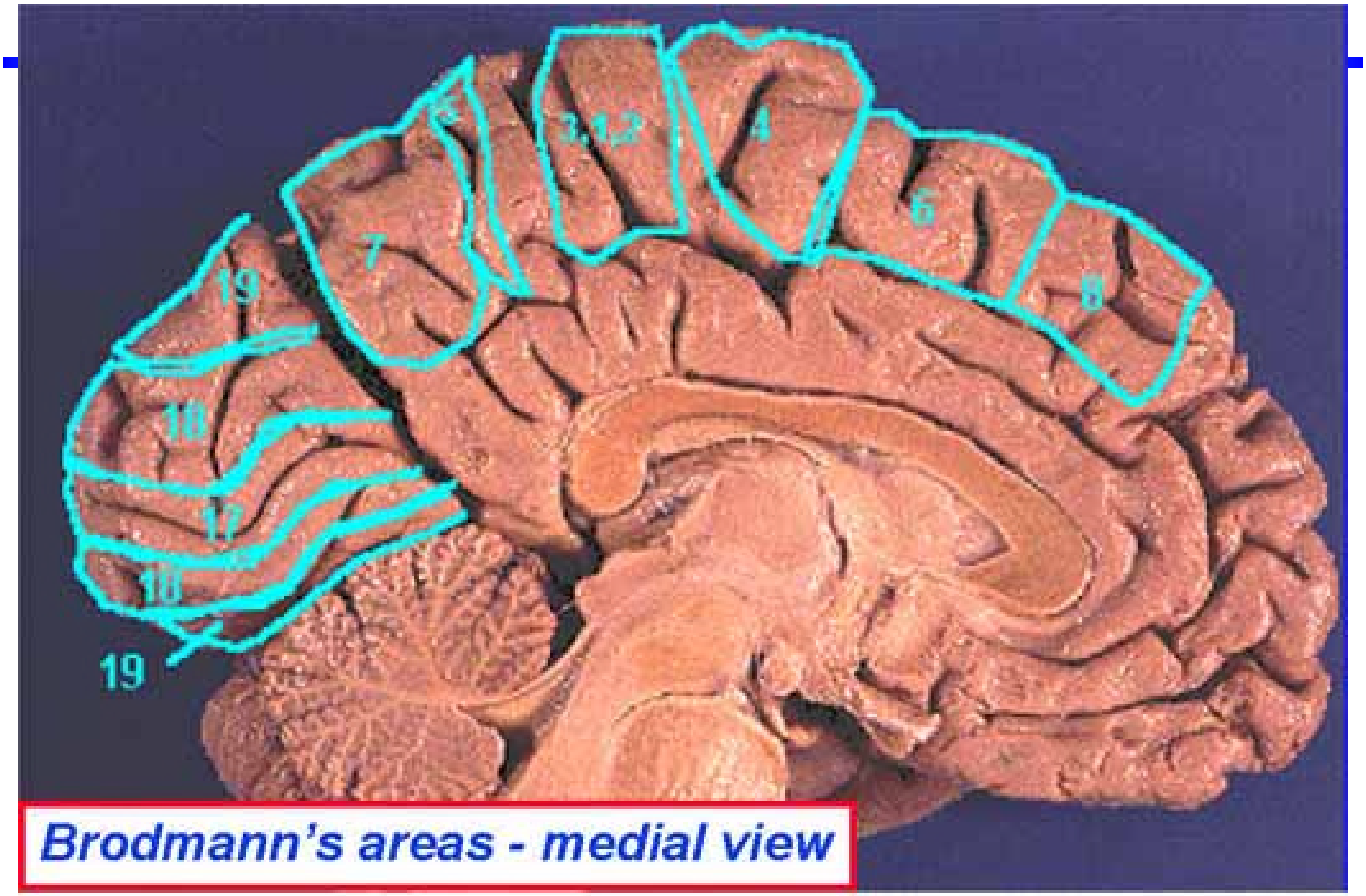


Lateral View

Brodmann's Areas (Medial View)

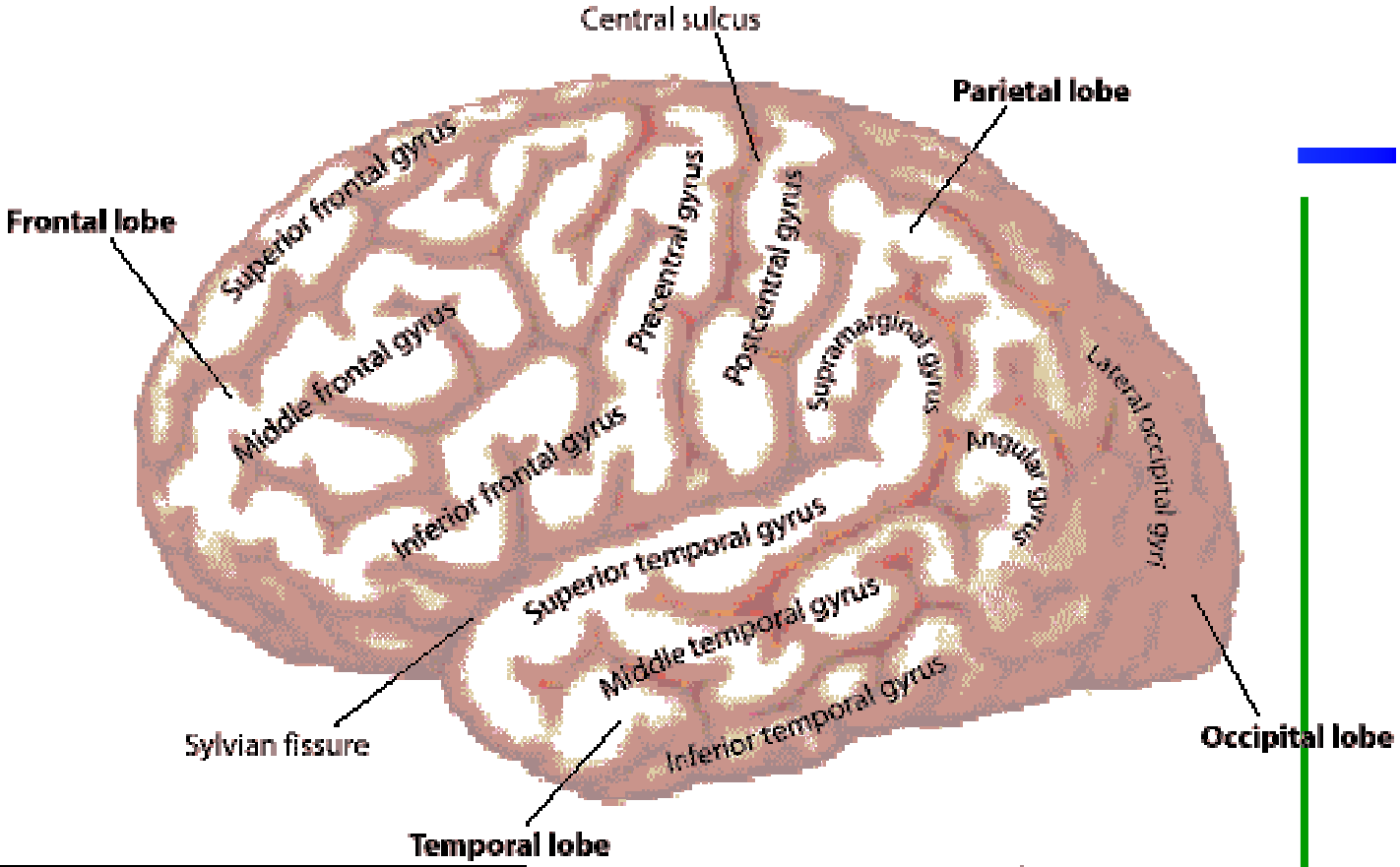


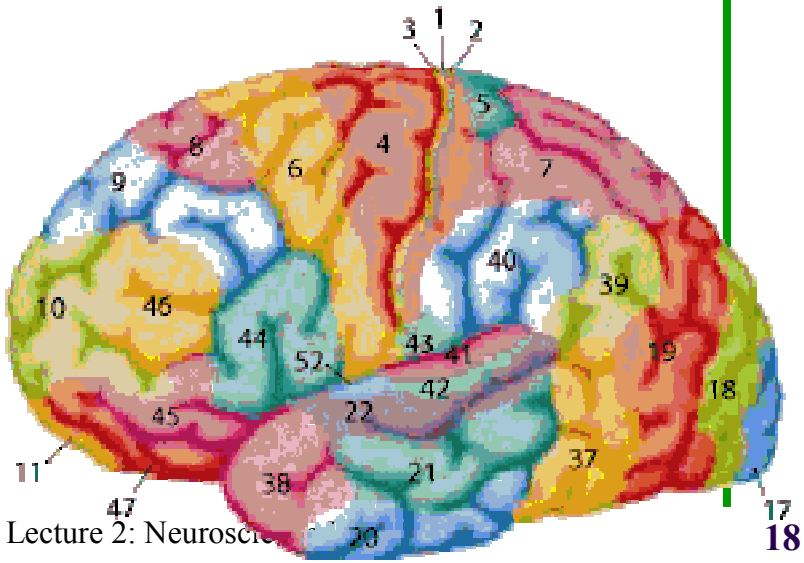

8
6
4
5
7
3,1,2
40
39
17
18
19
41
42
45
44
22
Brodmann's areas - lateral view



Brodmann's areas - medial view

Anatomical Areas, Brodmann Areas, Functional Areas…





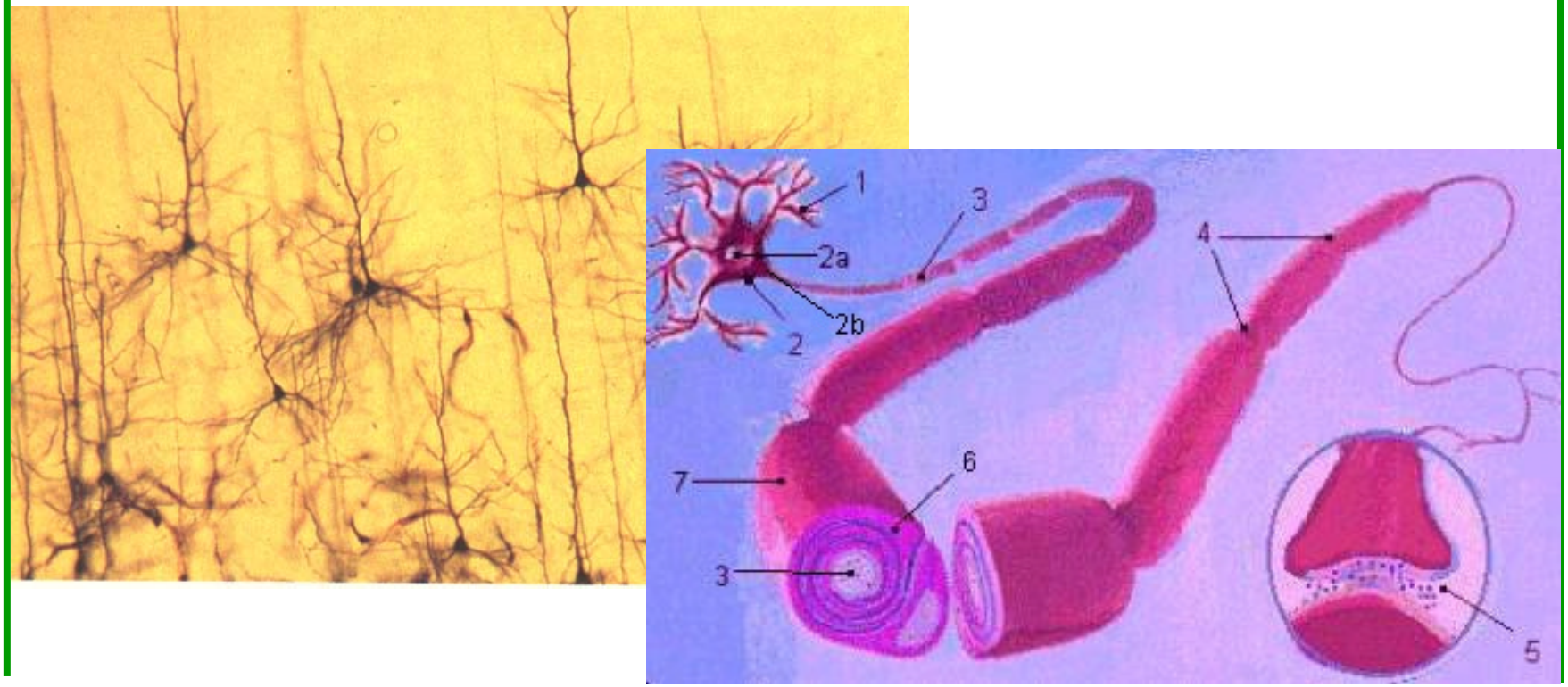
Neurons

Cell body (soma): where computation takes place

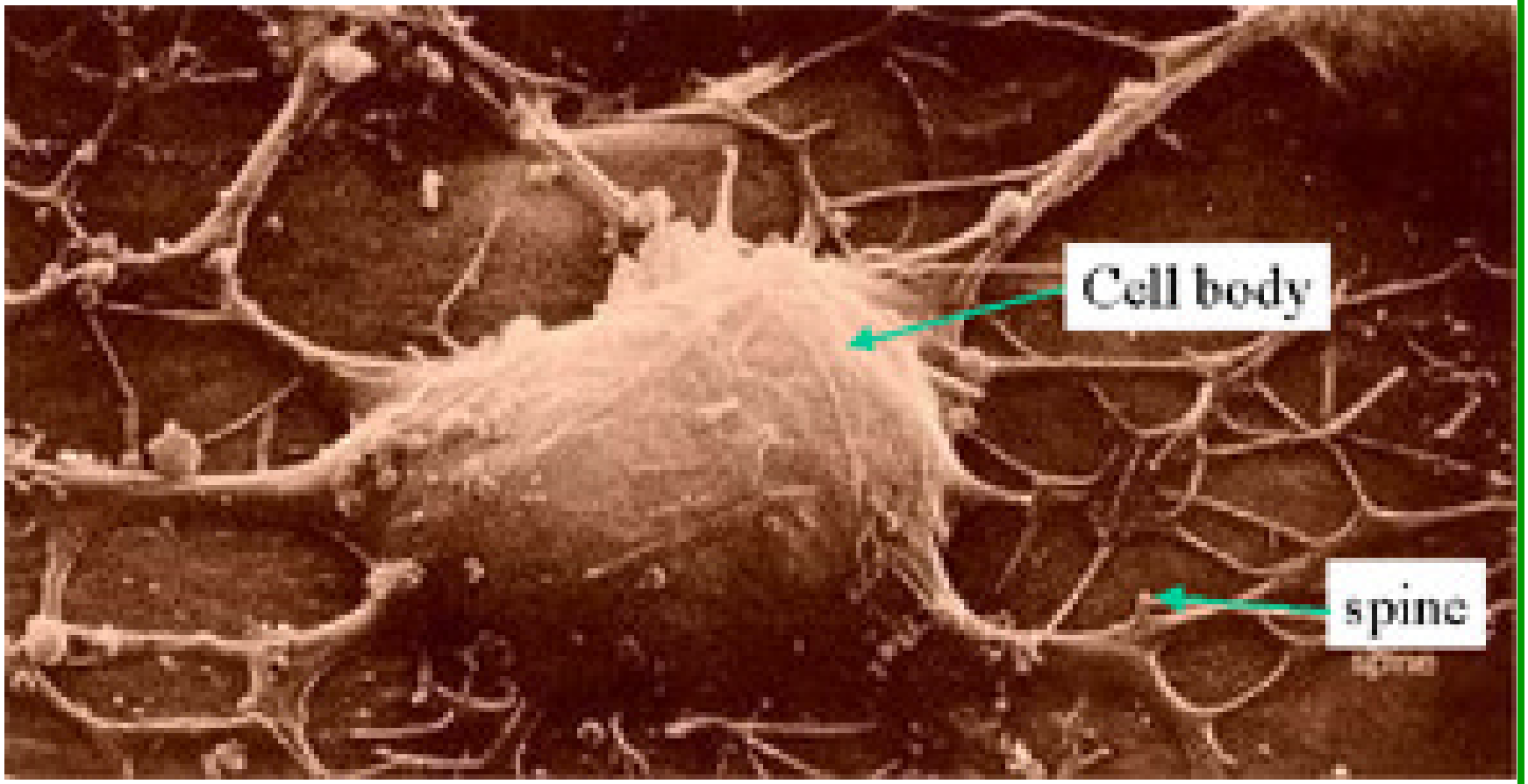
Dendrites: input branches

Axon: unique output (but may branch out)

Synapse: connection between **presynaptic** axon and **postsynaptic** dendrite (in general).



