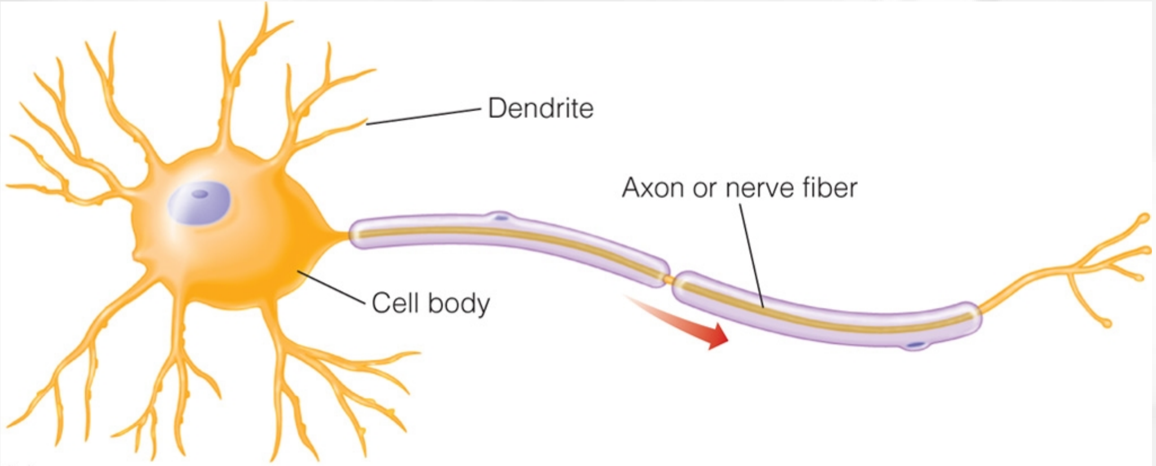
Neural Basis of Cognition

- Brain is important for cognition
- To understand cognition, it might help to understand the brain
- Today: brain structure and methods

Building Blocks of the Nervous System

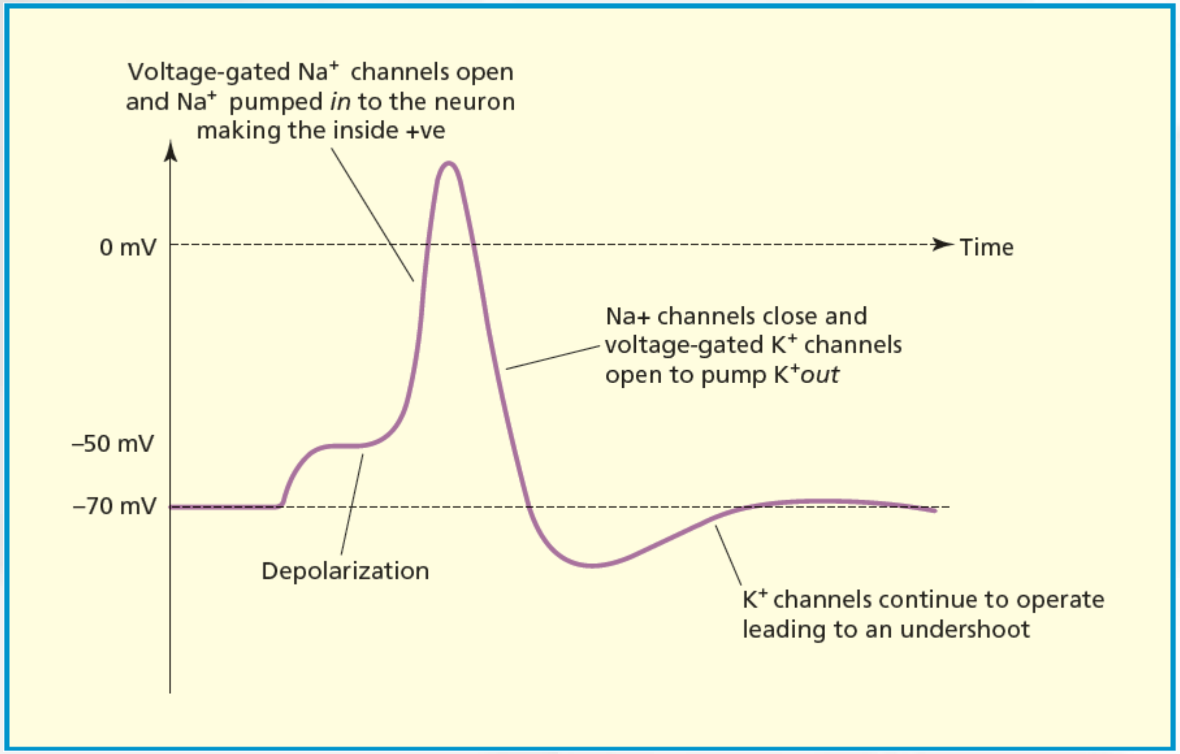
- Neurons: cells specialized to receive and transmit information in the nervous system
- Each neuron has a cell body, an axon, and dendrites



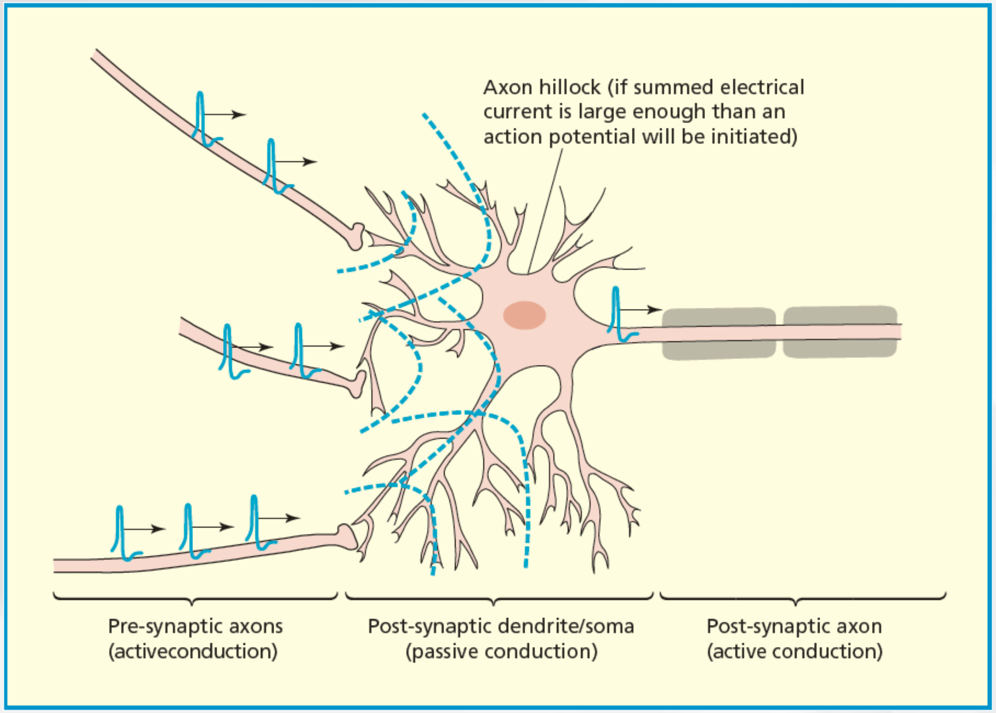
Neuron Factoids

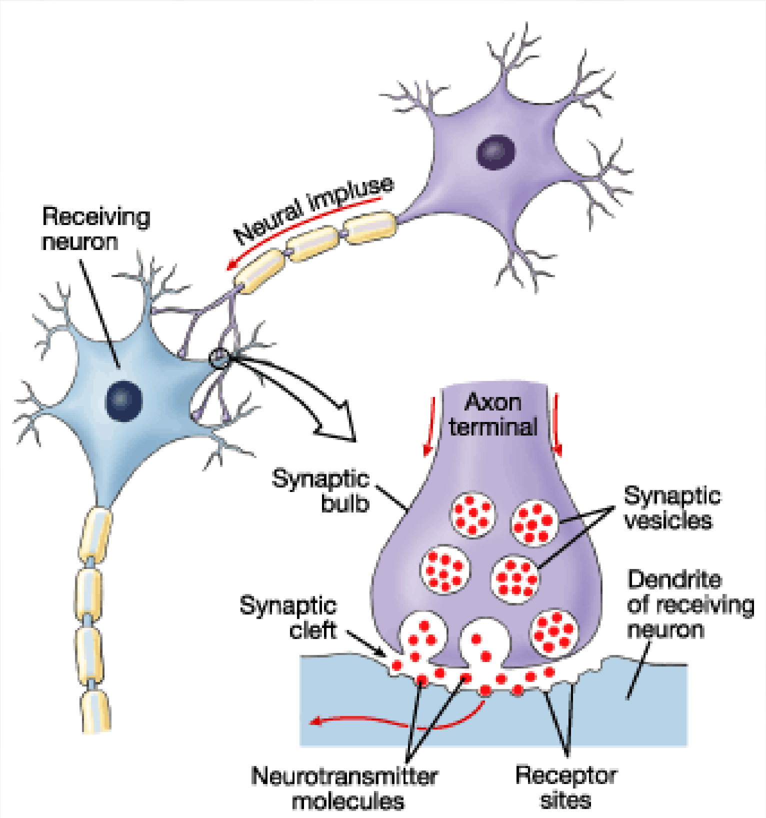
- Human brain has about 100 billion neurons
- Each neuron may connect with 10,000 other ones
- If all neurons connected, our brains would need to be 12.5 miles in diameter
- Neurons make up only 10% of brain cells (glia are the rest)
- We lose one cortical neuron per second
- Men have larger brains, more intrahemispheric connections
- Women have more folded brains, more interhemispheric connections

Neural Signals: Action Potential



How Neurons Communicate



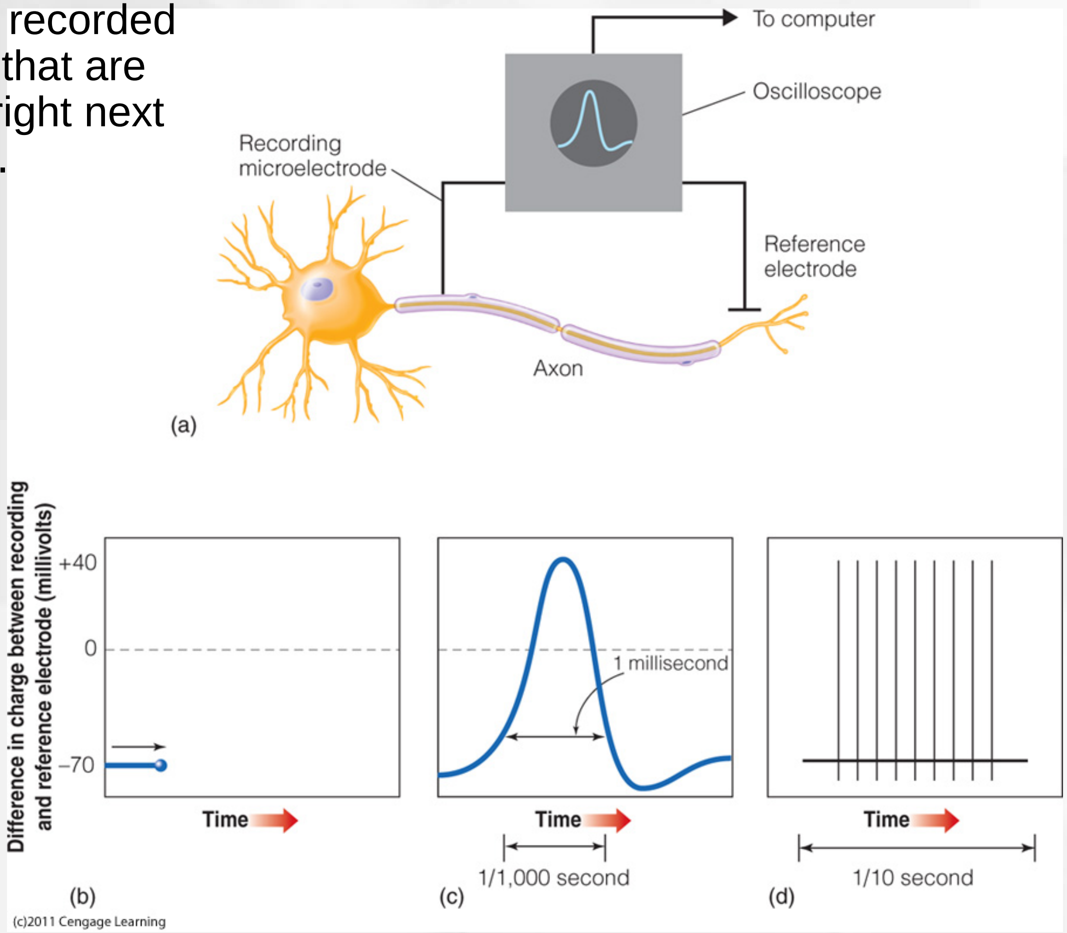


Neurotransmitters can be

- Excitatory: increases chance neuron will fire
- Inhibitory: decreases chance neuron will fire

Single-Cell Recording

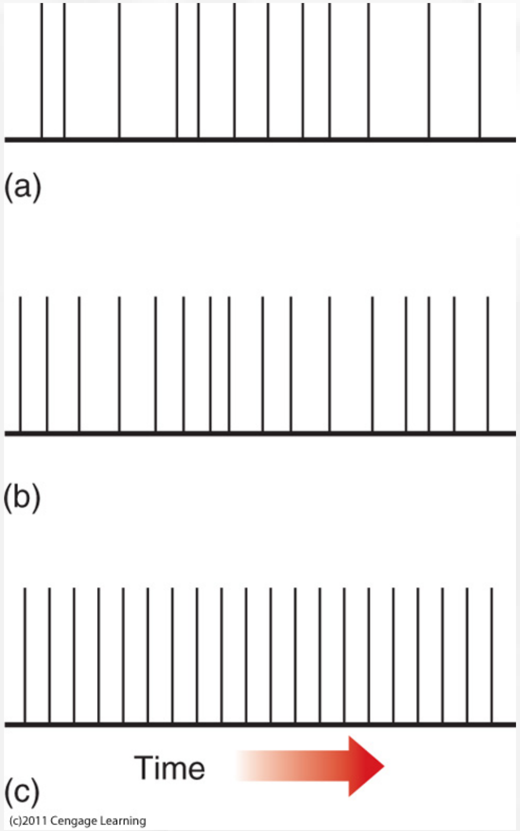
Action potentials are recorded tiny microelectrodes that are positioned inside or right next to the neuron's axon.