Electron Micrograph of a Real Neuron

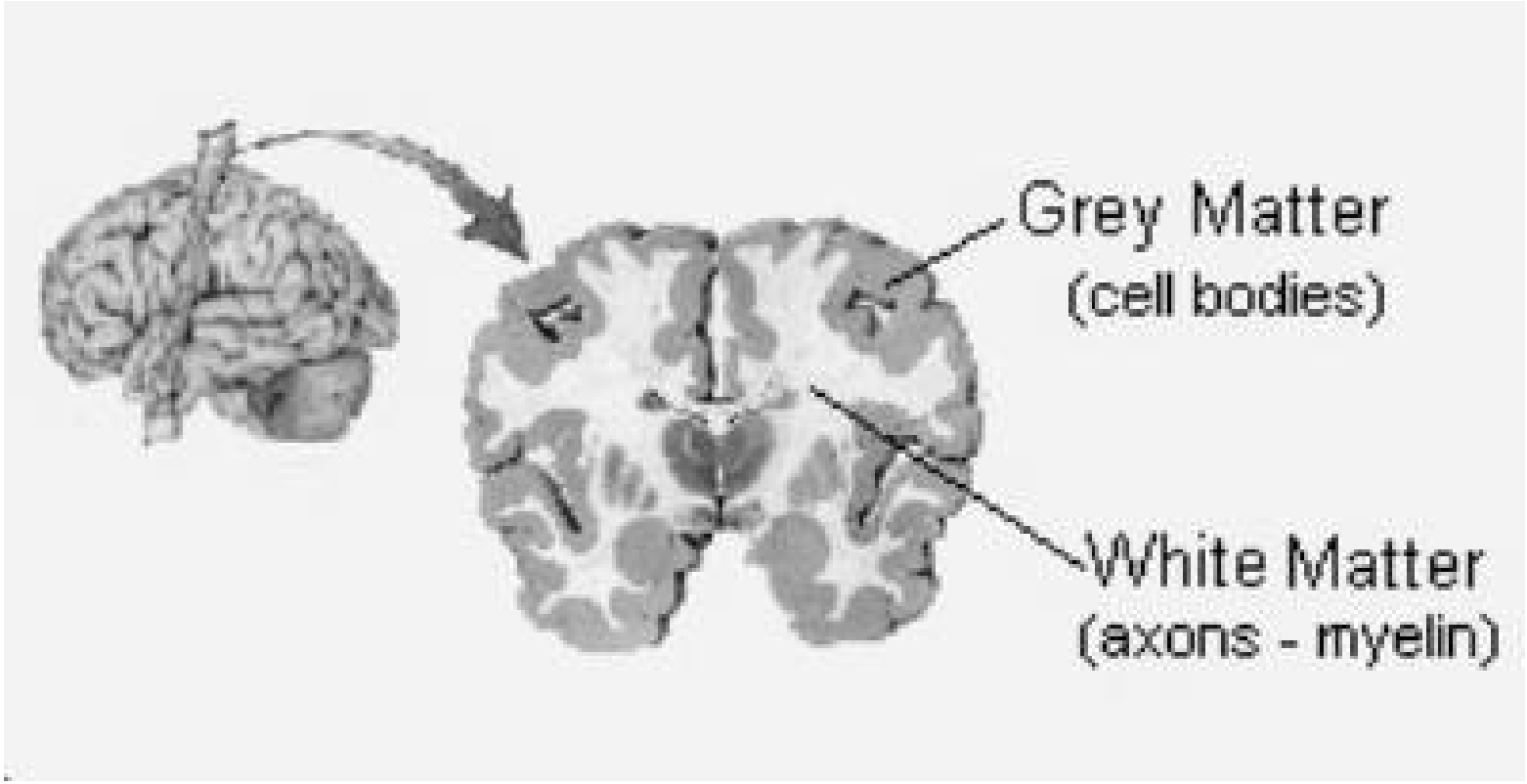


Grey and White Matters

Grey matter: neurons (cell bodies), at outer surface of brain

White matter: interconnections, inside the brain

Deep nuclei: clusters of neurons deep inside the brain



Major Functional Areas

Primary motor: voluntary movement

Primary somatosensory: tactile, pain, pressure, position, temp., mvt.

Motor association: coordination of complex movements

Sensory association: processing of multisensorial information

Prefrontal: planning, emotion, judgement

Speech center (Broca's area): speech production and articulation

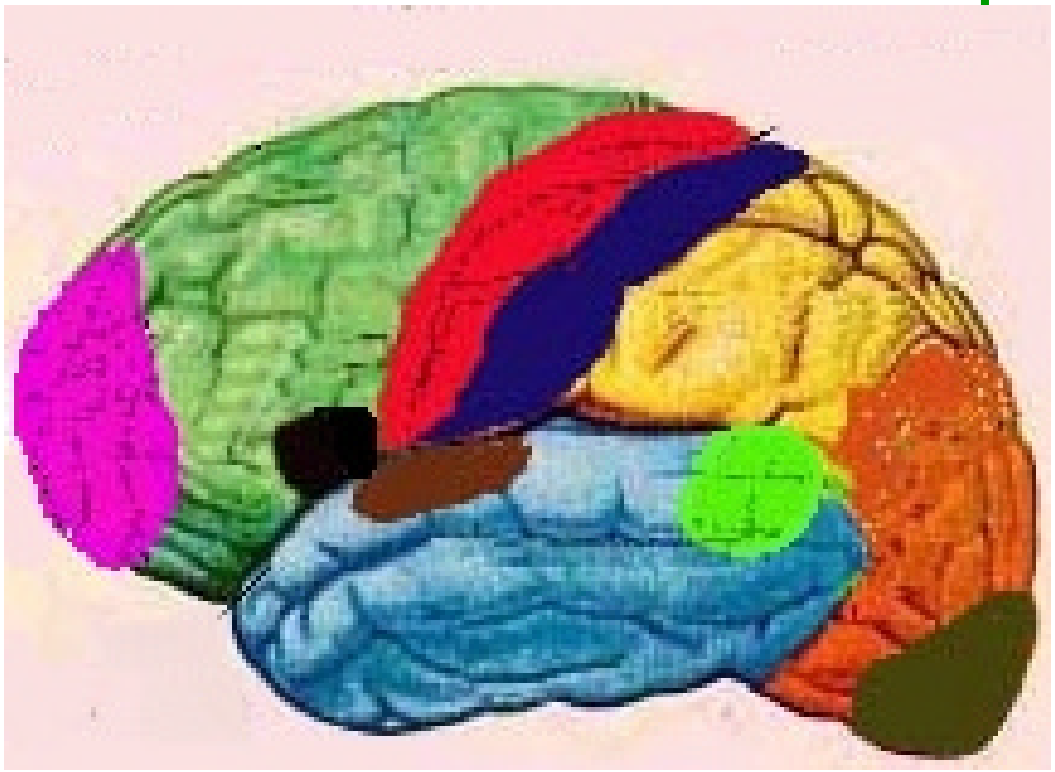
Wernicke's area: comprehension of speech

Auditory: hearing

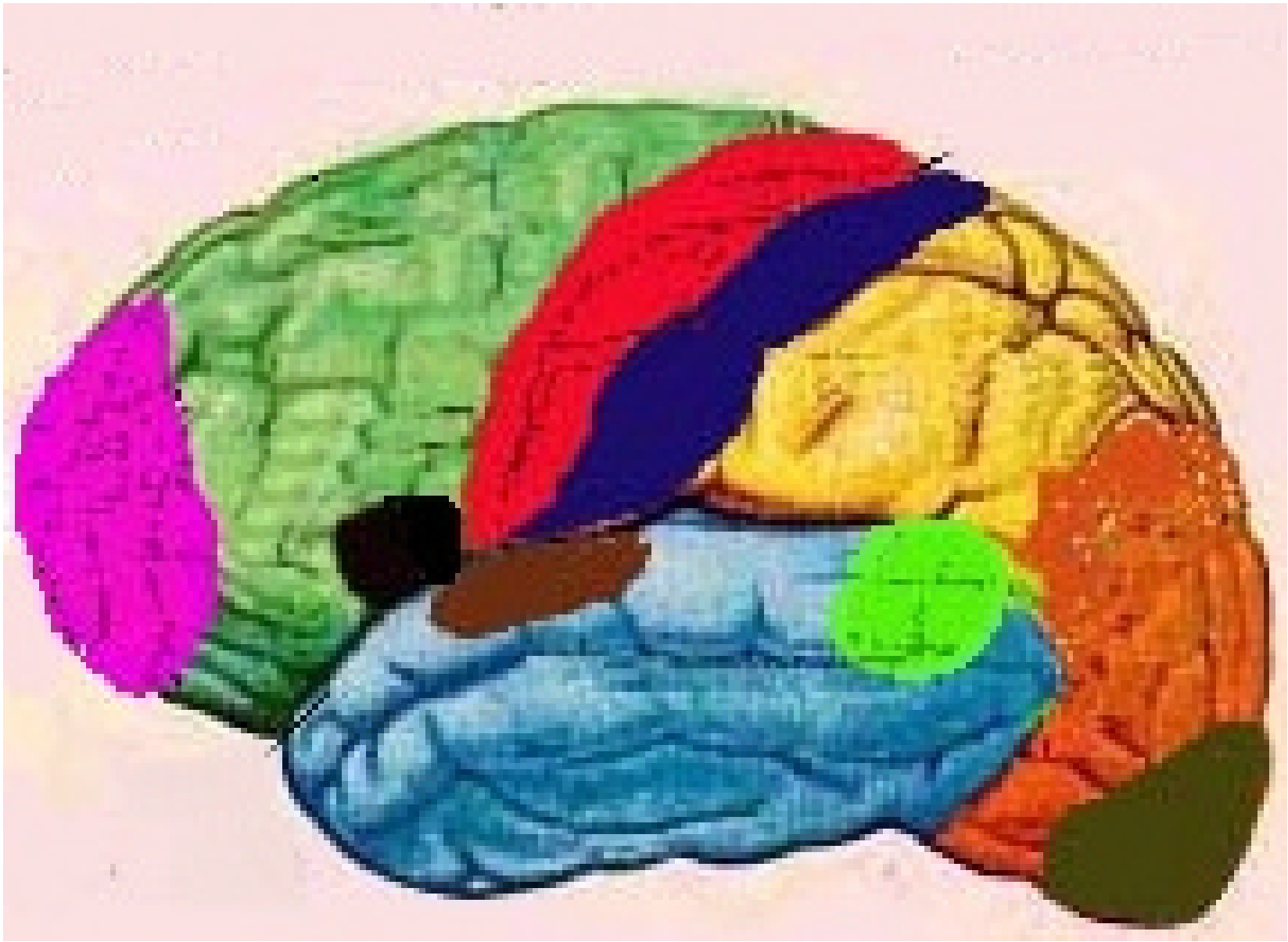
Auditory association: complex auditory processing