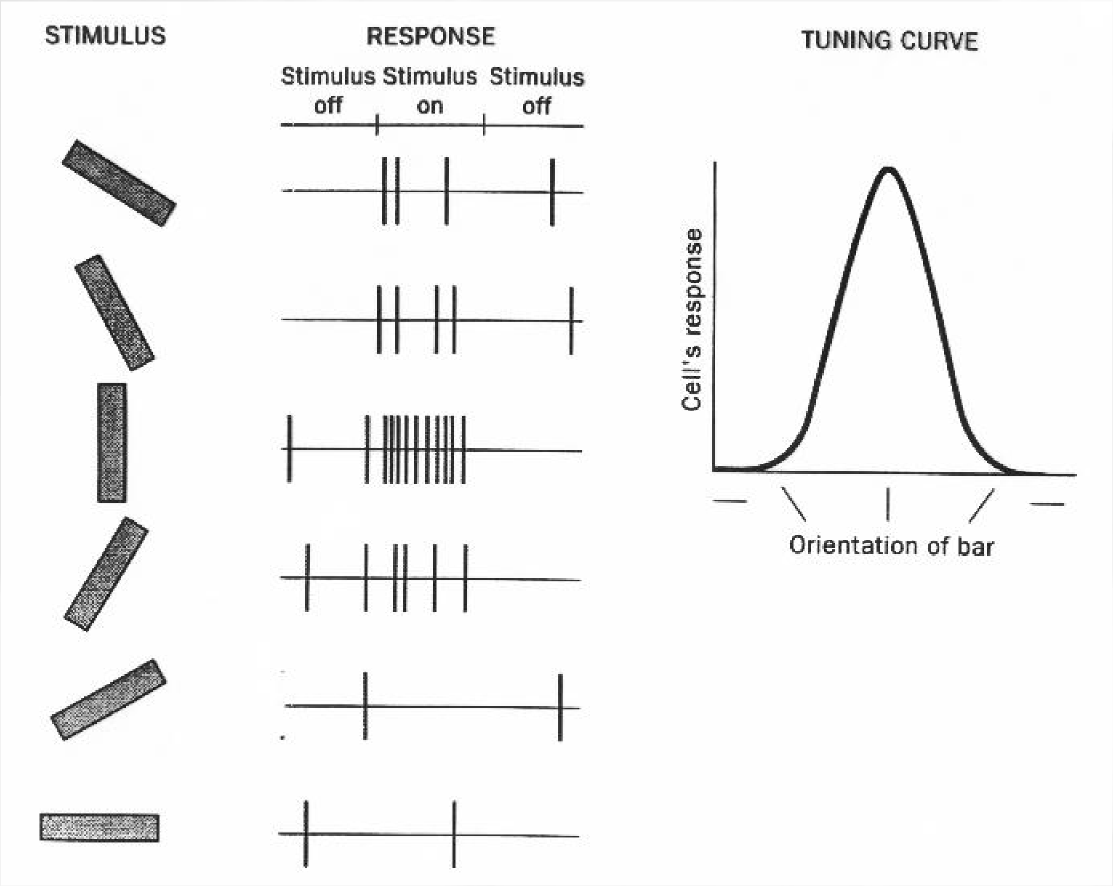
Neural spike (action potential) train

Neural Information Coding

- Amplitude of an action potential does not vary
- AP frequency (rate) = signal

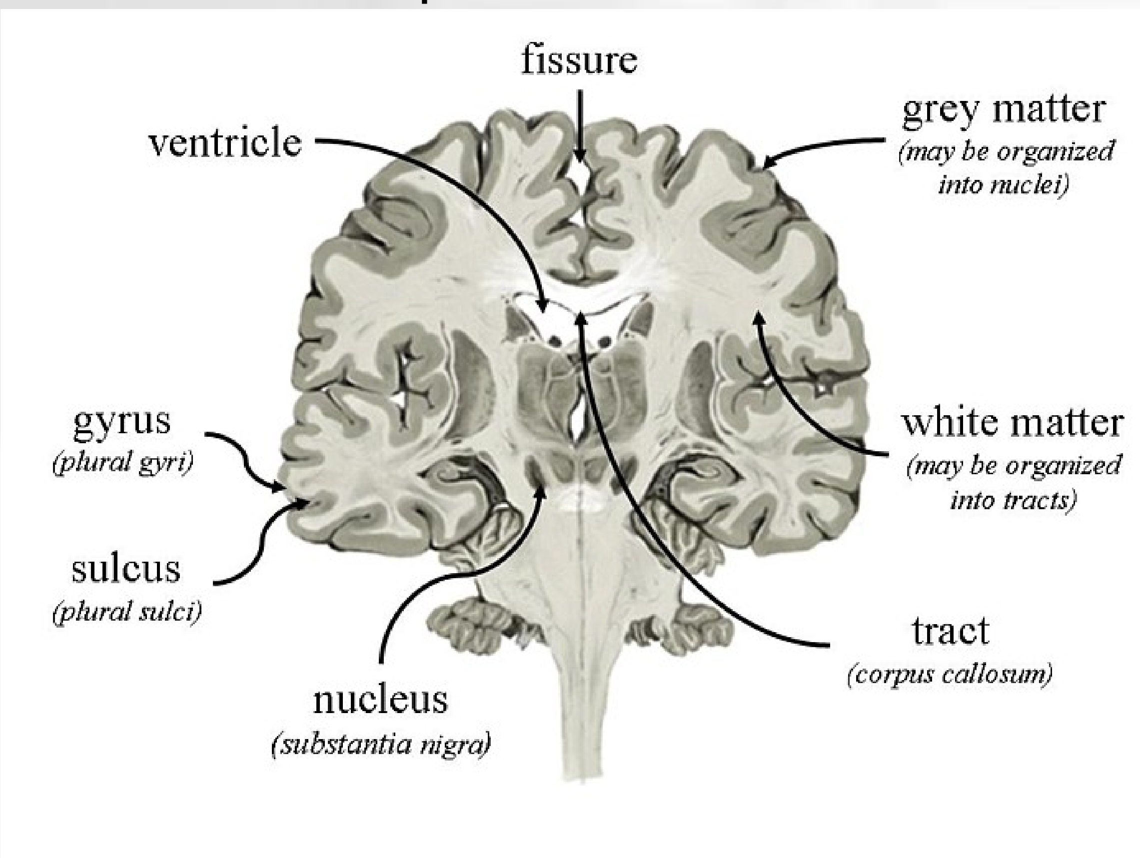


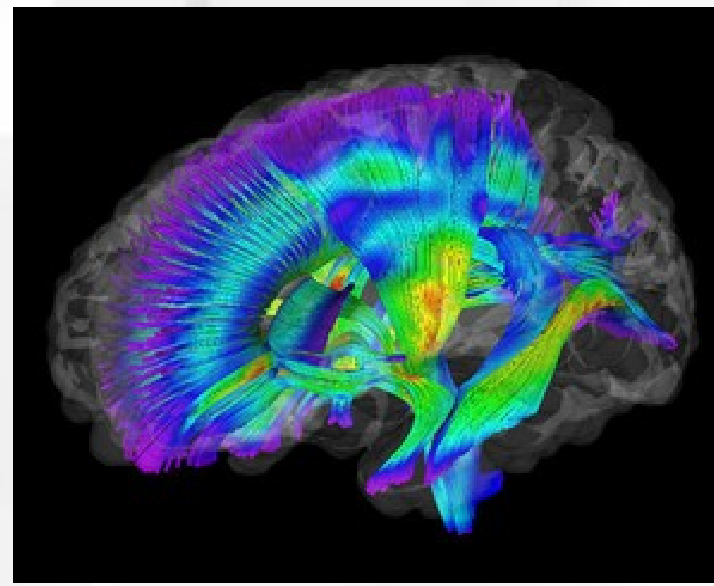
Neural selectivity reflected in “firing” or “spiking” rate



Structure of Brain: Gray Matter and White Matter

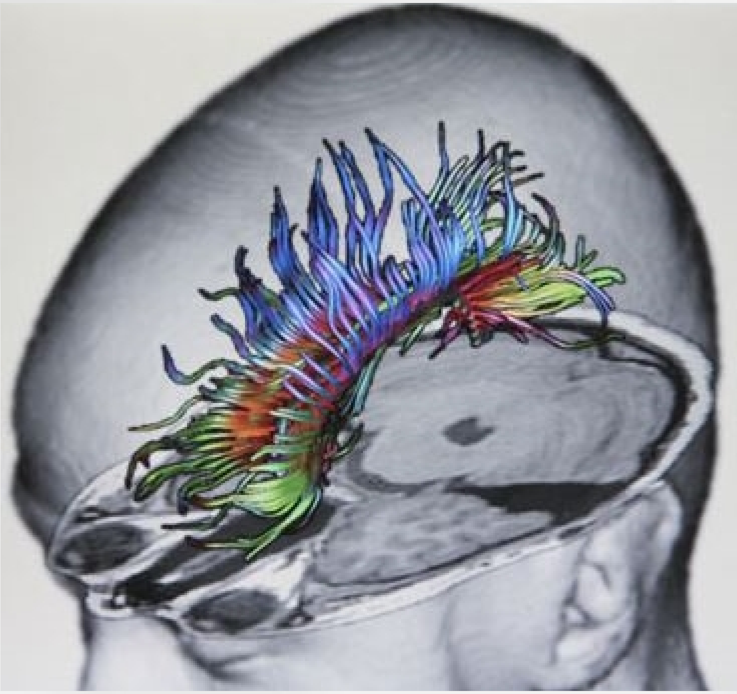
- Gray matter = neuronal cell bodies
- White matter = axons, myelin, and glia cells
  - axon tracts occur within hemispheres, between hemispheres, and between cortical and sub-cortical regions