Visual: low-level vision

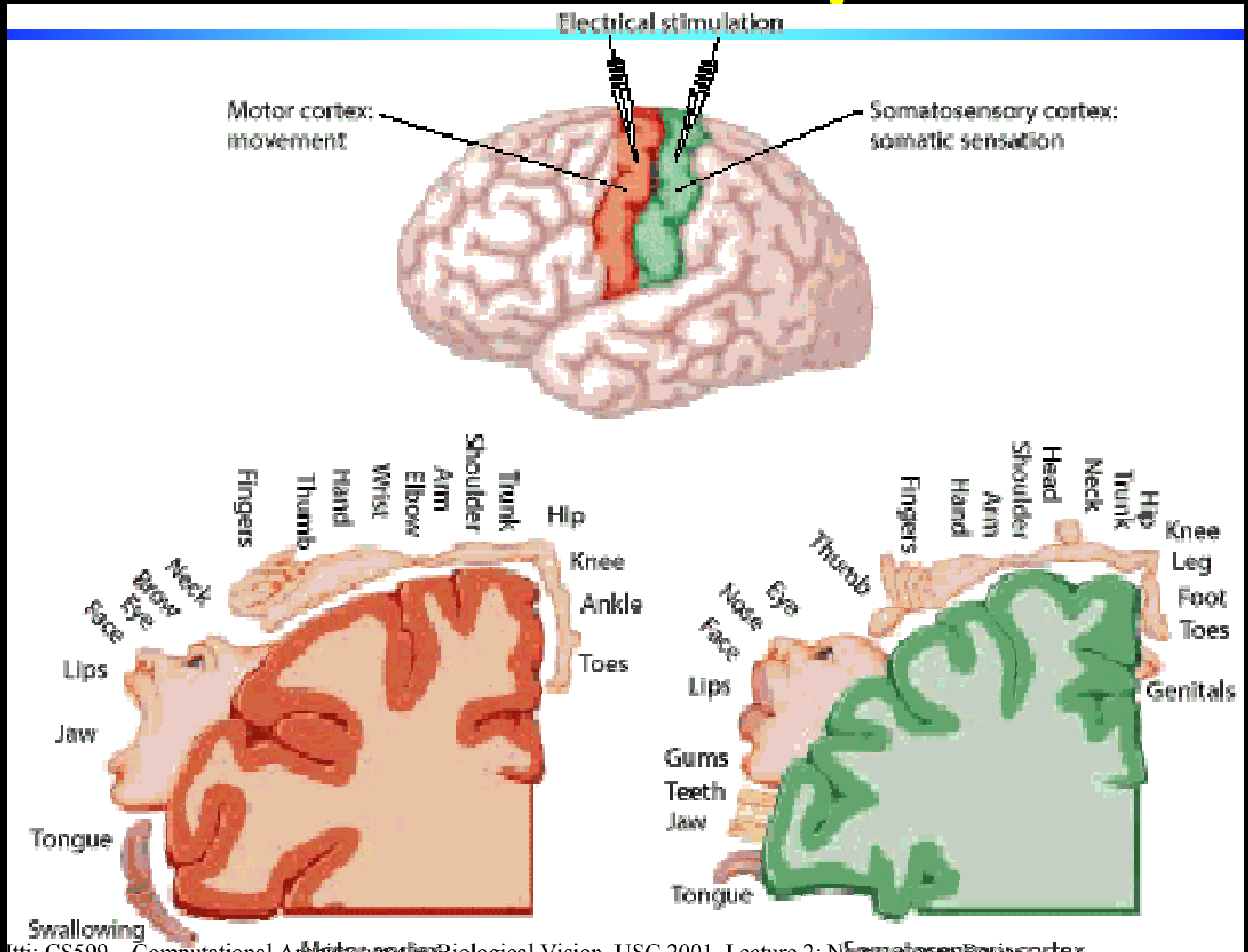
Visual association: higher-level vision



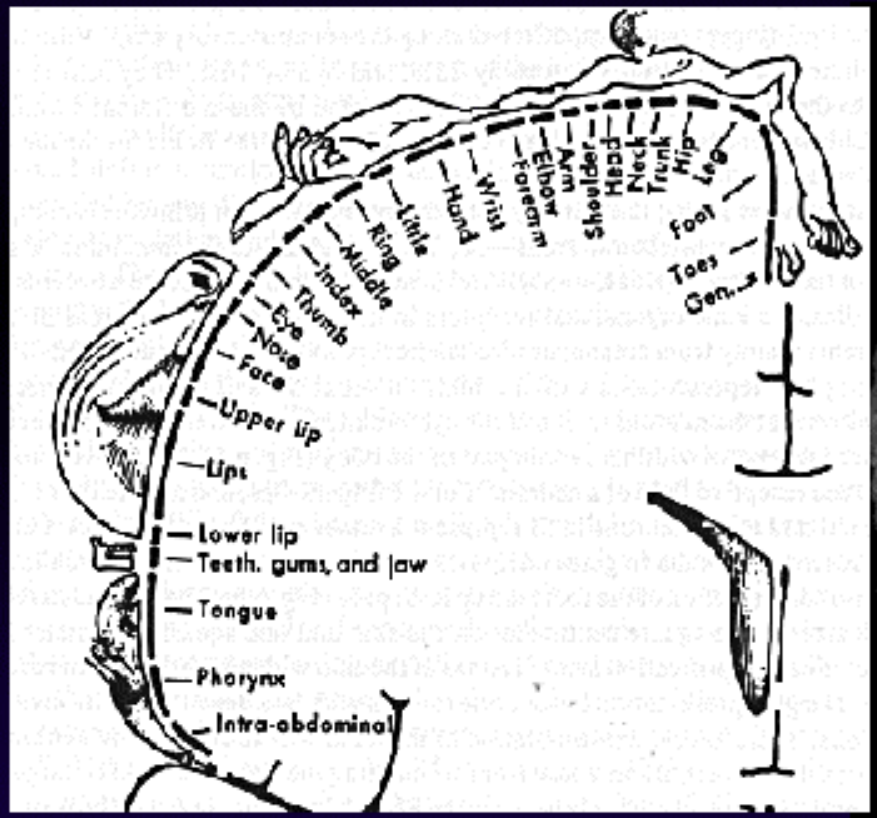
Major Functional Areas

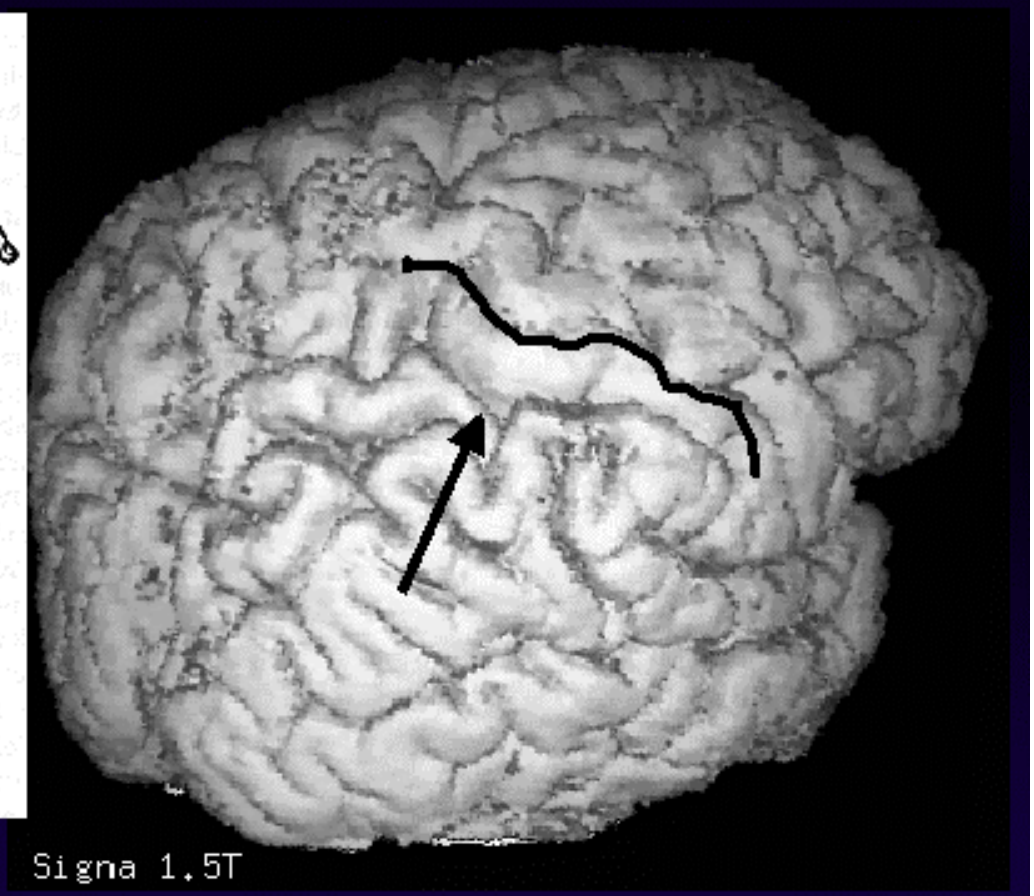


Motor and Somatosensory Homunculi



Somatosensory Localization



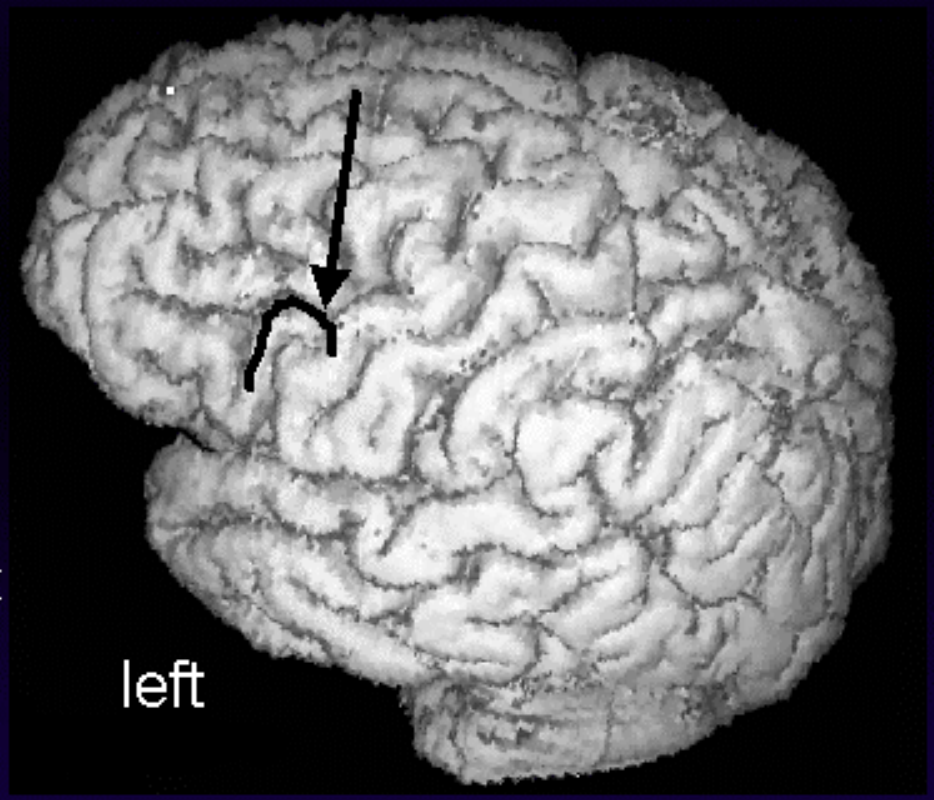


Supplementary Motor Area (SMA) and Premotor Area

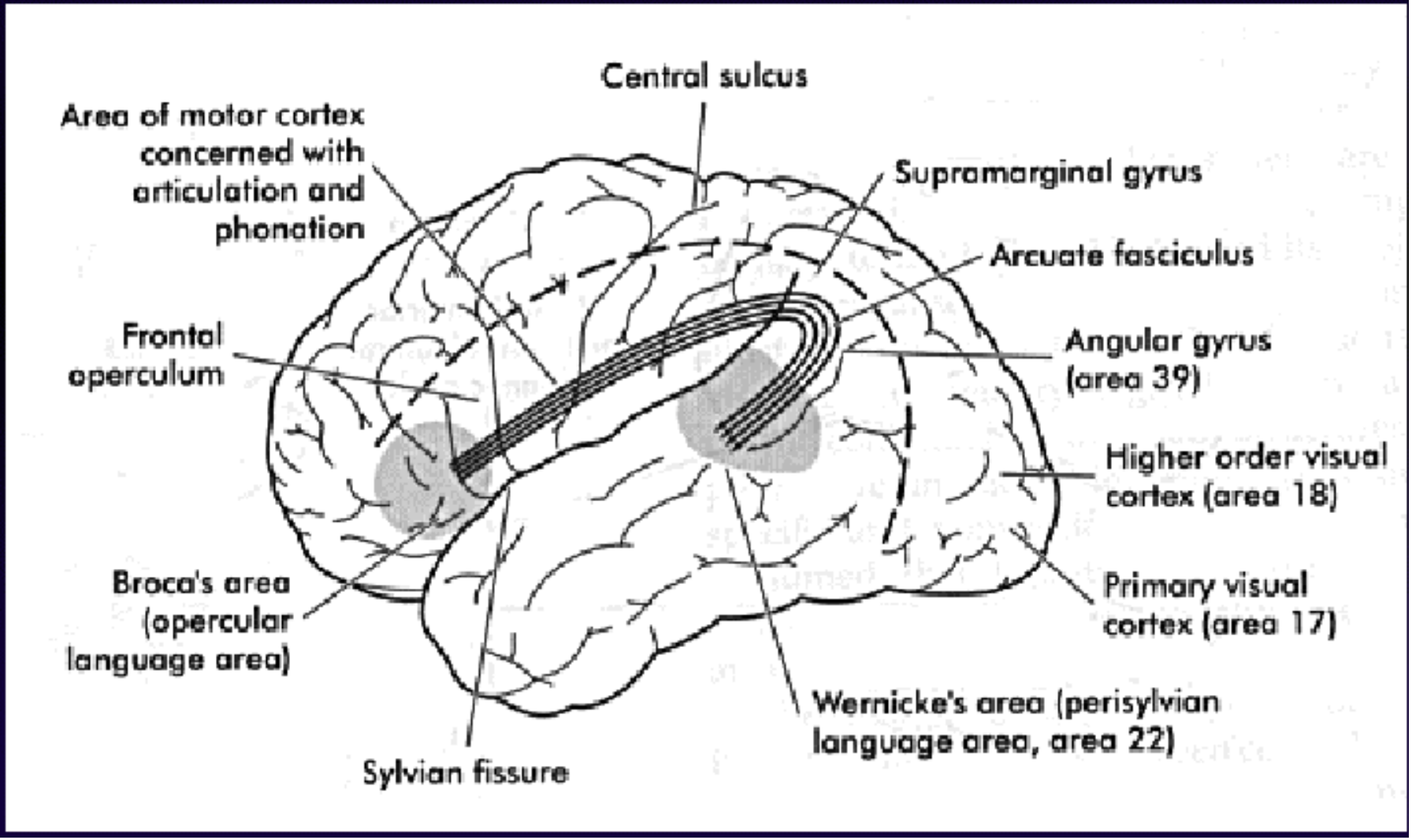
- Superior Frontal gyrus and Middle frontal gyrus (Brod. Area 6)
- Activated by complex motor tasks (touch all four fingers in a given sequence)

Activation of Broca's Area

- Operculum and triangular parts of inferior frontal gyrus (Area 44,45)
- Activated by word generation tasks - lateralizes to dominant side
- Covert word production



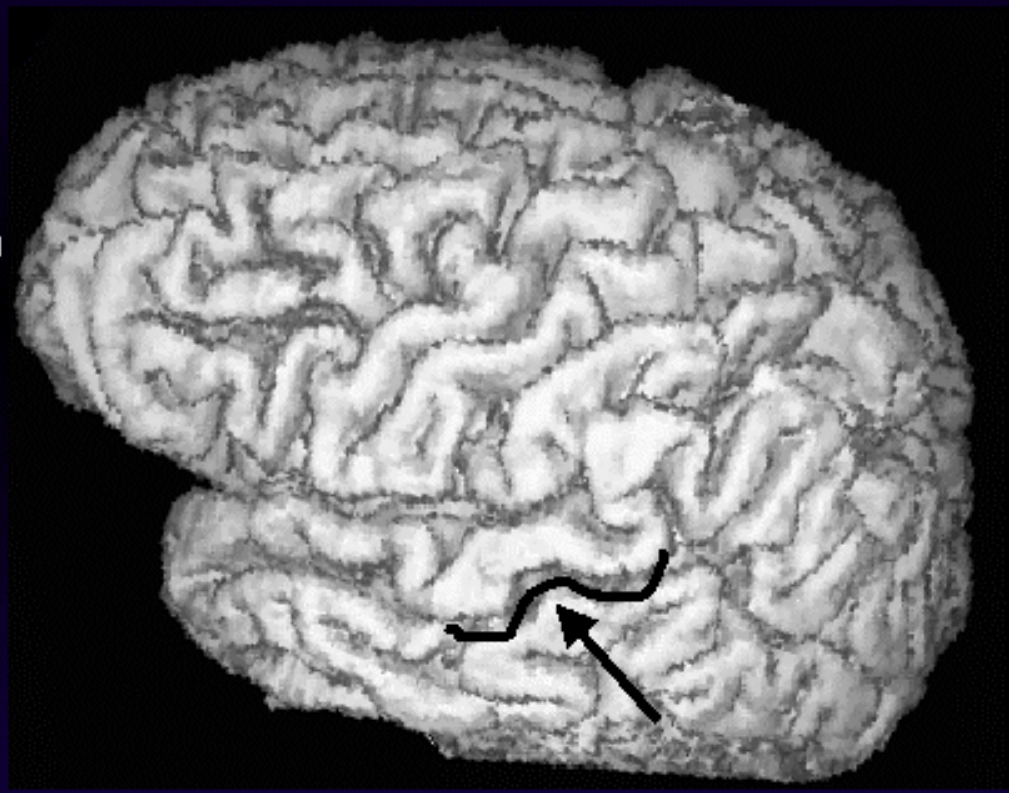
Cortical Regions - Language



Sites where stimulation interferes with speech

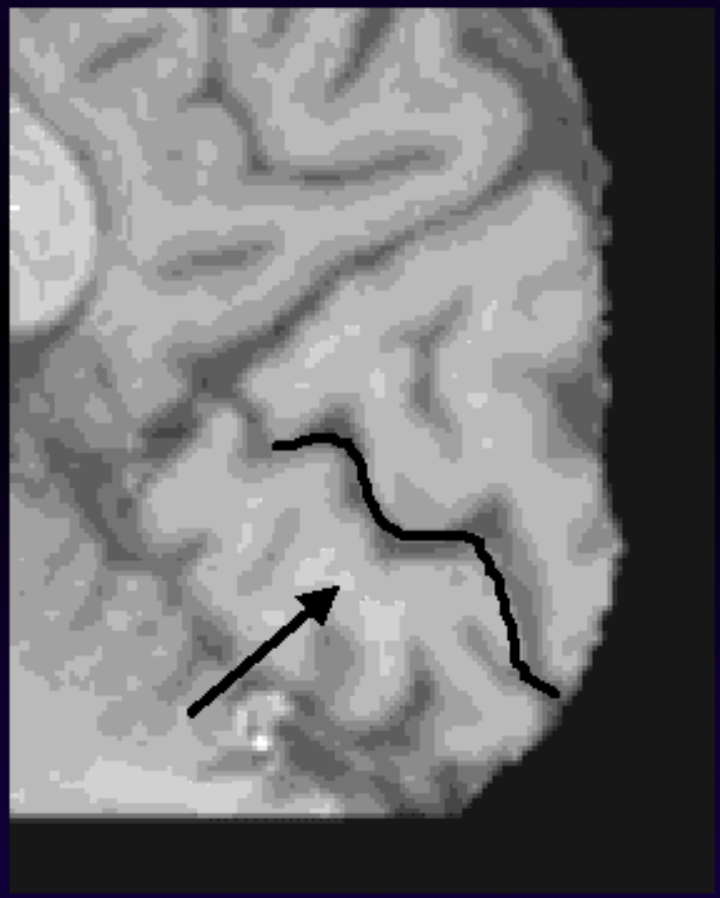
Activation of Auditory Areas

- Primary (A1)and auditory association areas (A2, Wernicke's)
- Increasing word presentation frequency increases response



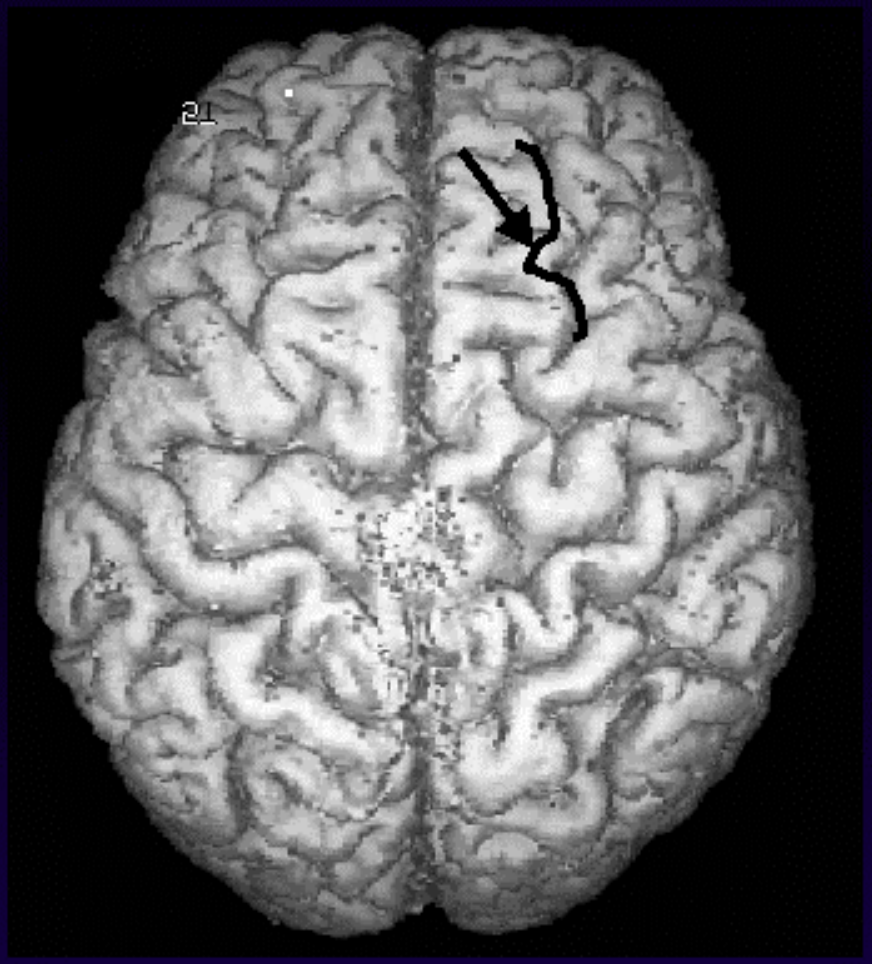
Activation of the Visual Cortex

- Primary visual area (V1) Area 17
- Visual association areas (V2-5) Area 18,19)
- Stimulus activates banks of the calcarine sulcus
- Retinotopic



Cognitive Tasks

- Silent (internal) speech
- Mental imagery of prior motor or visual task
- Memory load activation of prefrontal cortex (2 back paradigm)



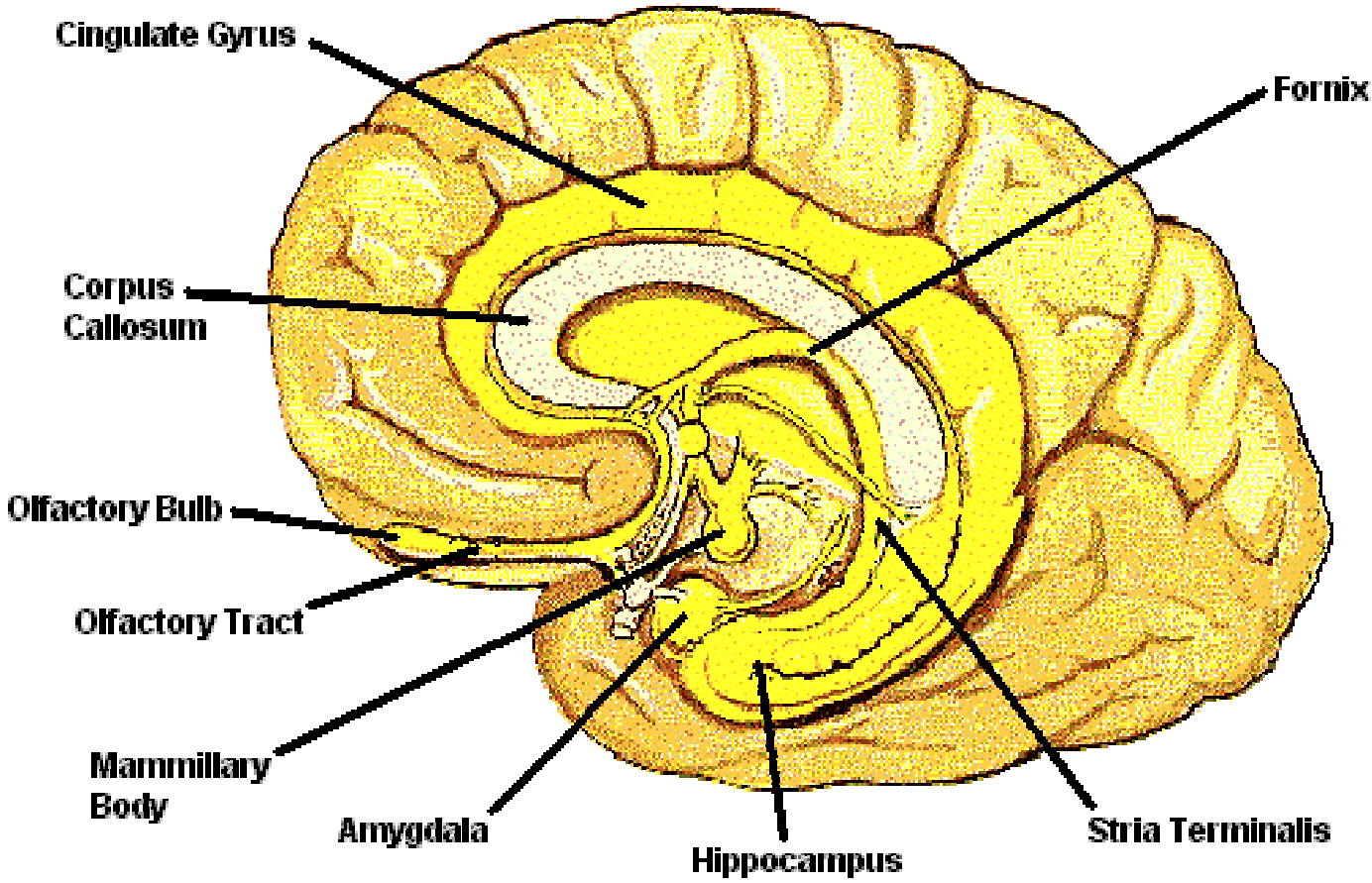
Cohen et al Human Brain Mapping 1:293-304, 1994

Limbic System

Cortex “inside” the brain.