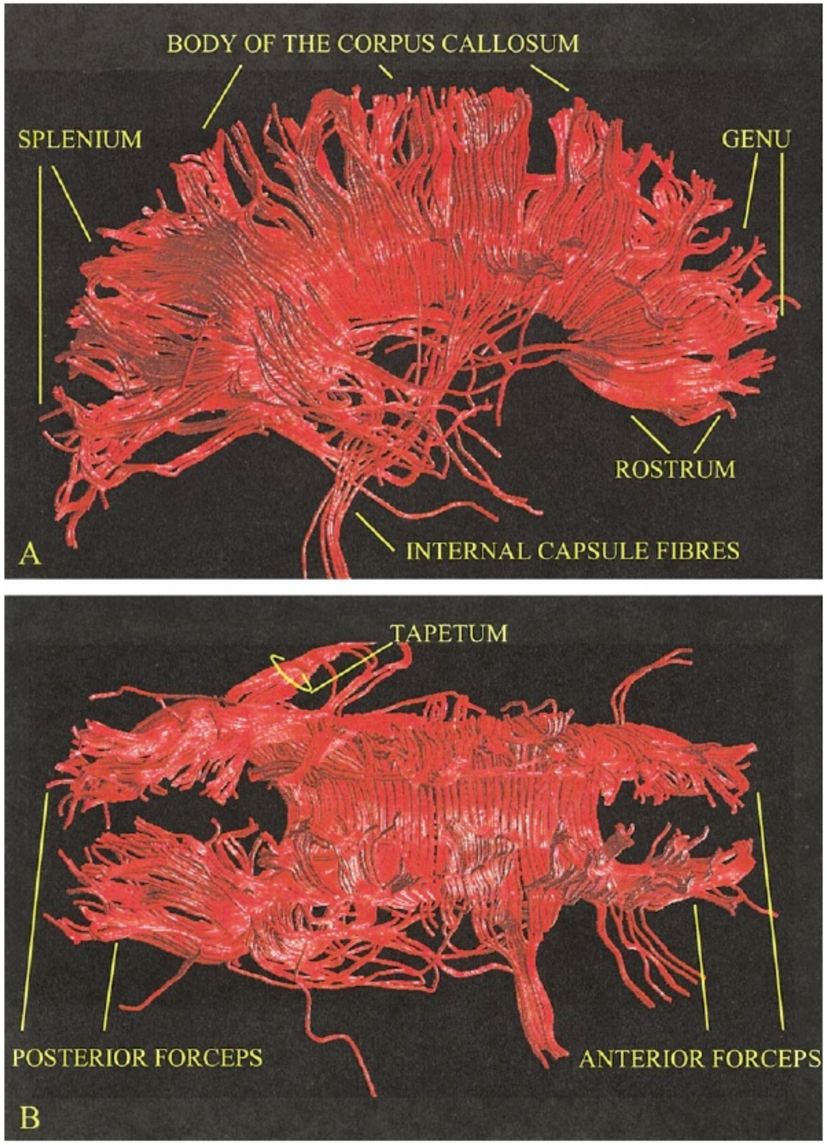




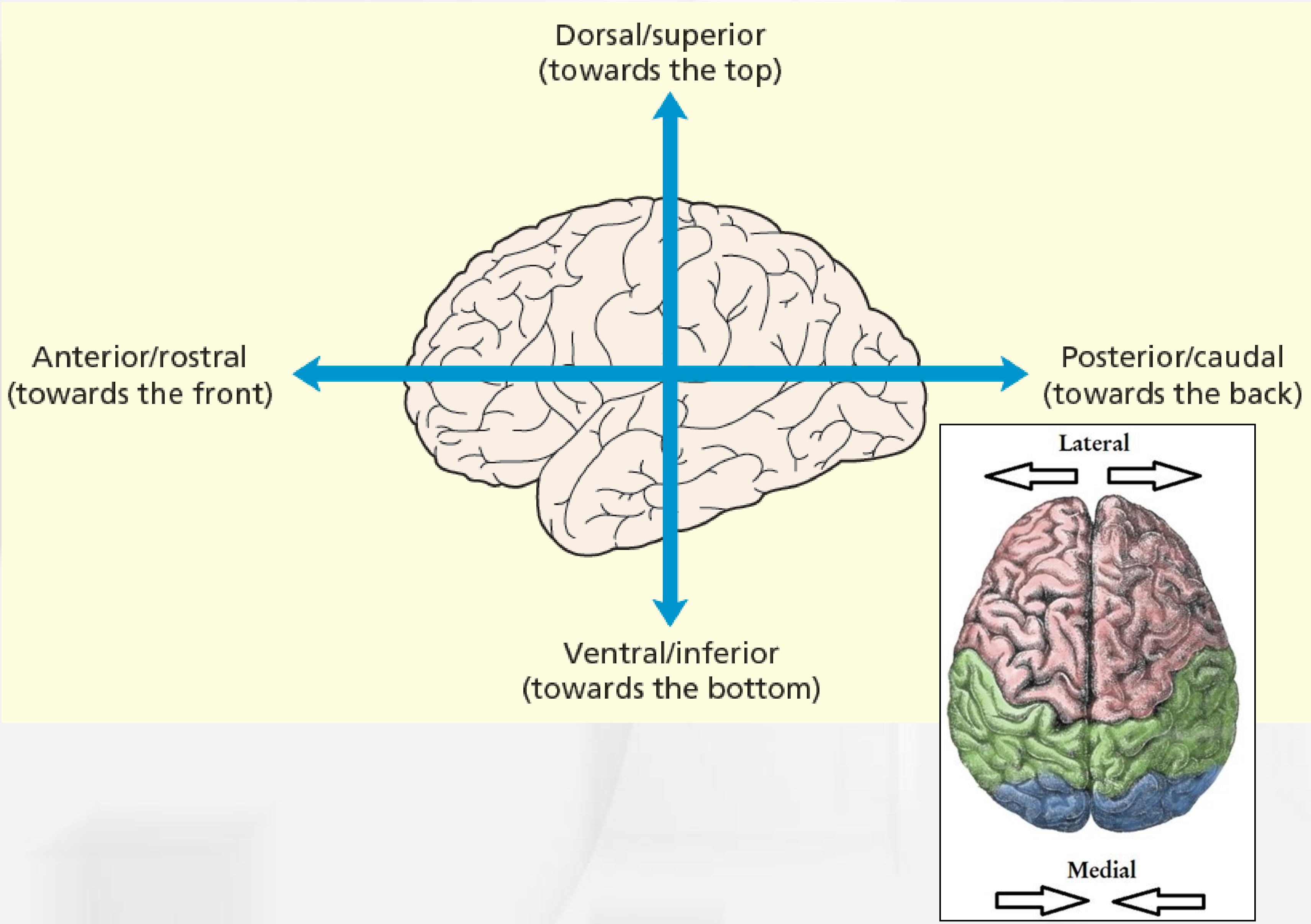
Corpus Callosum

Massive white matter tract linking the two hemispheres

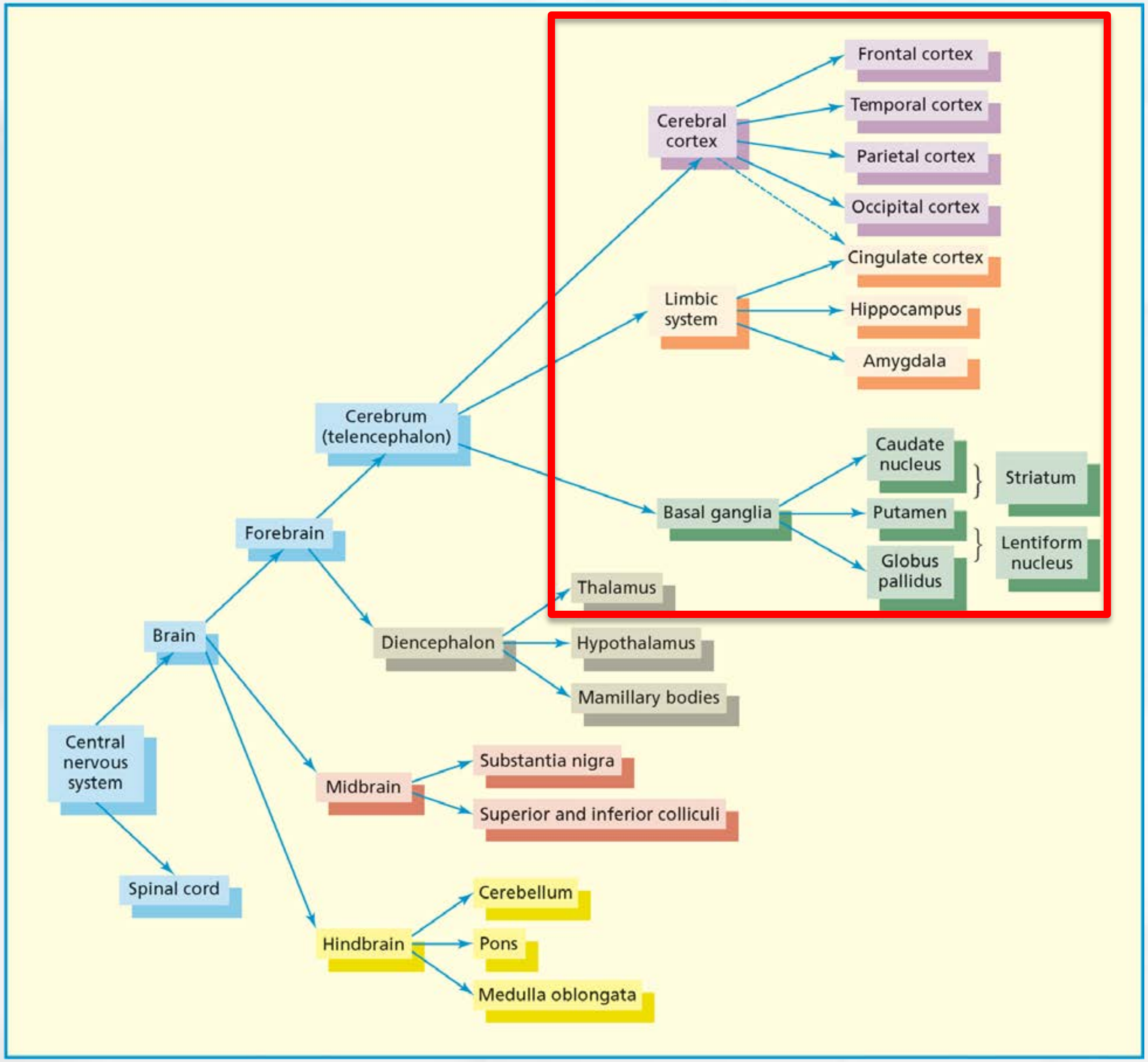




Terms of Reference

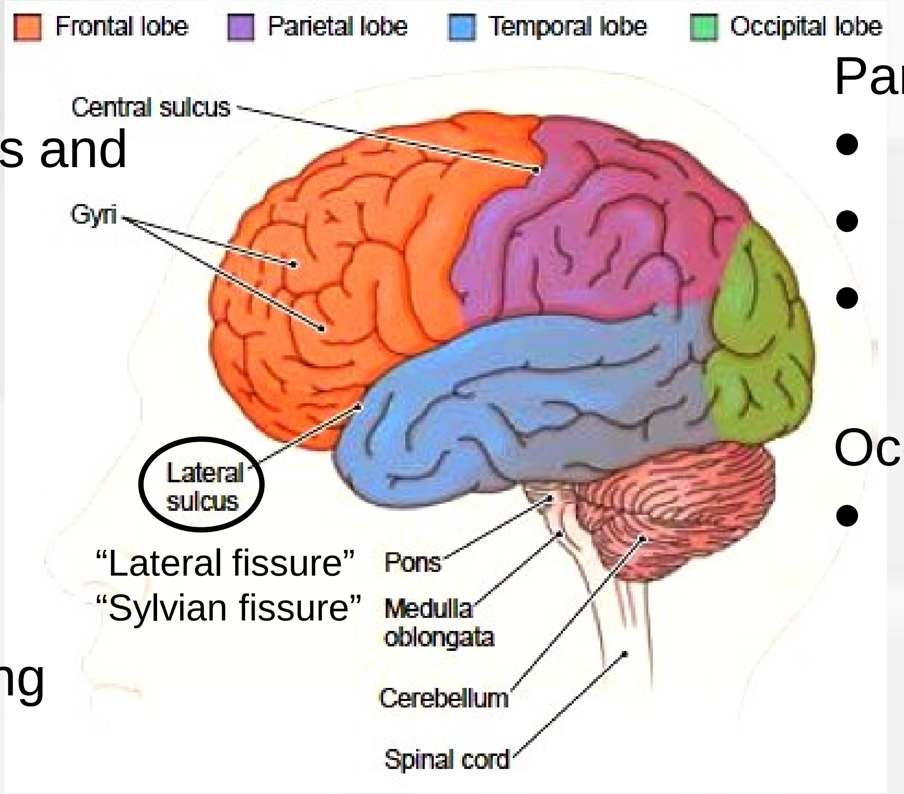


An Overview of the Central Nervous System



Lobes of the Cerebral Cortex

Frontal lobe:
- Executive functions and cognitive control
- Language
- Motor control and planning



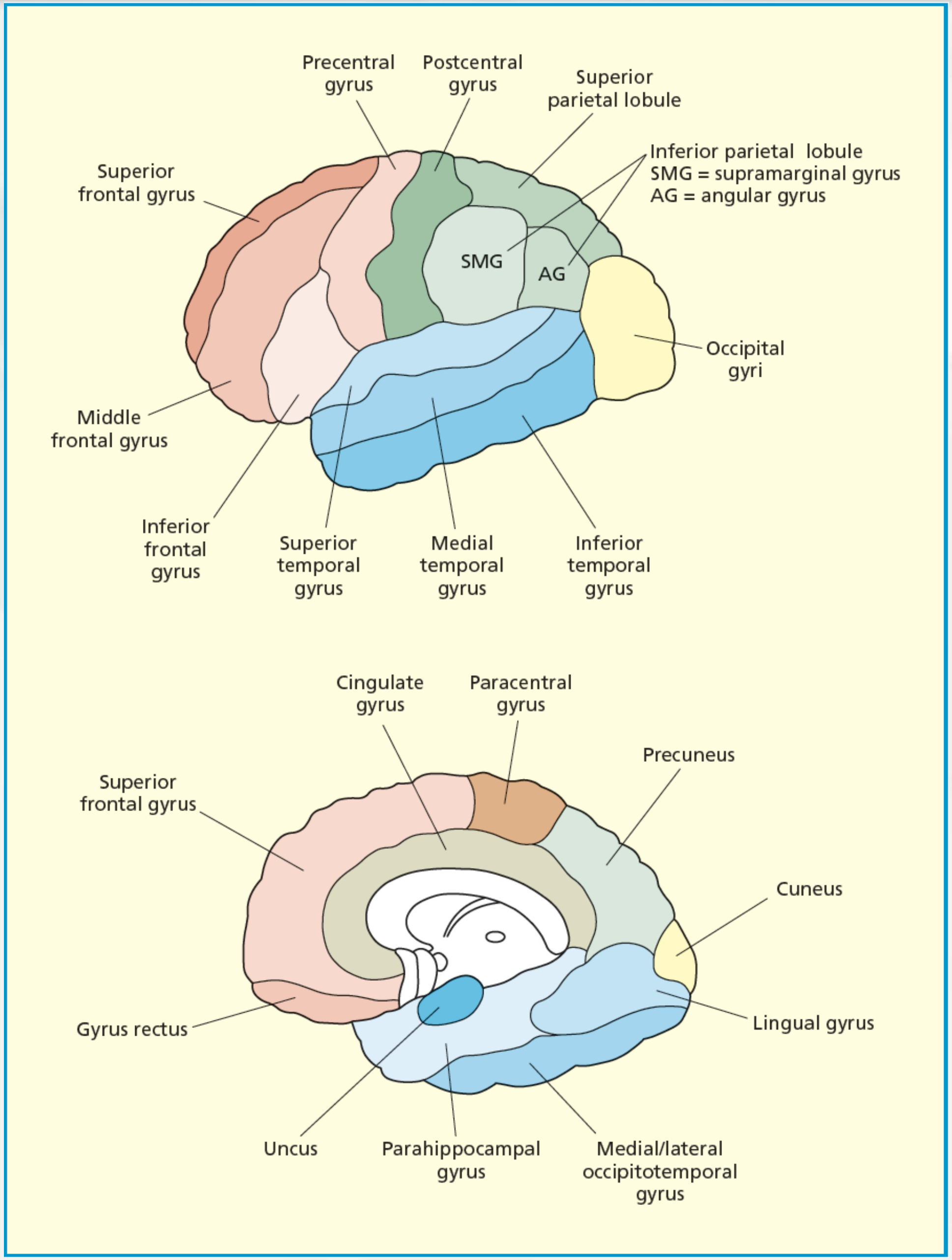
"Lateral fissure"
"Sylvian fissure"