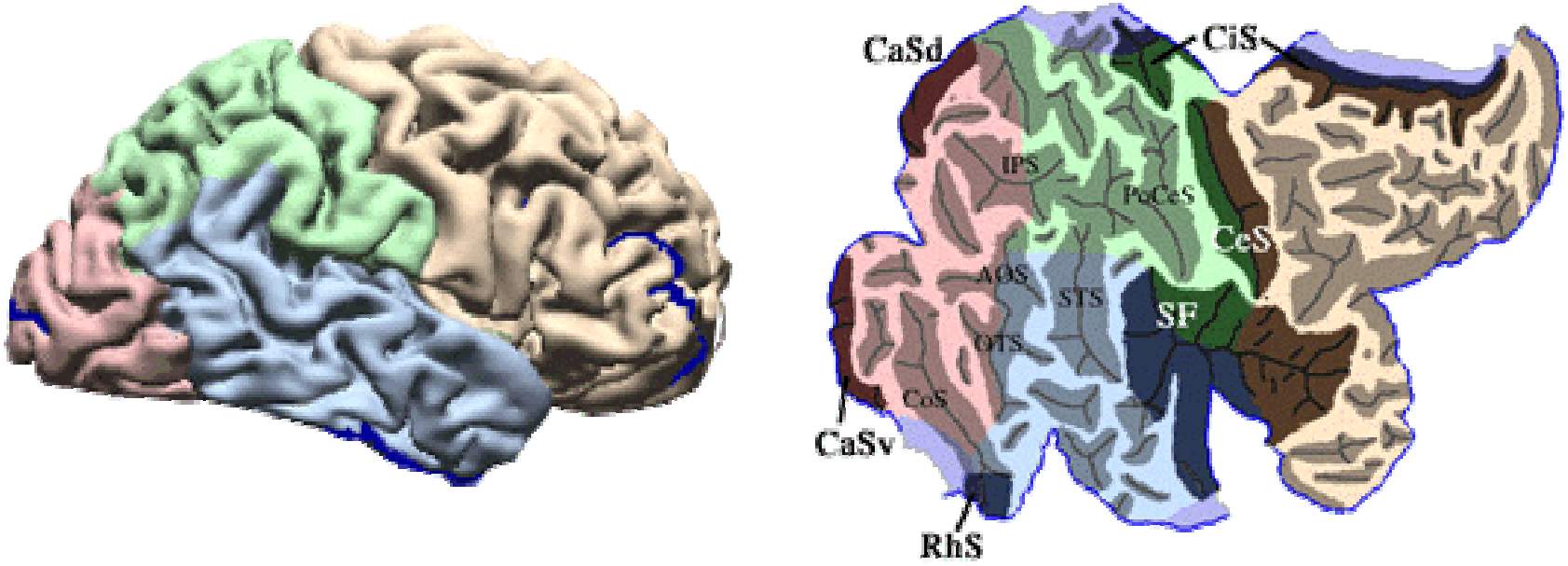
Involved in emotions, sexual behavior, memory, etc

(not very well known)



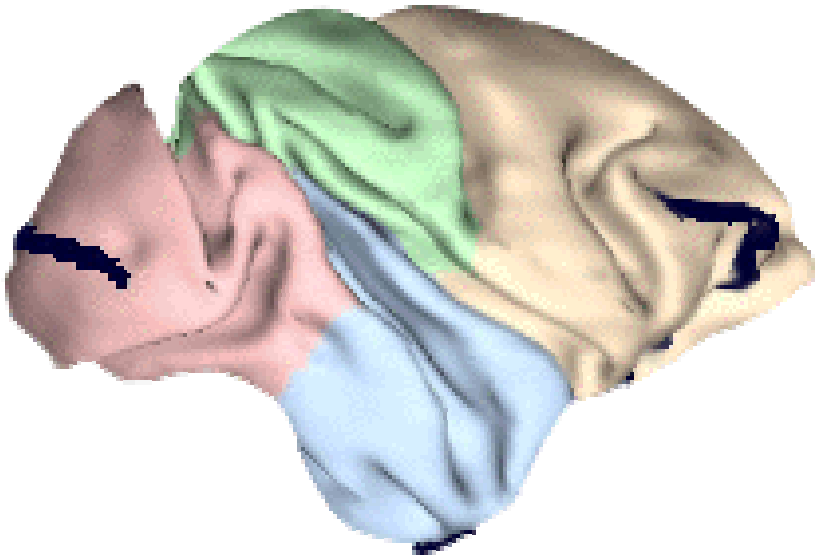
"Flat map" representation

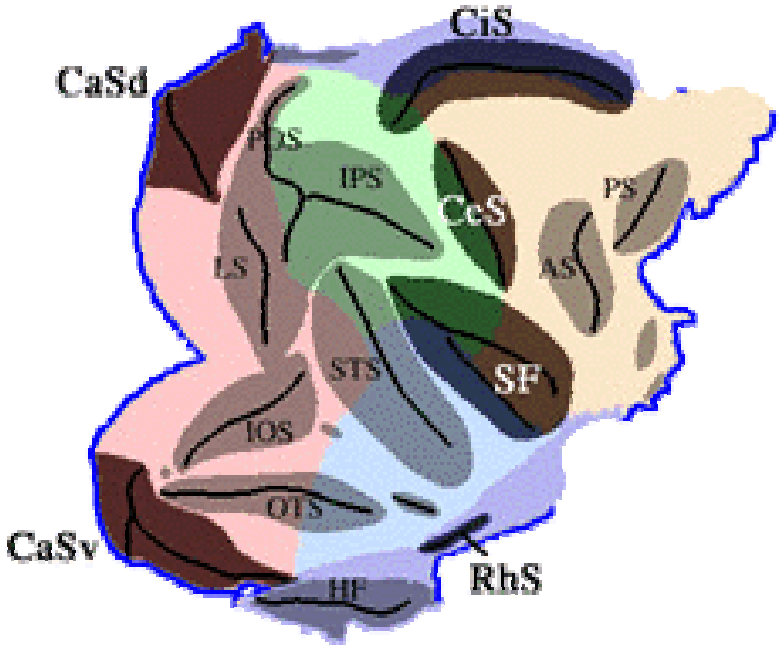
Goal: unfold all circonvolutions in cortex, so that exposed as well as usually unexposed (in sulci) areas are well visible.



Flat Map of Monkey Brain

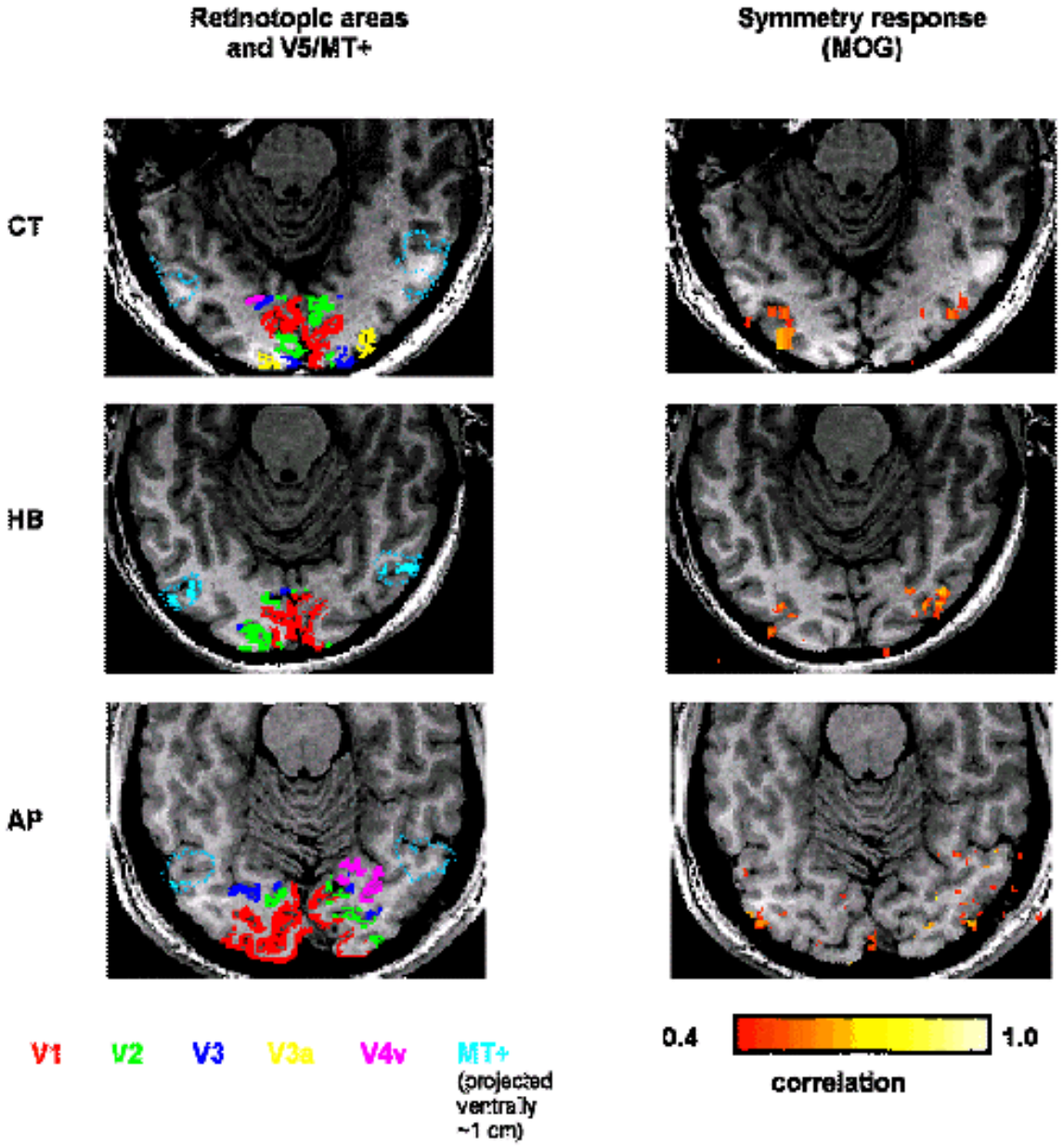
Note how the monkey brain has less developed frontal lobe and fewer circonvolutions (grooves) than human brain.



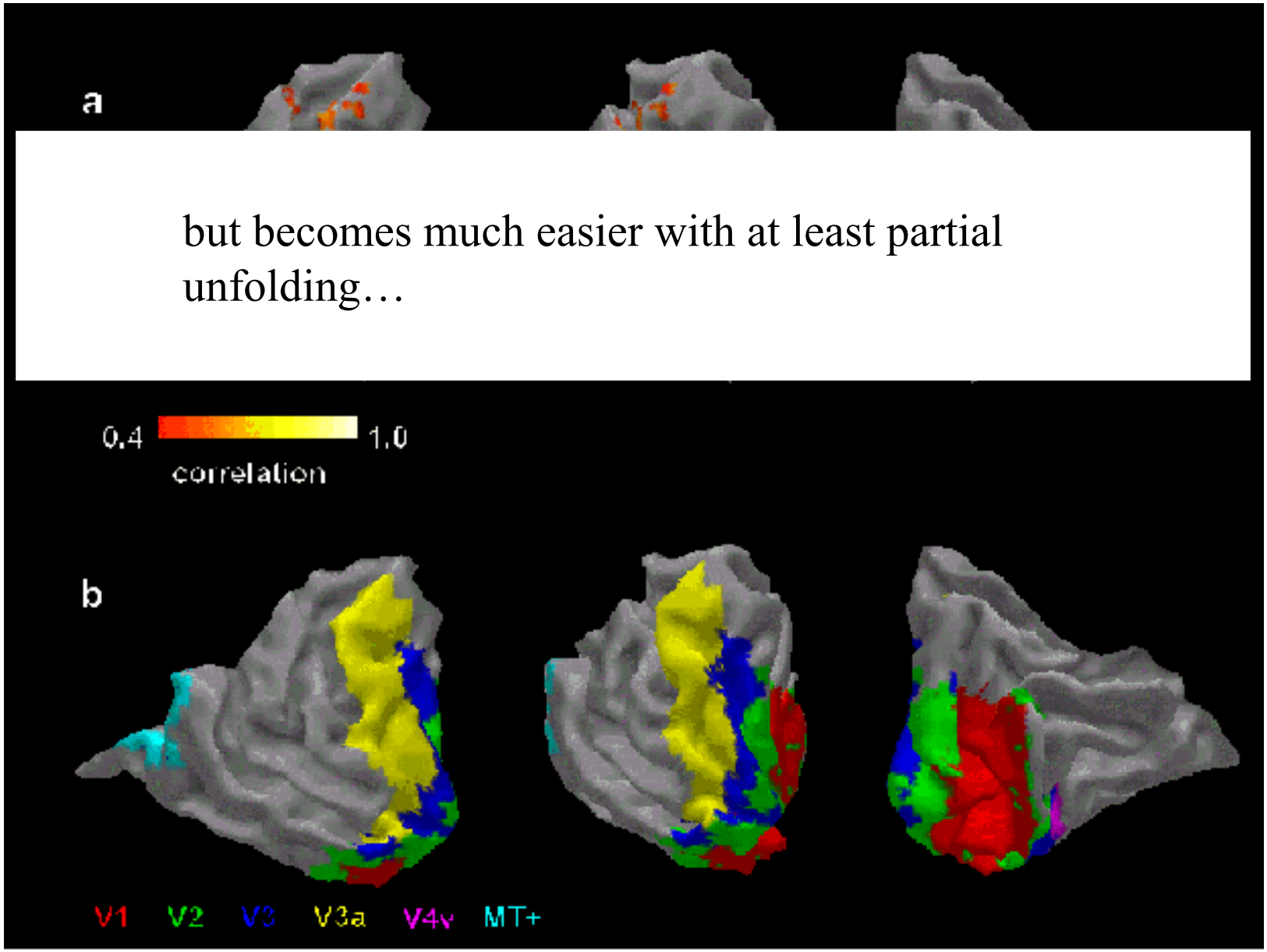


Use of Flat Maps: Visual Cortex Mapping

Brain activity as seen on brain slices is difficult to put together in brain areas…



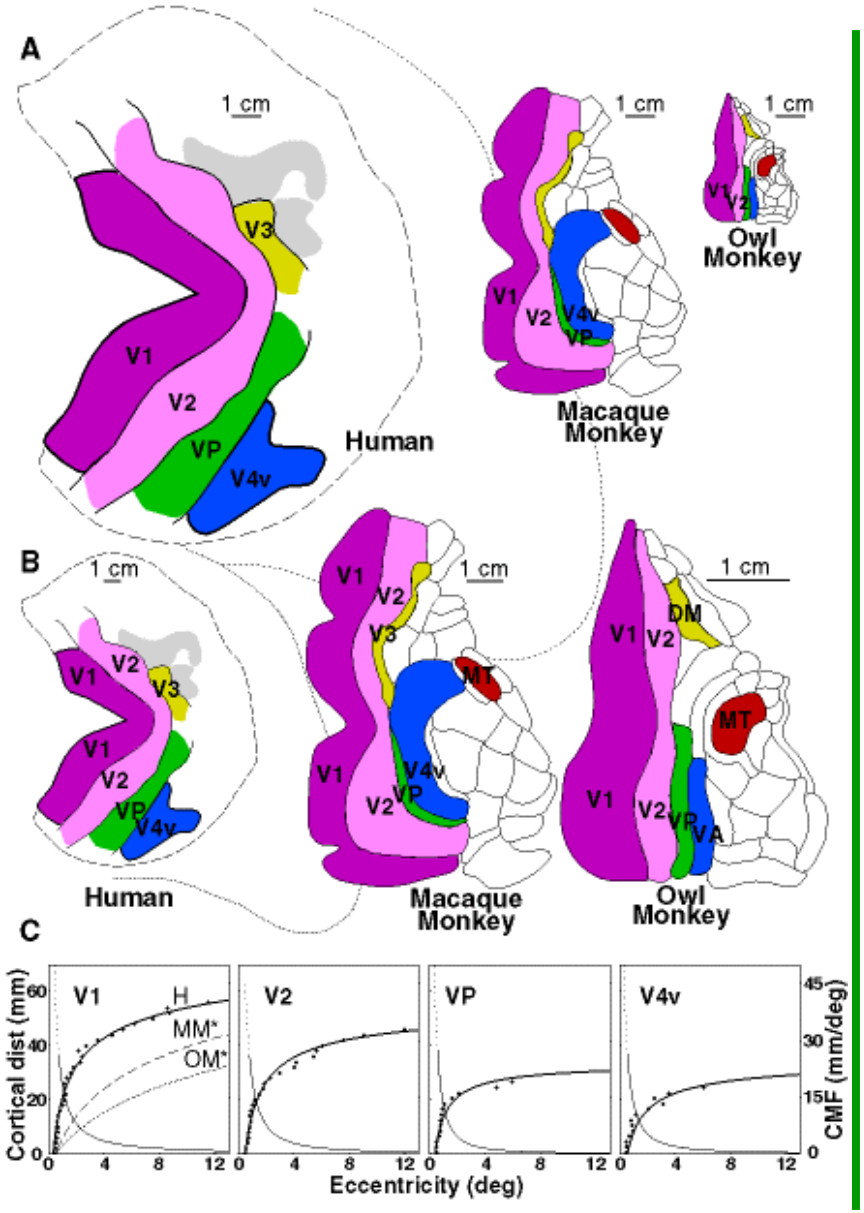
Use of Flat Maps: Visual Cortex Mapping



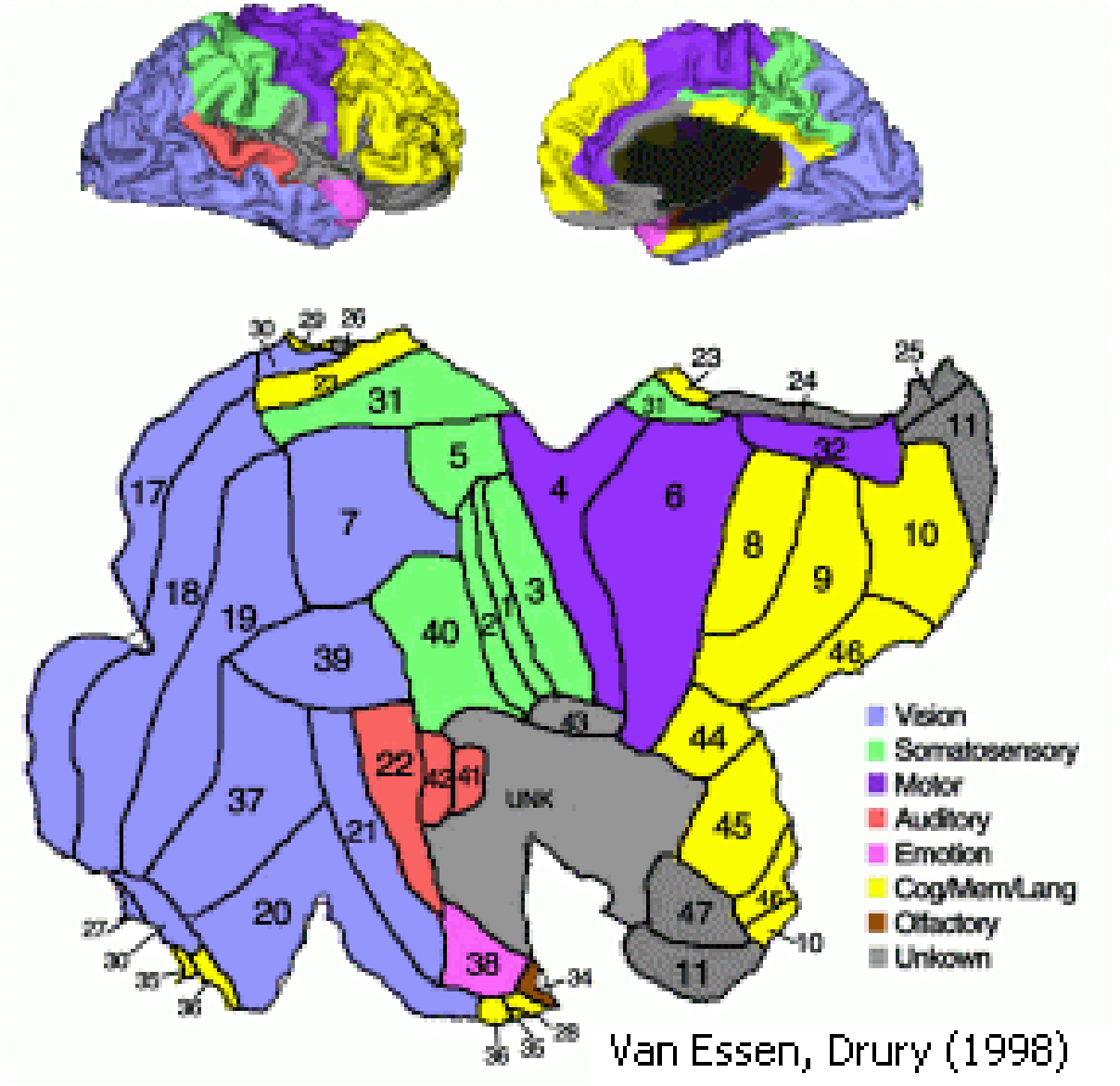
Comparison Across Species

Frontal cortex most developed in humans.

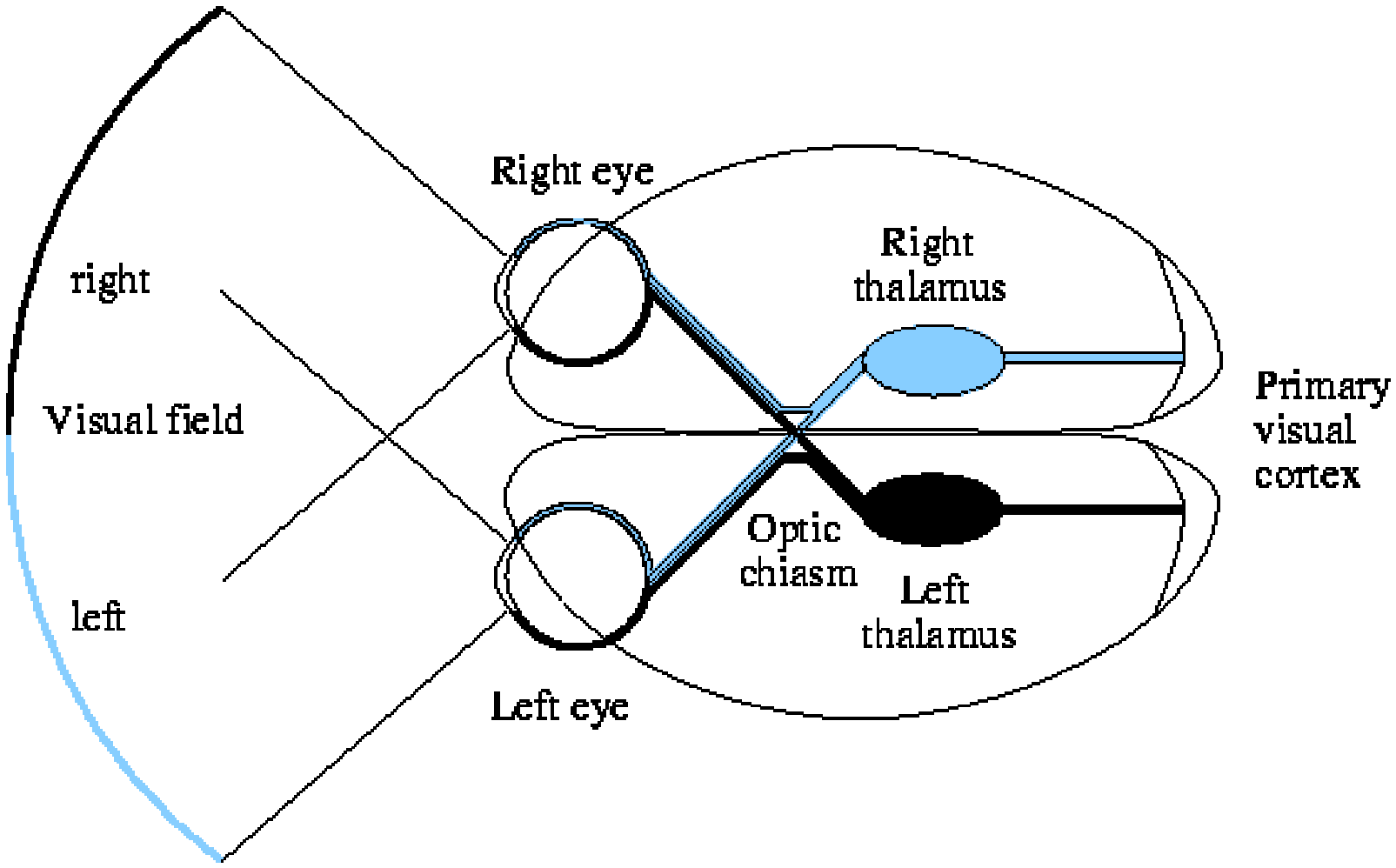
Relatively speaking, association areas (involved with more complex / higher-level processing) are larger in humans, compared to primary (sensory, motor, visual, etc) areas.



Major Functional Areas (other source)

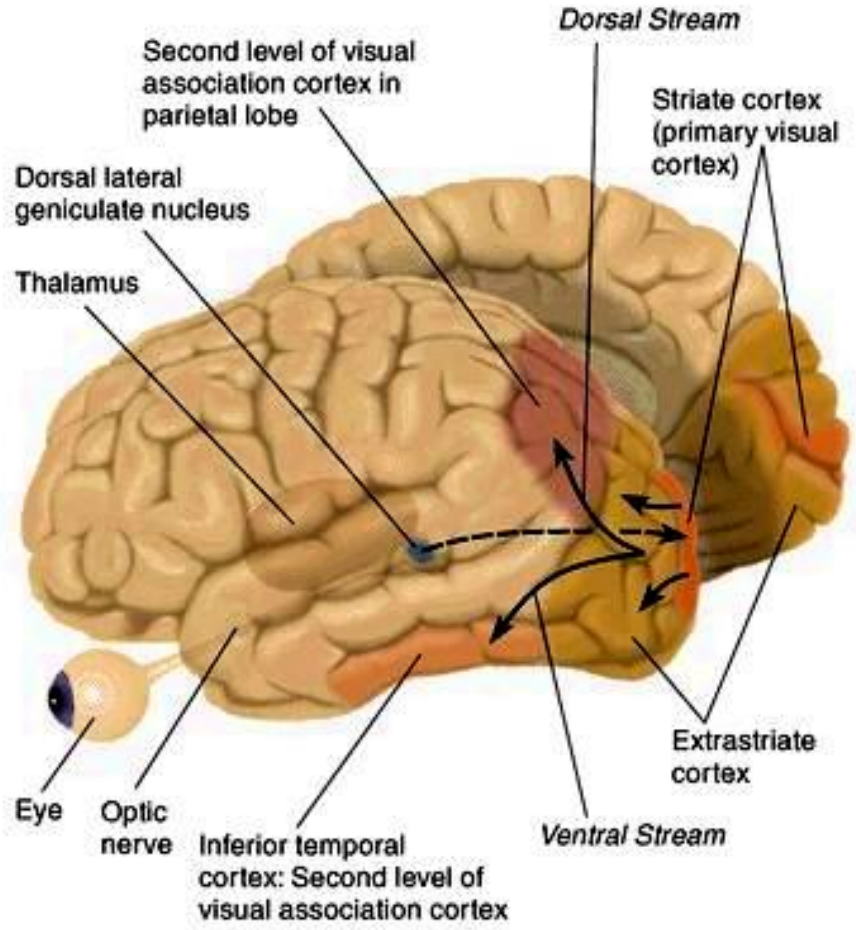


Visual Input to the Brain



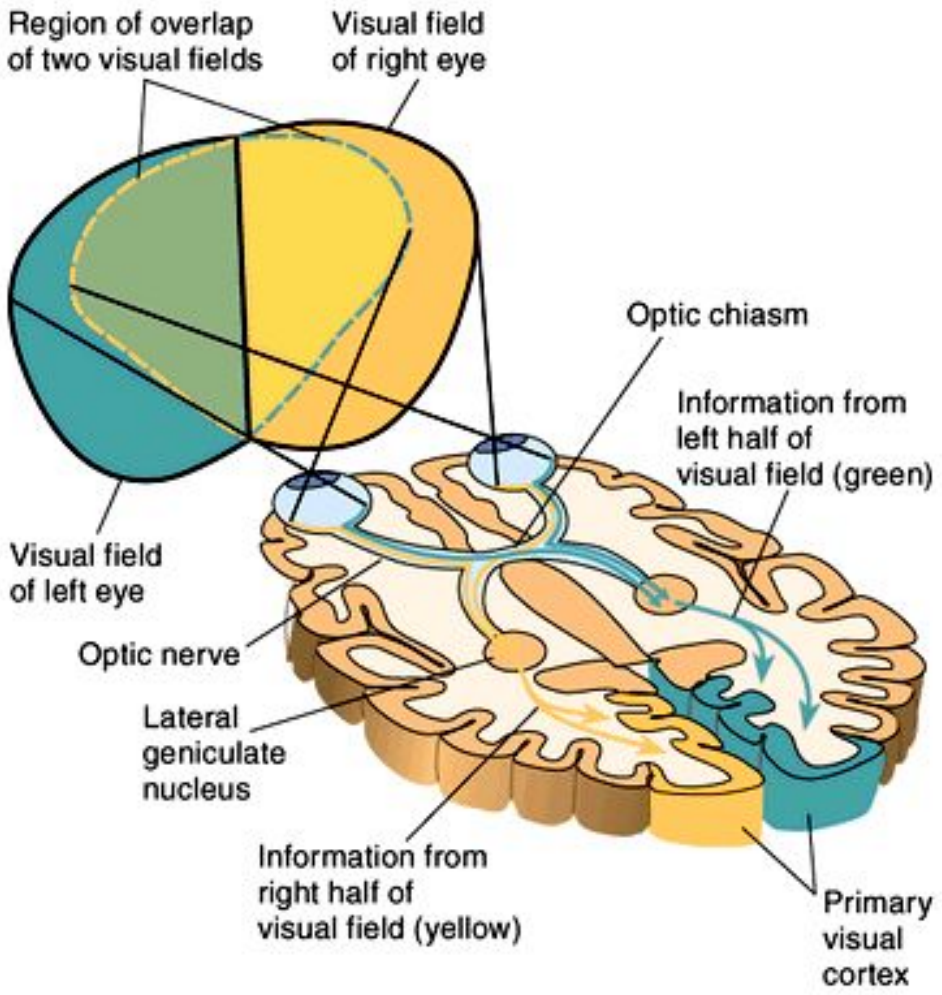
Human Visual System

► The Human Visual System



Primary Visual Pathway

► **The Primary Visual Pathway**

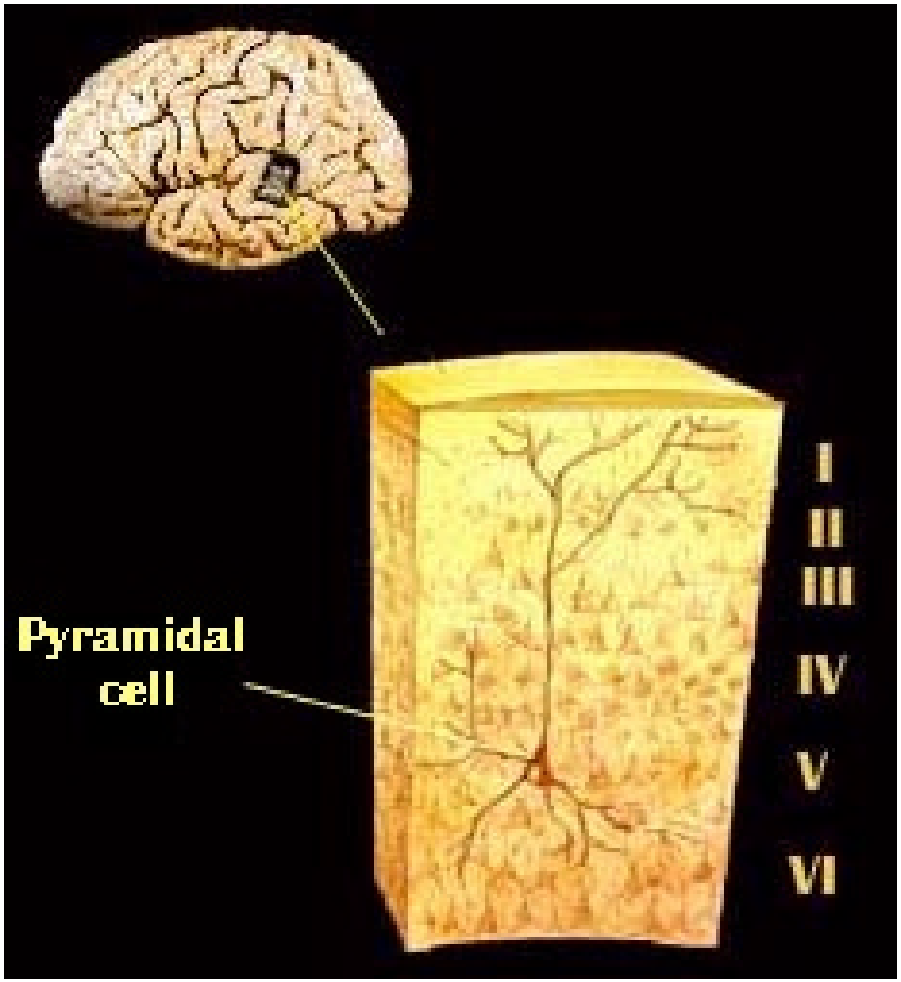


Layered Organization of Cortex

Cortex is 1 to 5mm-thick, folded at the surface of the brain (grey matter), and organized as 6 superimposed layers.