Temporal lobe:
- Auditory processing
- Language
- Memory
- Object recognition

Parietal lobe:
- Tactile perception
- Language
- Attention, spatial and numerical cognition

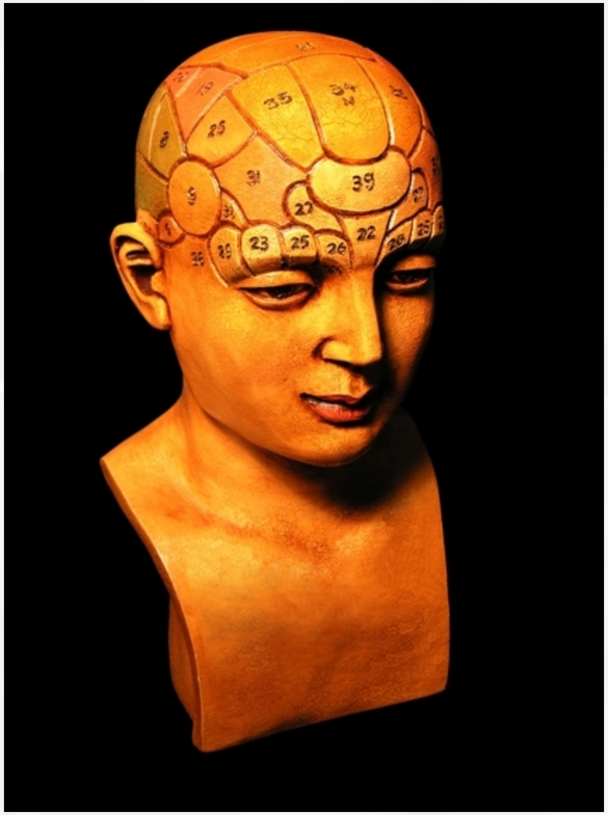
Occipital lobe:
- Visual processing

Each lobe has a characteristic set of gyri and sulci



Localization of Function

- One way to understand brain function is to map specific functions to specific areas of the brain
- This idea goes back at least to phrenology (early 1800's)
- Reality is more complex
  - Human cognitive functions rarely have 1-to-1 mapping to a brain area
  - Cognitive "function" ≠ Brain "function"
    - Avoid mistakes of phrenology



Localization of Function: Perception

- Fusiform face area (FFA) responds specifically to faces
  - Temporal lobe
  - Damage to this area causes prosopagnosia (inability to recognize faces)
- Parahippocampal place area (PPA) responds specifically to places (indoor/outdoor scenes)
  - Temporal lobe
- Extrastriate body area (EBA) responds specifically to pictures of bodies and parts of bodies

What function is localized in FFA?

- Original claim: face recognition is important for social animals like humans, so we evolved a specialized neural system for conspecific recognition
- But, let’s do a little experiment:

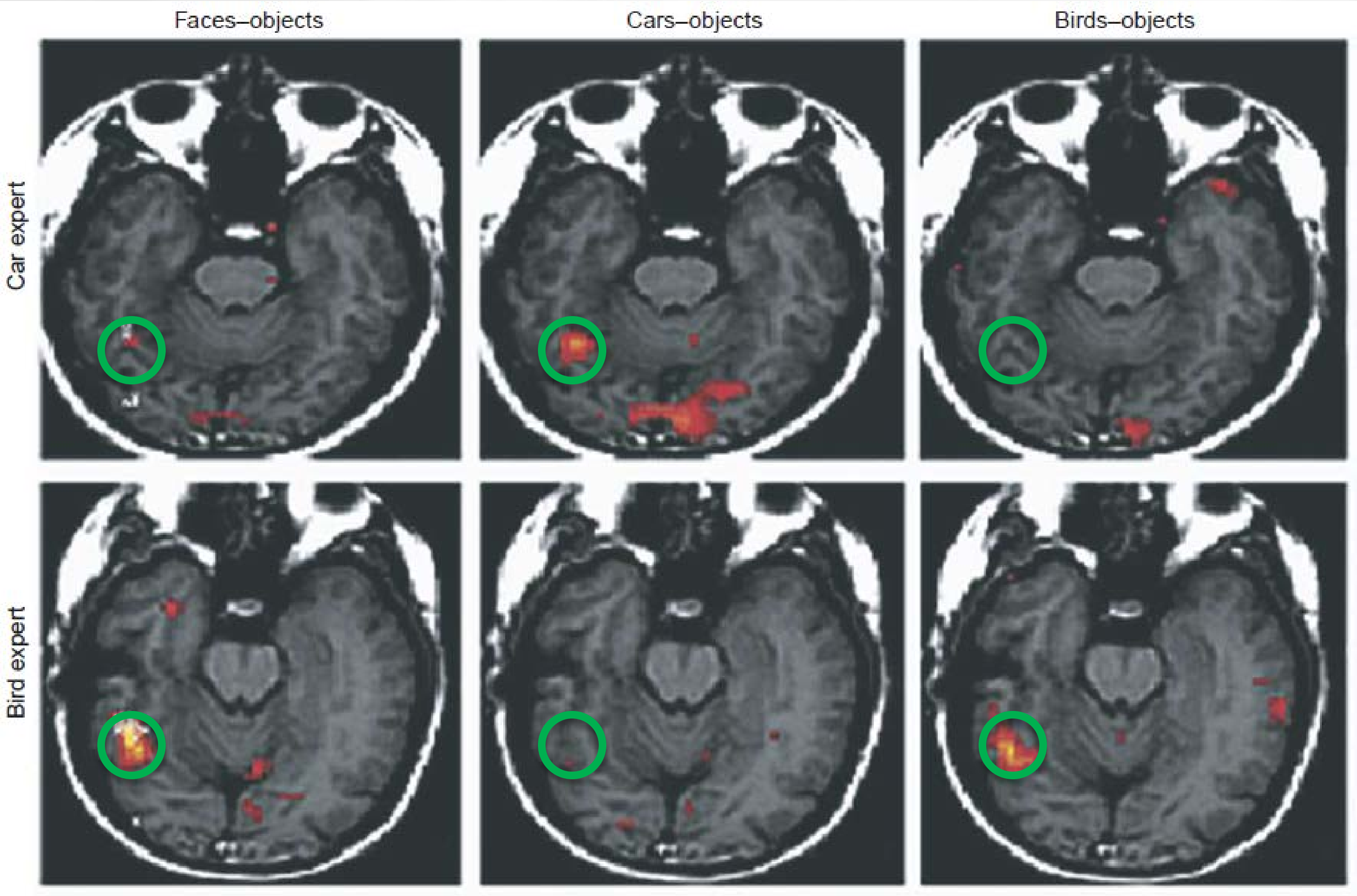






- Faces are among the few objects we identify at the individual level

What function is localized in FFA?