Layer names:

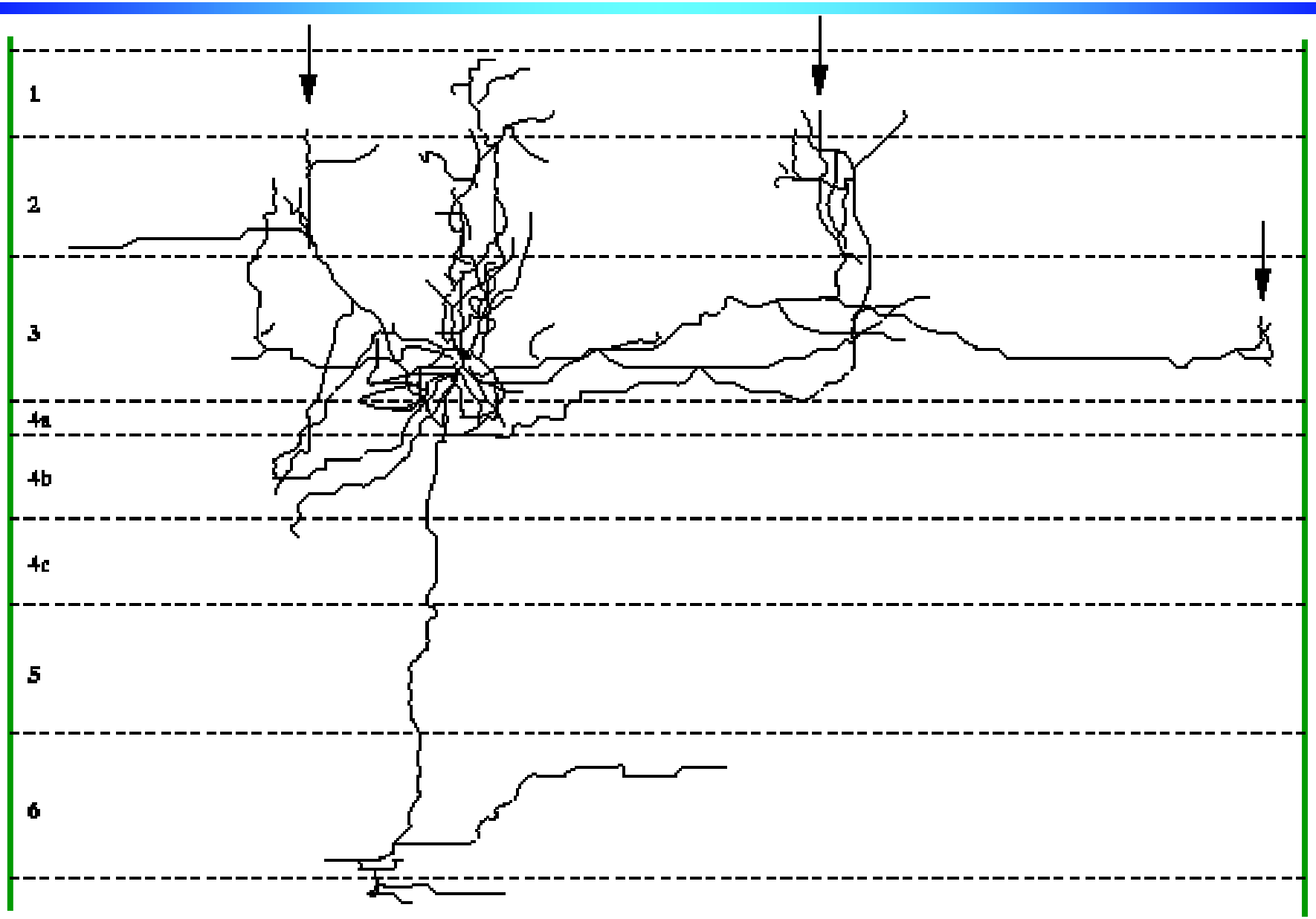
1: Molecular layer
2: External granular layer
3: External pyramidal layer
4: internal granular layer
5: Internal pyramidal layer
6: Fusiform layer



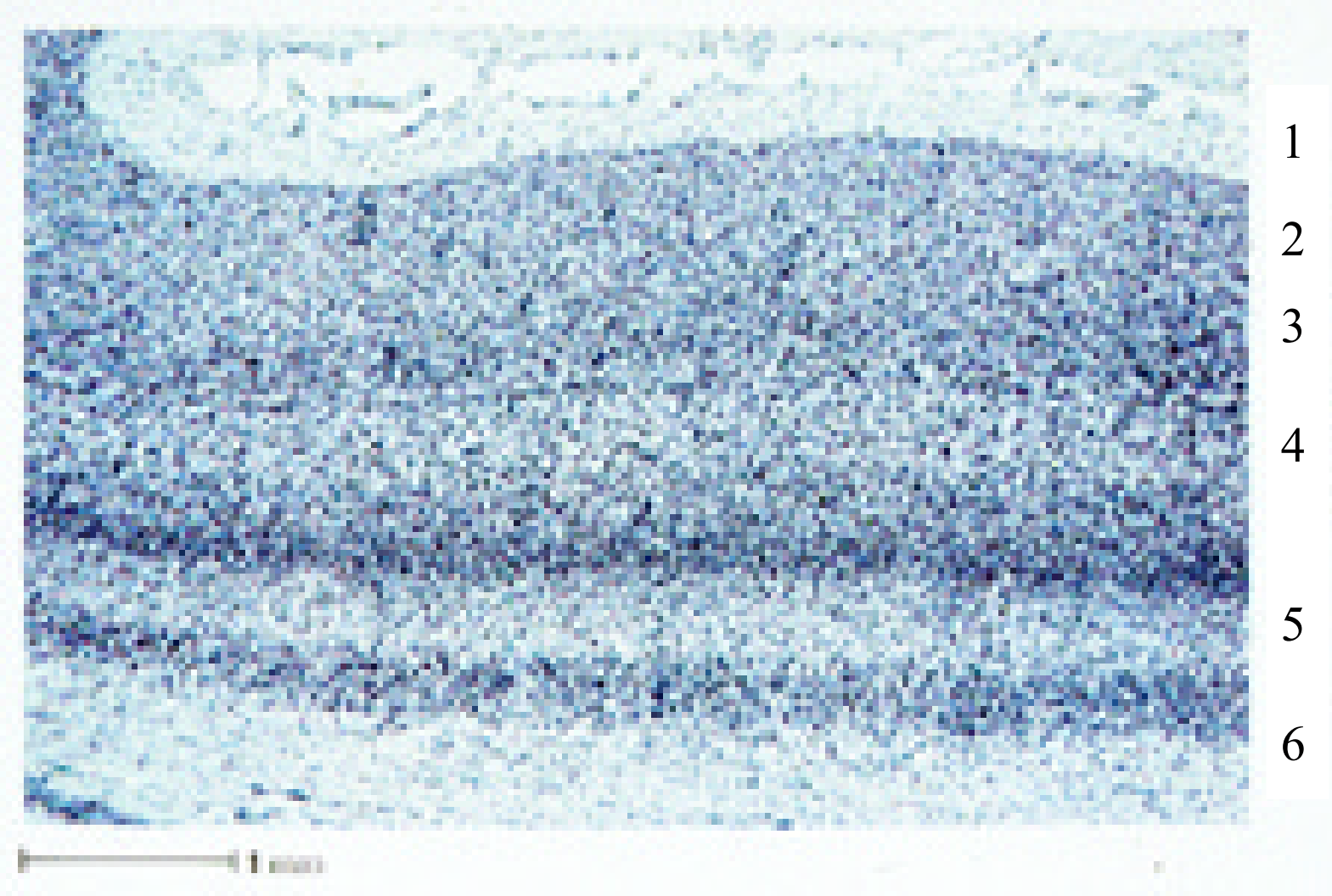
Basic layer functions:

Layers 1/2: connectivity
Layer 4: Input
Layers 3/5: Pyramidal cell bodies
Layers 5/6: Output

Layered Organization of Cortex

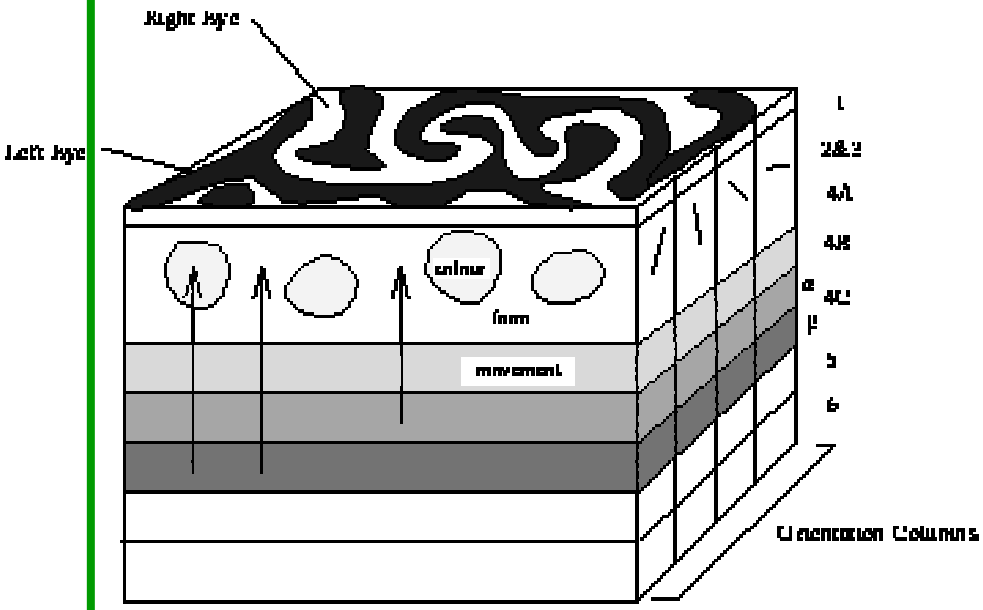


Slice through the thickness of cortex

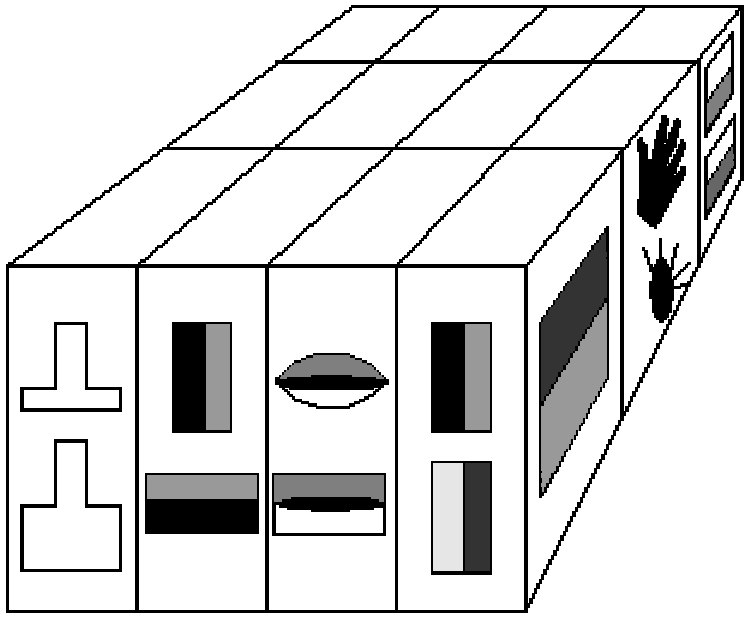


Columnar Organization

Very general principle in cortex: neurons processing similar "things" are grouped together in small patches, or "columns," or cortex.



In primary visual cortex…



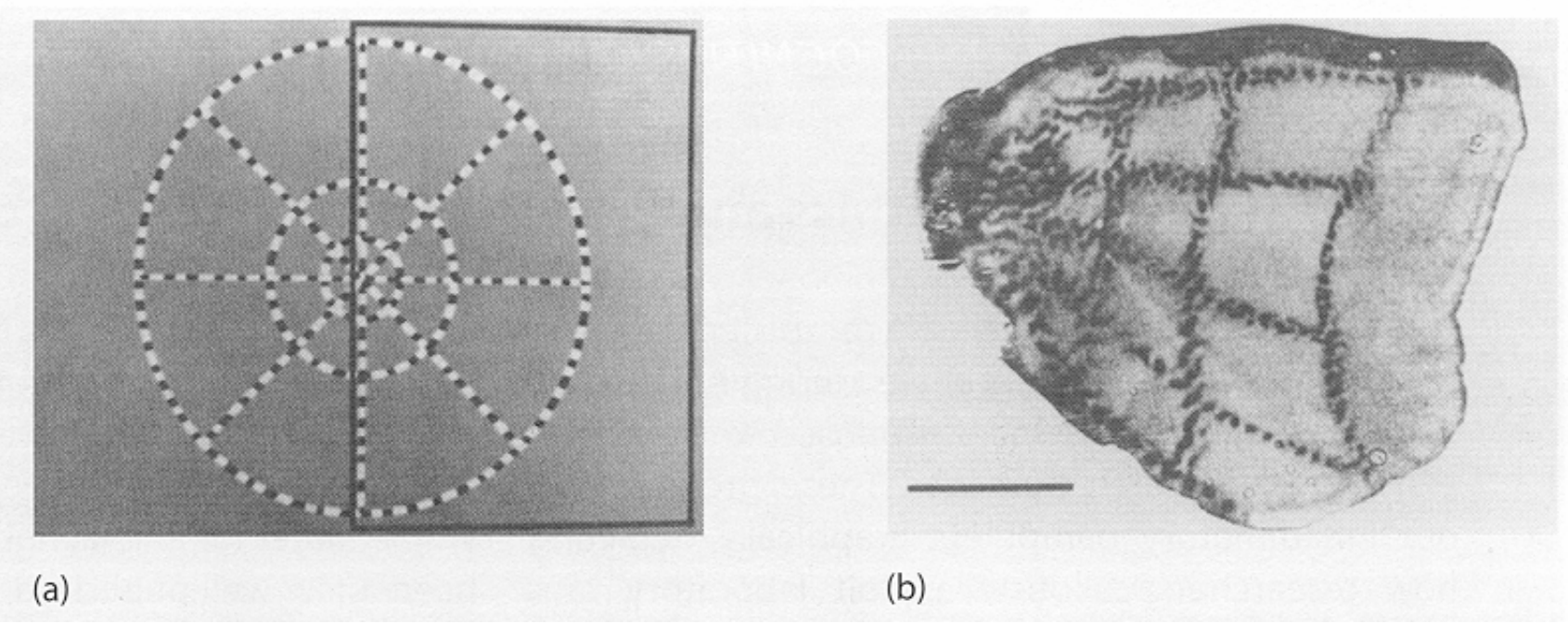
as in higher (object recognition) visual areas…

and in many, non-visual, areas as well (e.g., auditory, motor, sensory, etc).

Retinotopy

Many visual areas are organized as **retinotopic** maps: locations next to each other in the outside world are represented by neurons close to each other in cortex.

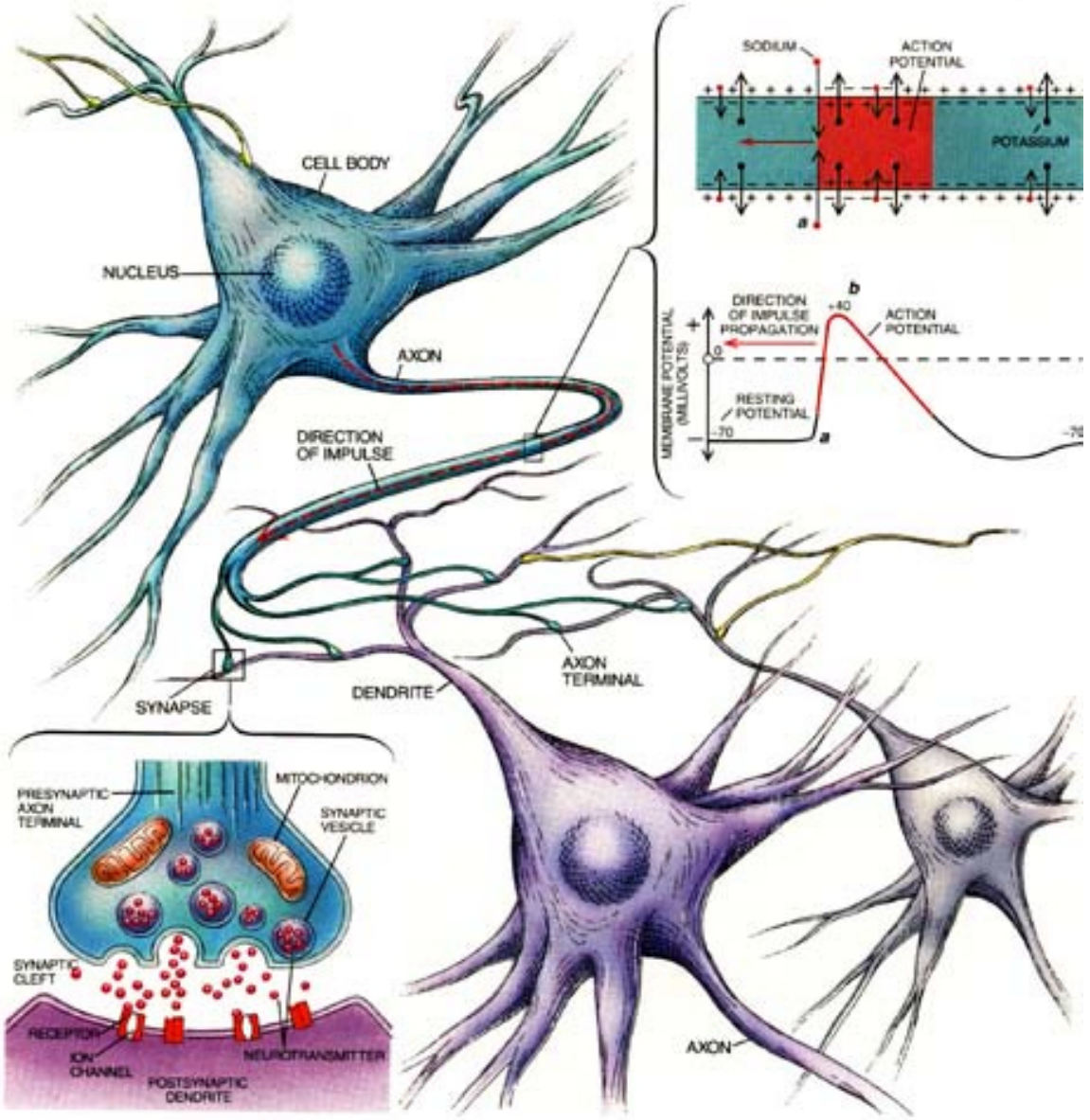
Although the **topology** is thus preserved, the mapping typically is **highly non-linear** (yielding large deformations in representation).