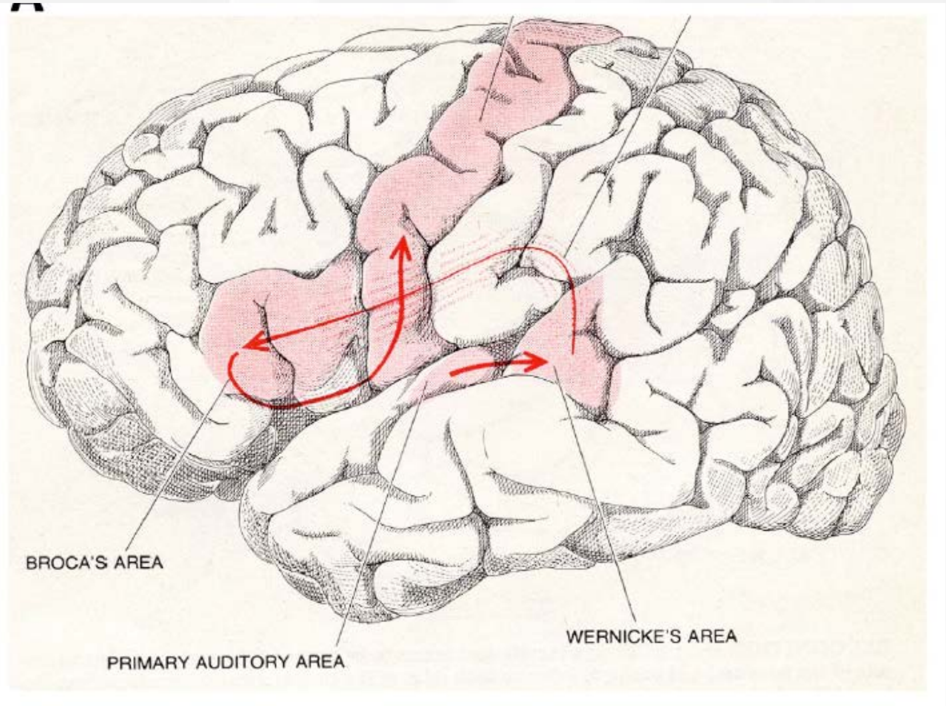
- FFA specialized for expert, individual-level object identification

Localization of Function: Language

Wernicke-Lichtheim-Geschwind model of language

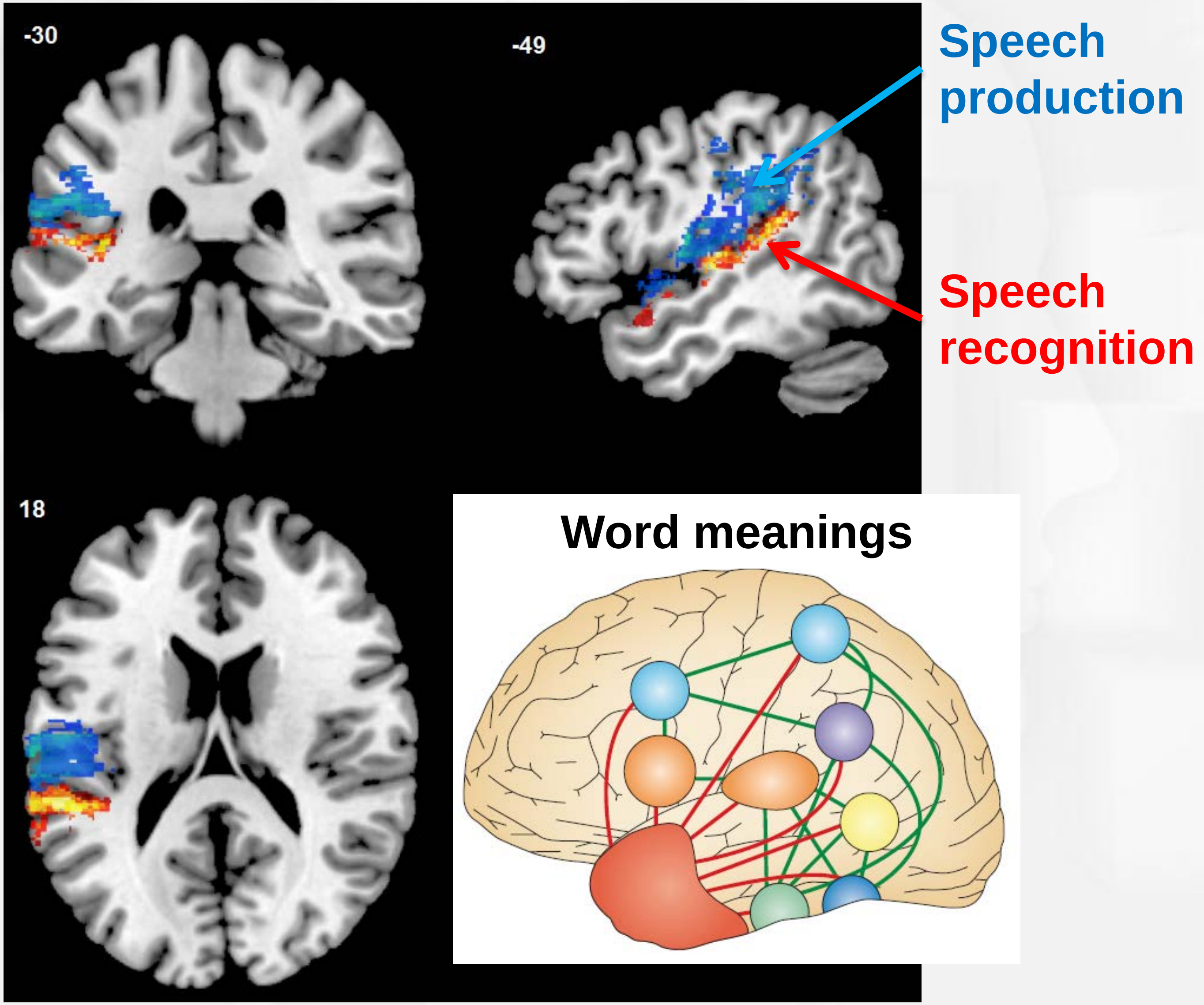
(1870’s – 1970’s):

- Language production: Broca’s area (inferior frontal lobe)
- Language comprehension: Wernicke’s area (posterior temporal lobe)



Localization of Function: Language

21st century view:



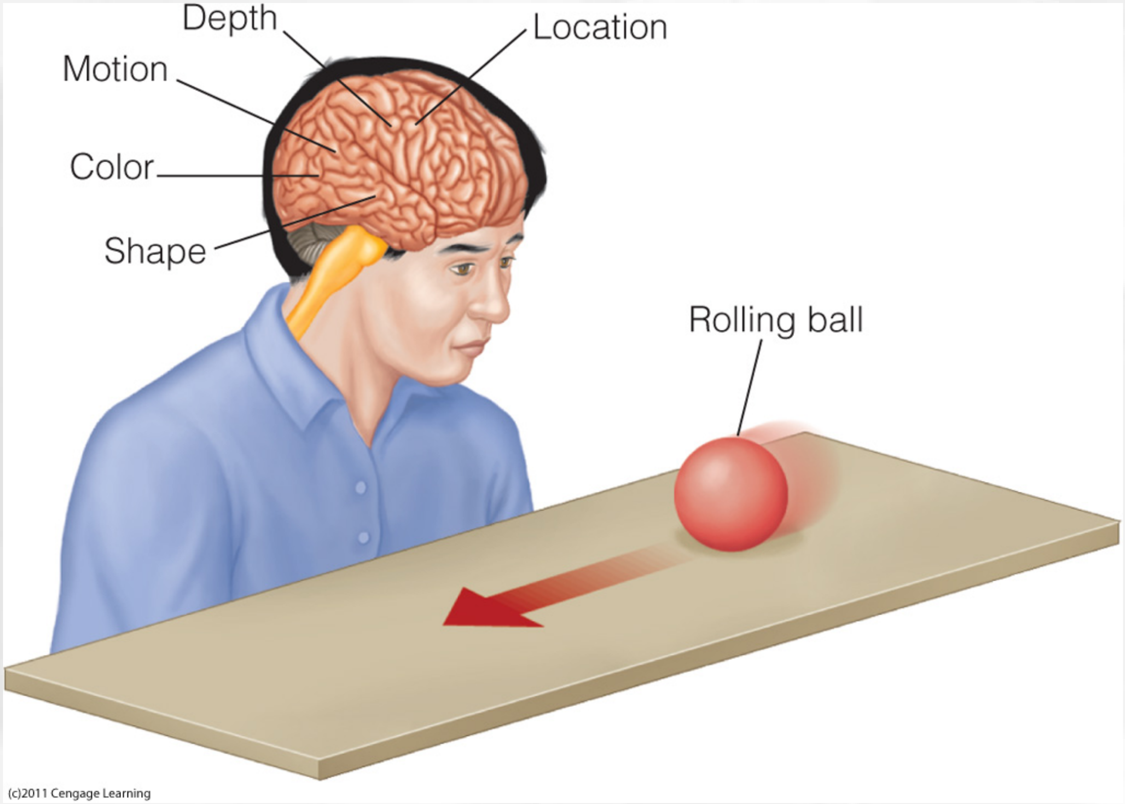
Distributed Processing in the Brain

Not a 1-to-1 mapping between cognitive functions and brain regions

- Many different brain regions may contribute to a cognitive function
- One brain region may play an important role in many cognitive functions