Stimulus shown on screen…

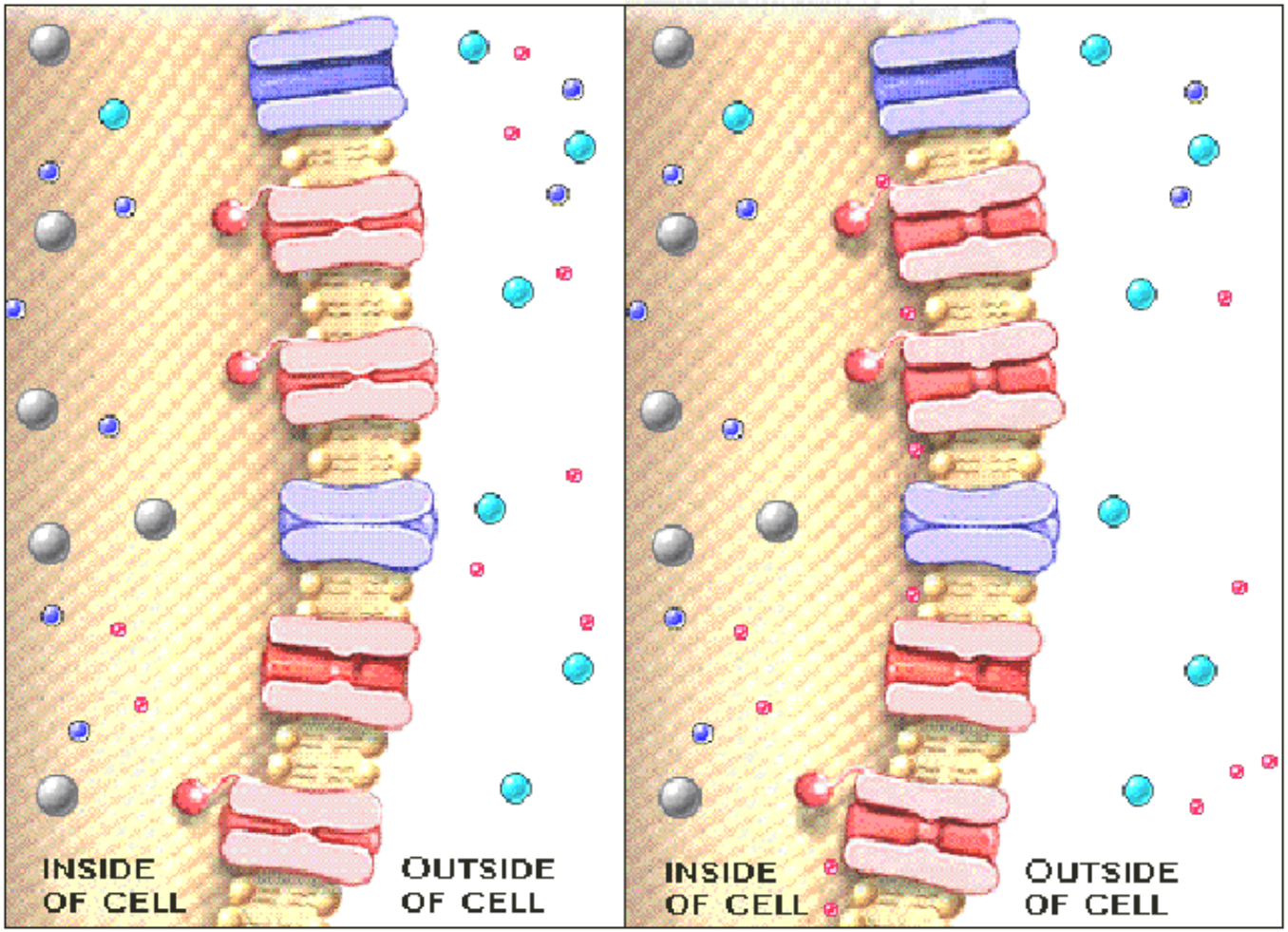
and corresponding activity in cortex!

Neurons and Synapses



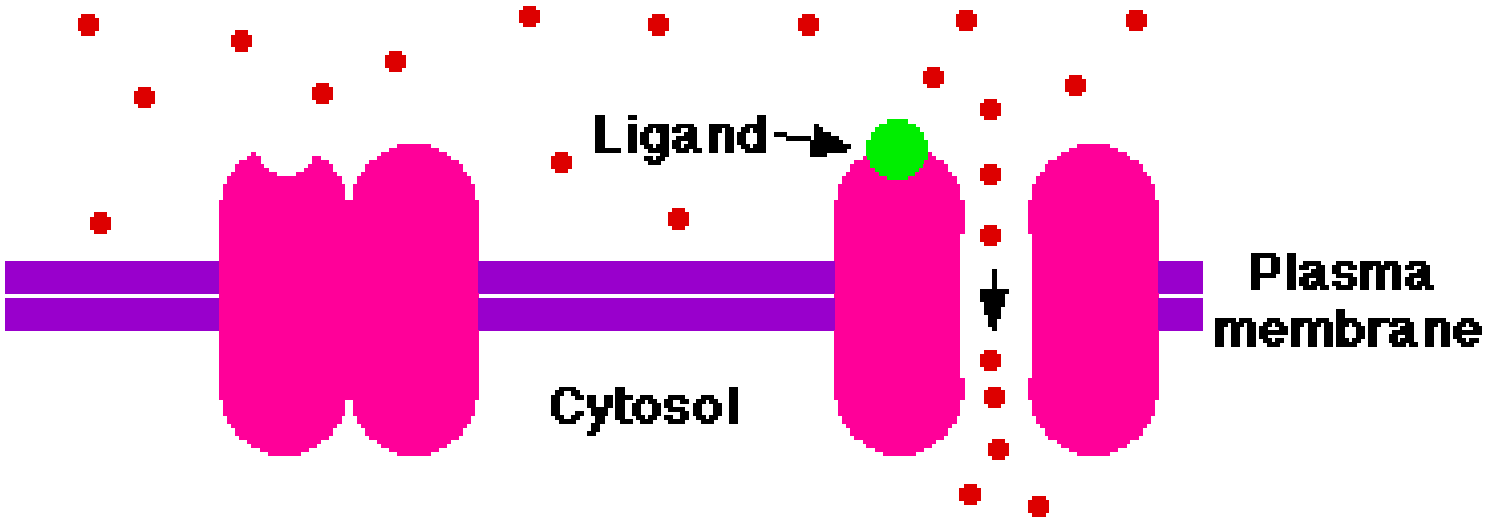
Transmenbrane Ionic Transport

Ion channels act as gates that allow or block the flow of specific ions into and out of the cell.



Gated Channels

A given chemical (e.g., neurotransmitter) acts as ligand and gates the opening of the channel by binding to a receptor site on the channel.

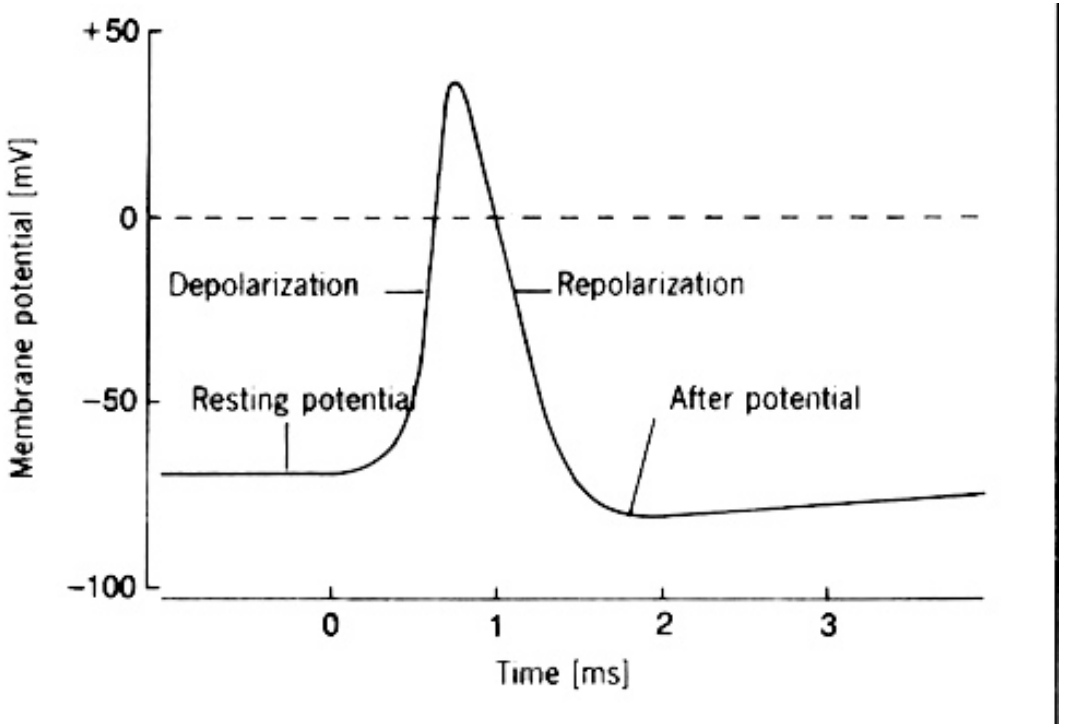


Facilitated diffusion through a ligand-gated channel

Action Potential

At rest, the inside of the cell rests at a **negative potential** (compared to surroundings)

Action potential consists of a brief "**depolarization**" (negative rest potential decreases to zero) followed by "**repolarization**" (inside of membrane goes back to negative rest potential), with a slight "**hyperpolarization**" overshoot before reaching rest.

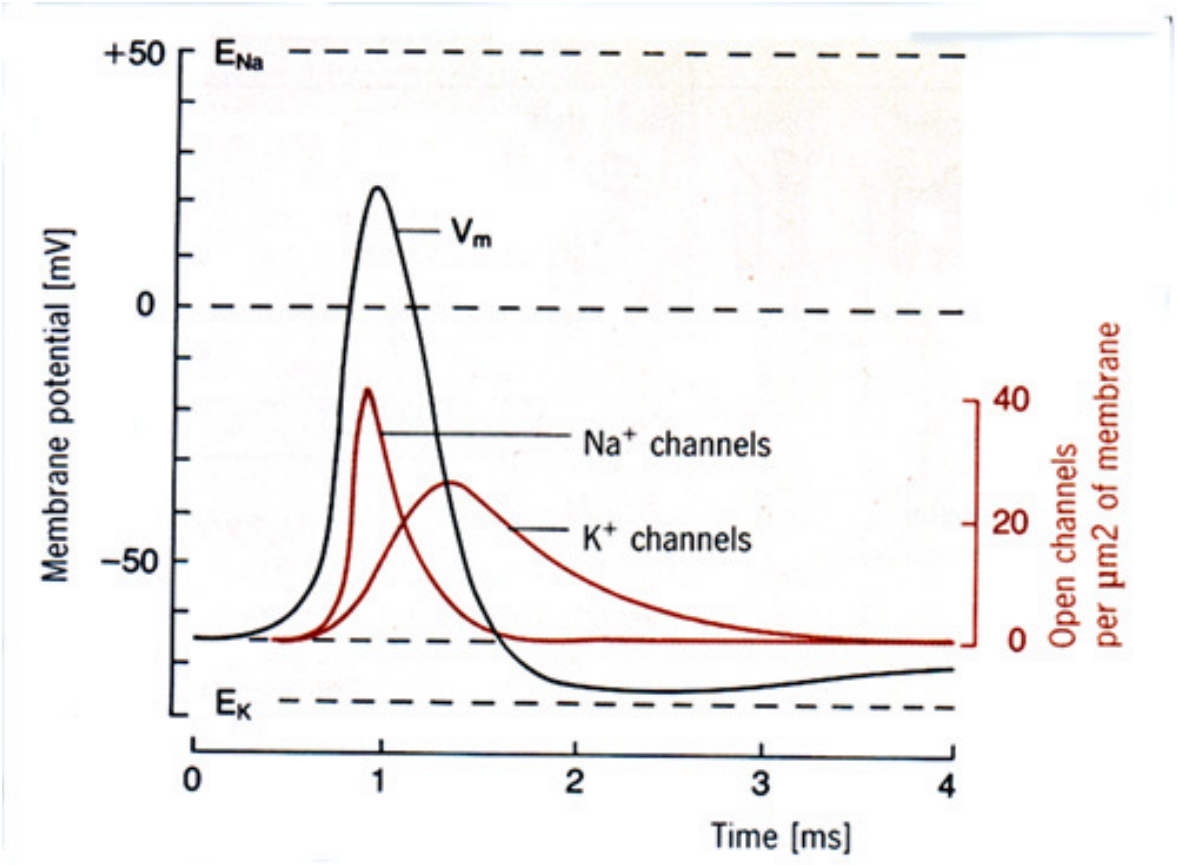


Action Potential and Ion Channels

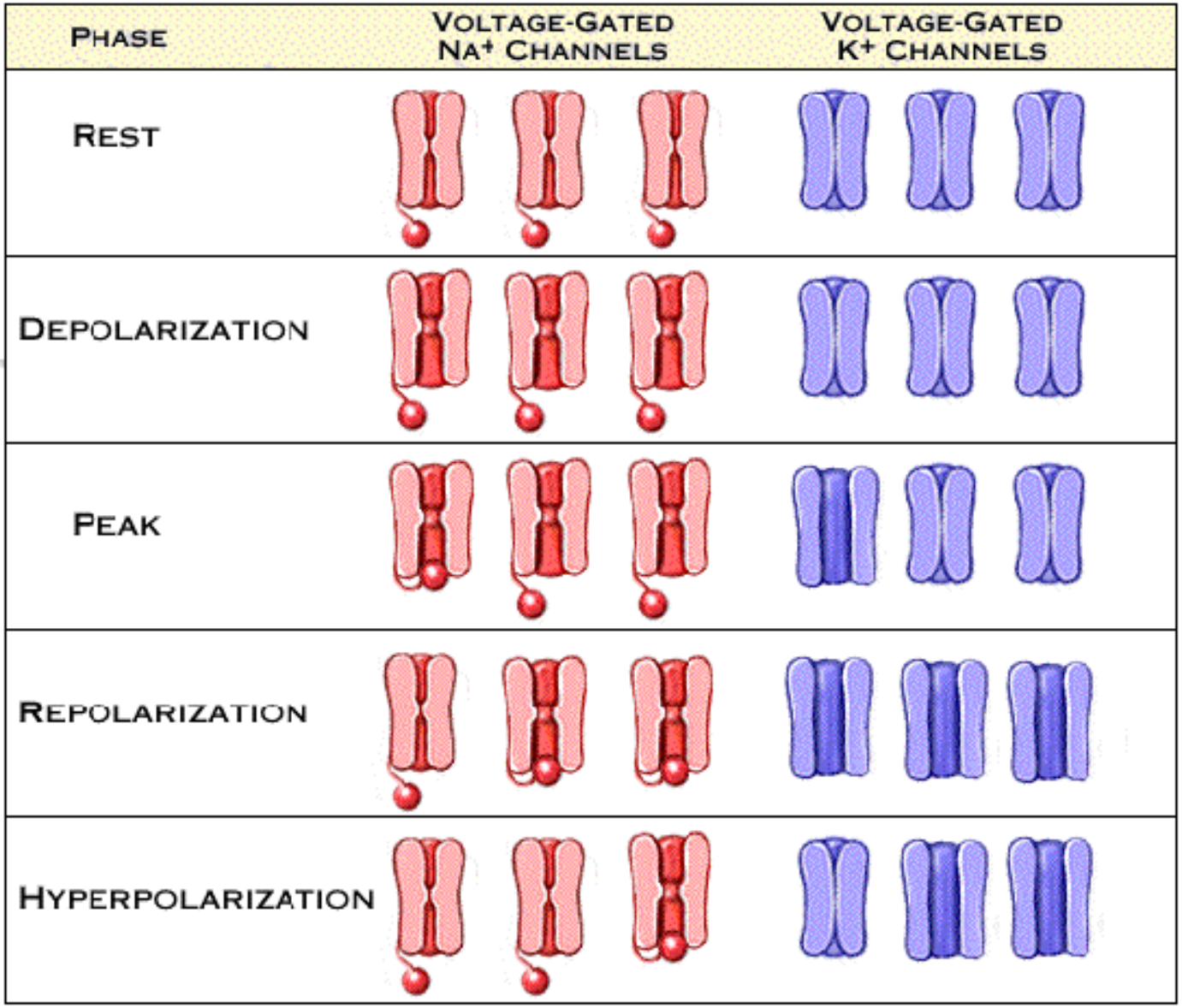
Initial depolarization is due to opening of **sodium (Na+) channels**

Repolarization is due to opening of **potassium (K+) channels**

Hyperpolarization happens because K+ channels stay open longer than Na+ channels (and longer than necessary to exactly come back to resting potential).



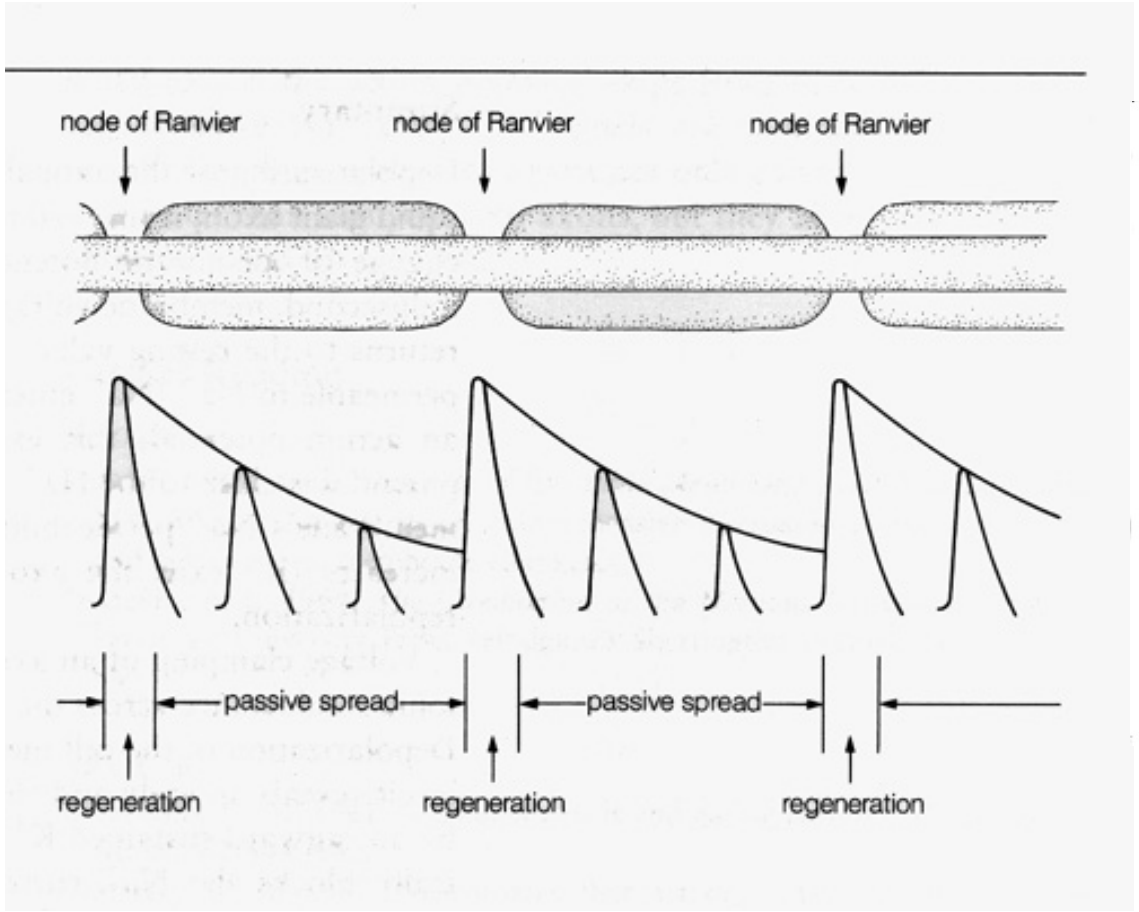
Channel activations during action potential

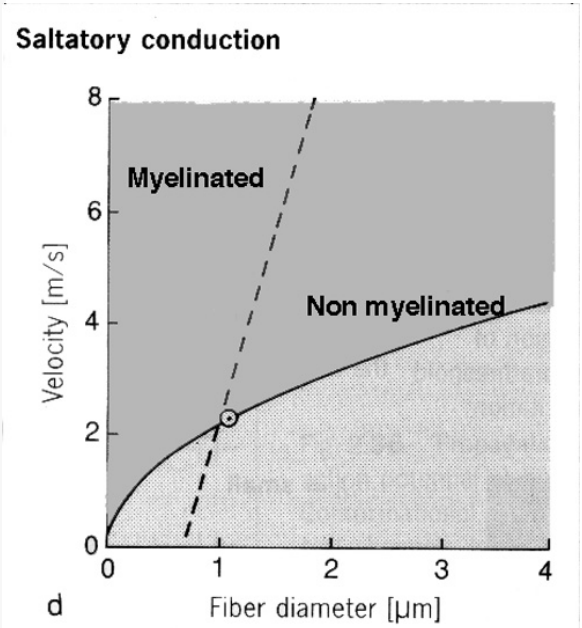


Saltatory Conduction along Myelinated Axons

Schwann cells wrap around axons, yielding an insulating **myelin** sheet except at regularly spaces locations (nodes of Ranvier).

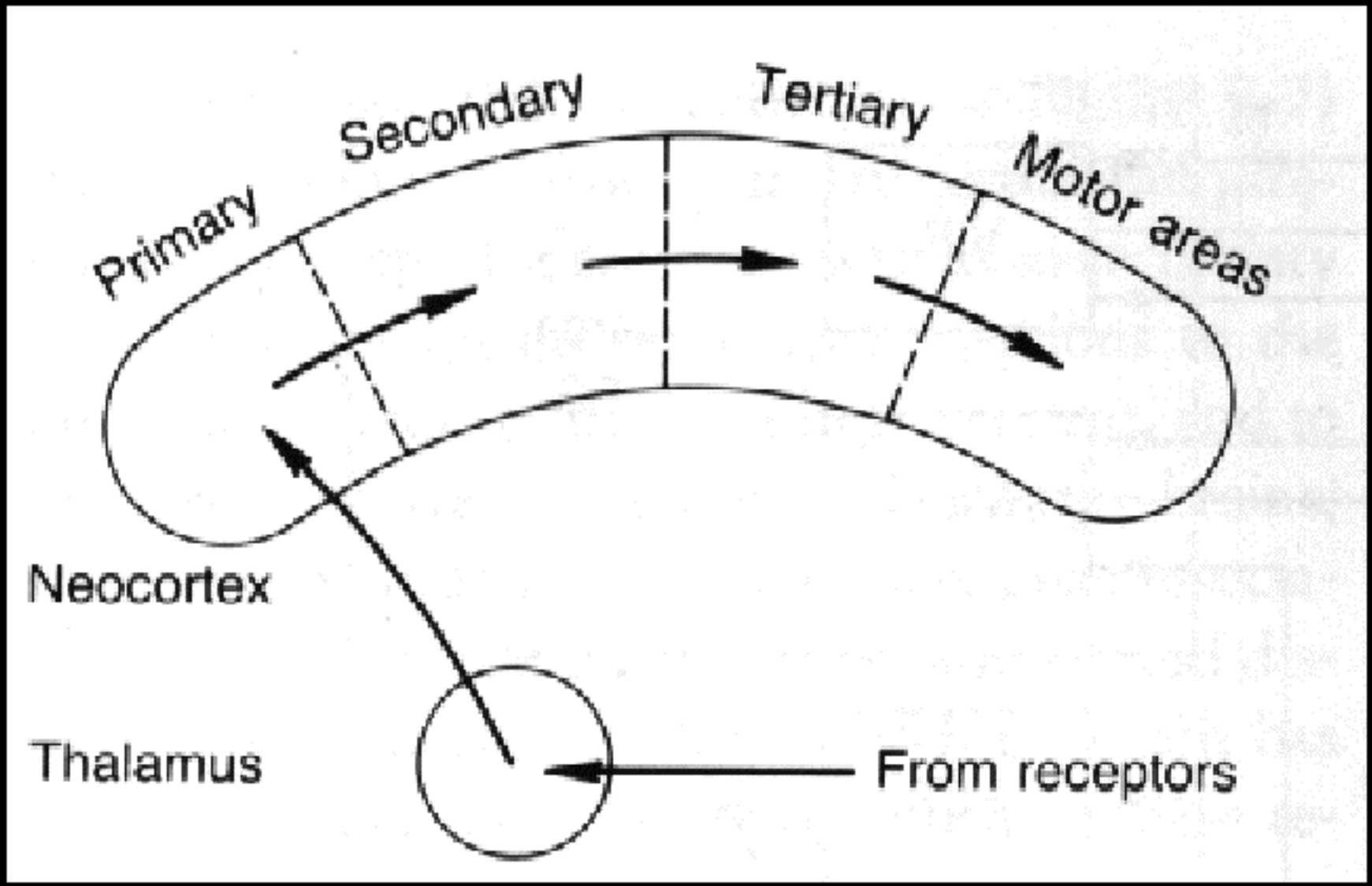
Provides much faster conduction of action potentials.





Serial Processing

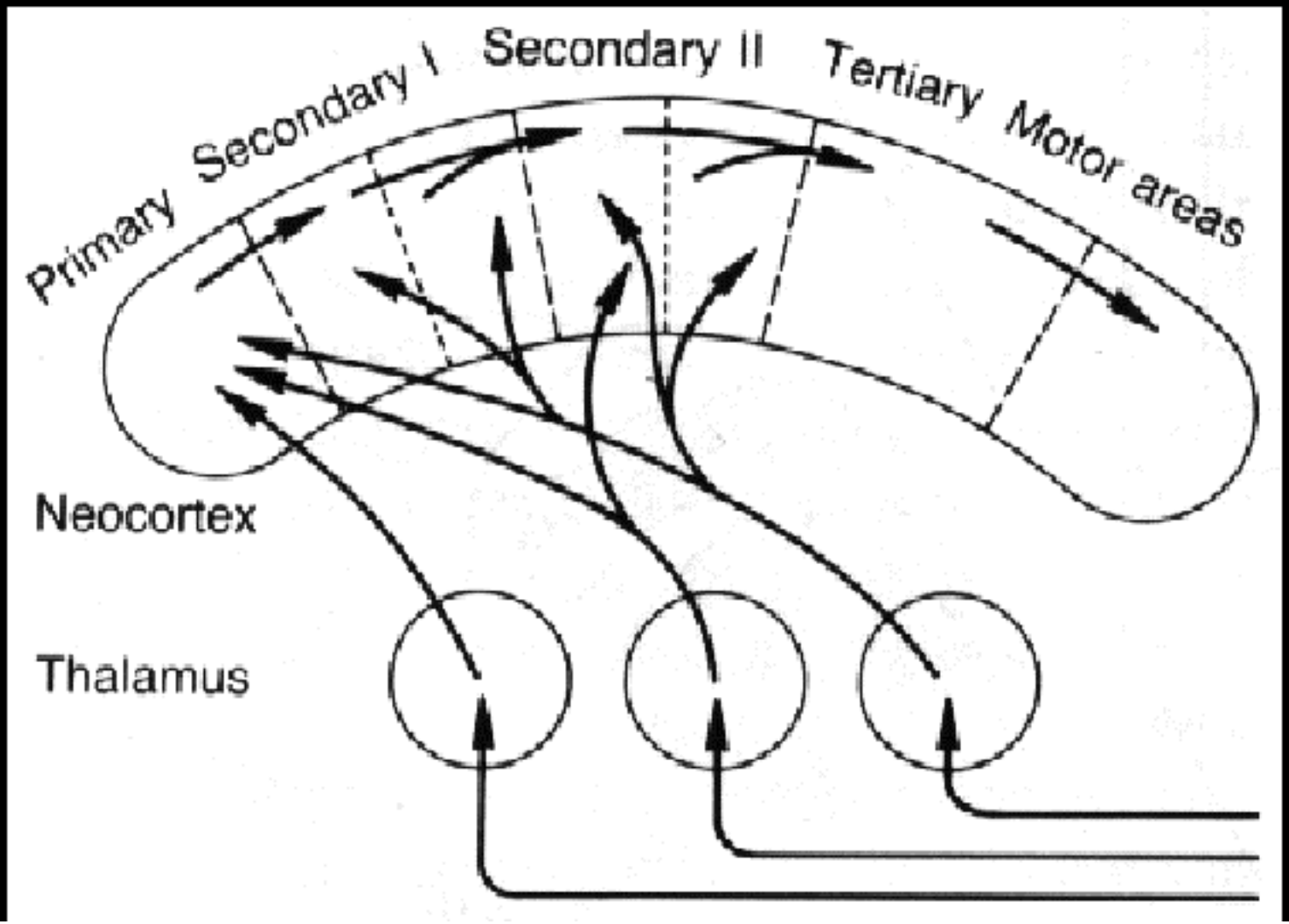
Relay stations



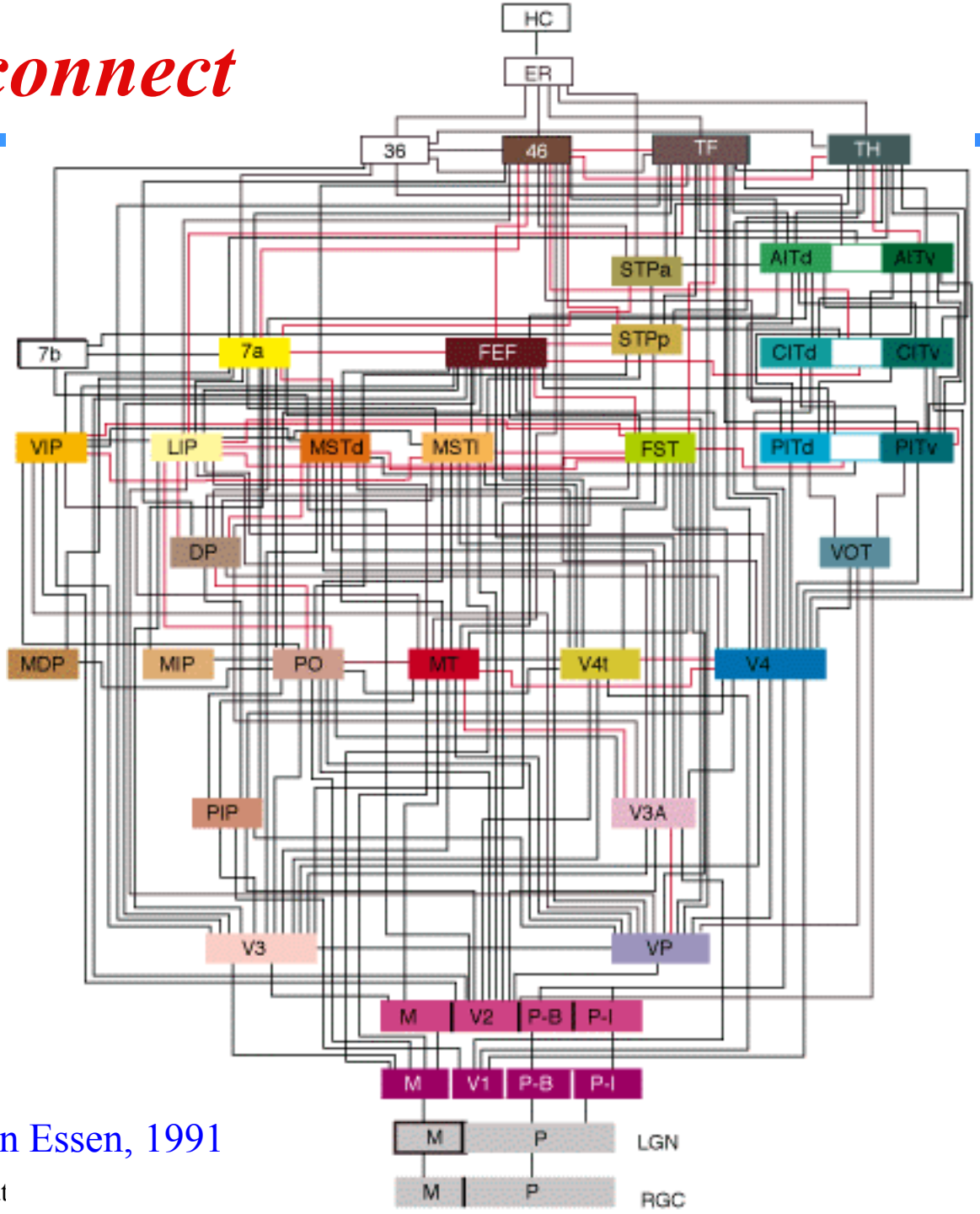
Parallel Processing

multiple routes to cortex

1) geniculostriate and tectopulvinar systems

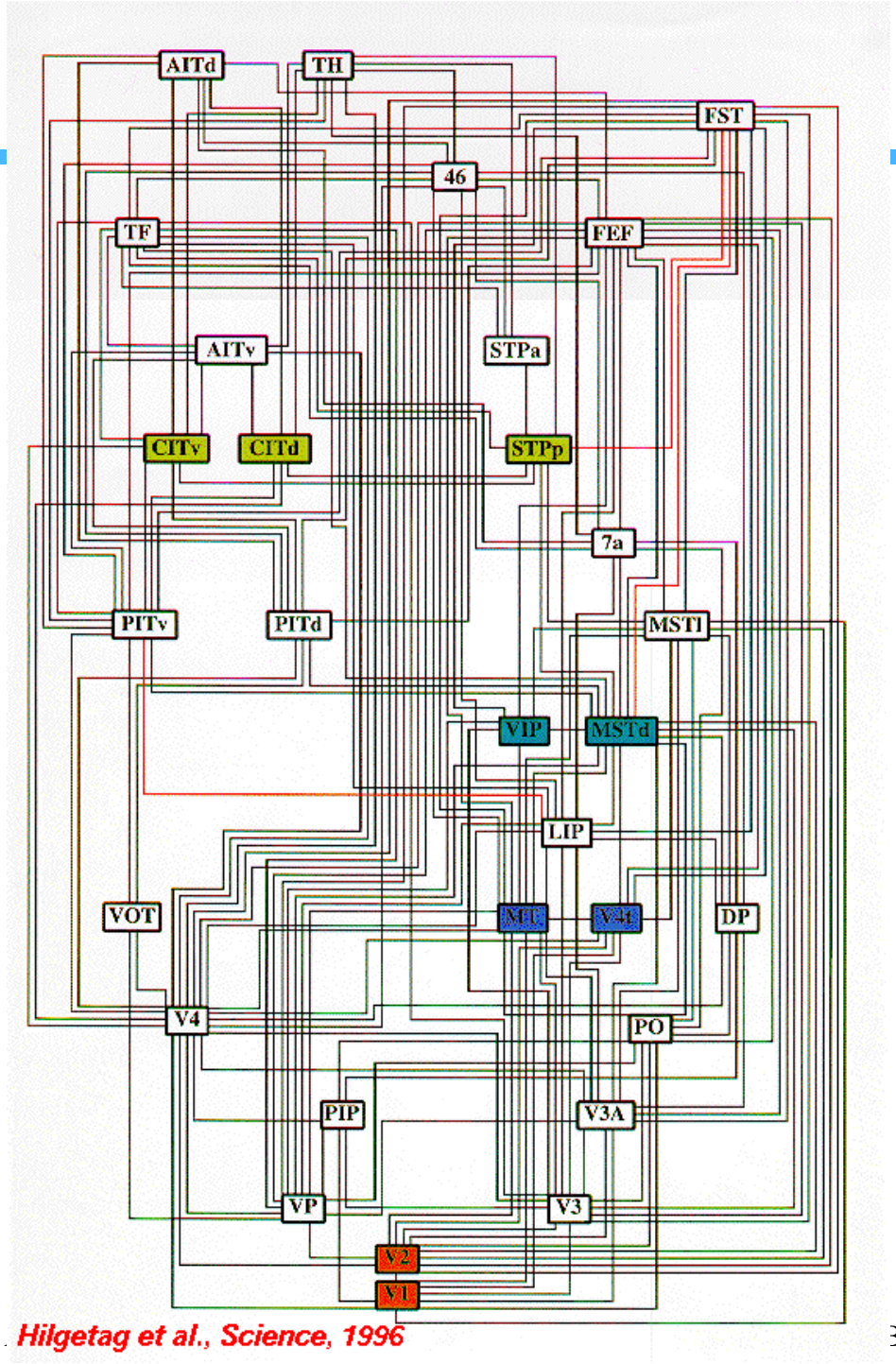


Interconnect



Felleman & Van Essen, 1991

Interconnect… *(other source)*



Hilgetag et al., Science, 1996

More on Connectivity