Computer metaphor: each software program uses many computer components (sound card, monitor, keyboard, etc.) and each component is used by many programs

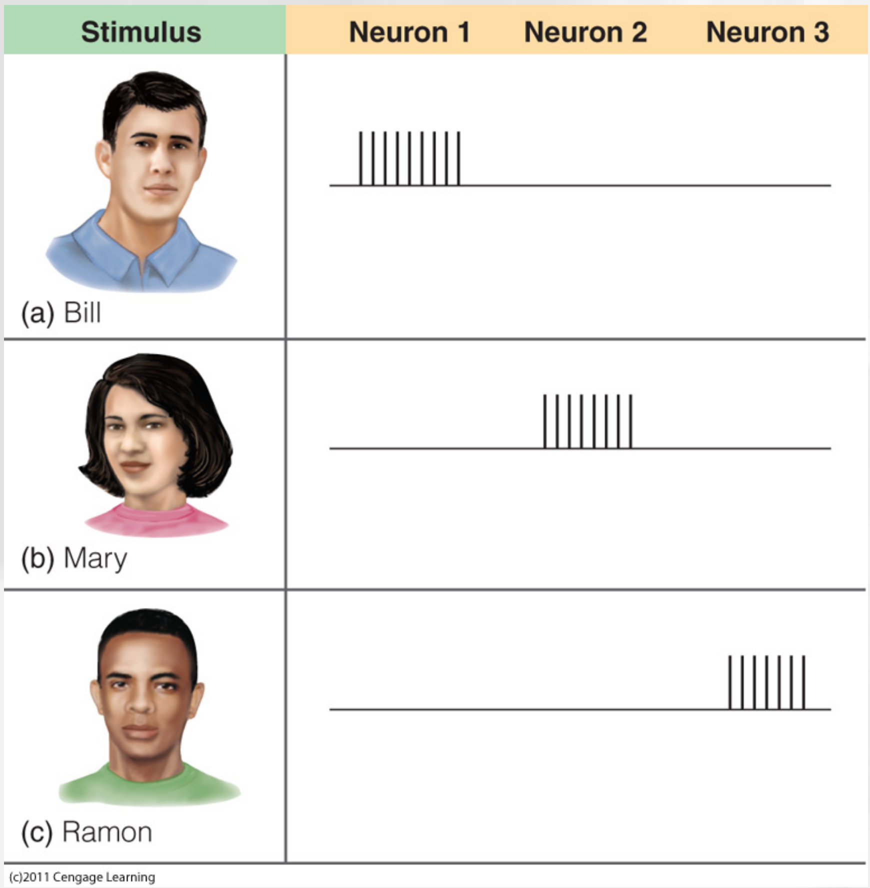
- Understanding the brain components and what they do for cognitive functions is ***cognitive neuroscience***



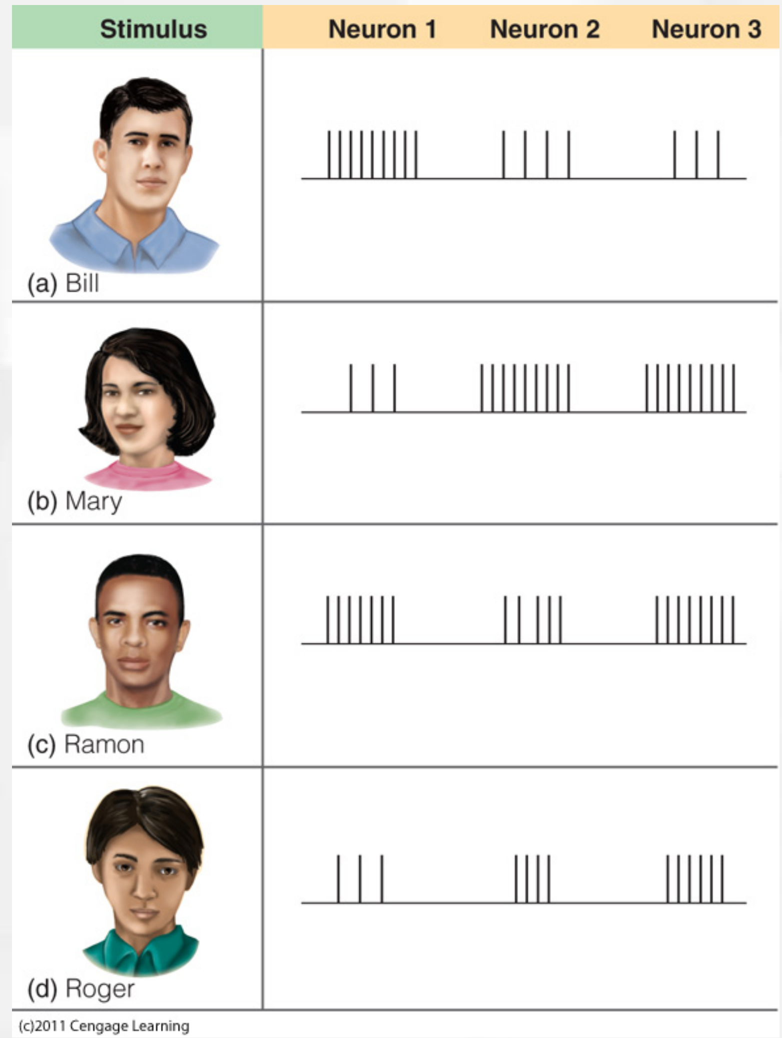
As this person watches the red ball roll by, different properties of the ball activate different areas of his cortex. These areas are in separate locations, although there is communication between them.

Neural Representations

Localist representation

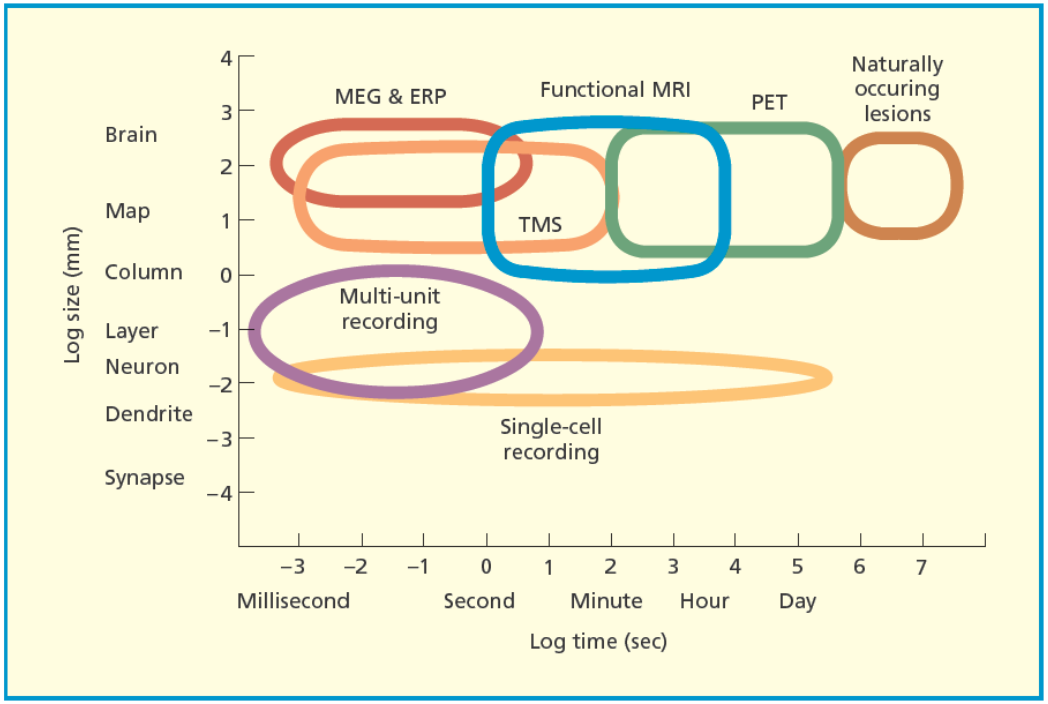


Distributed representation



The Methods of Cognitive Neuroscience

- Temporal resolution
- Spatial resolution
- Invasiveness



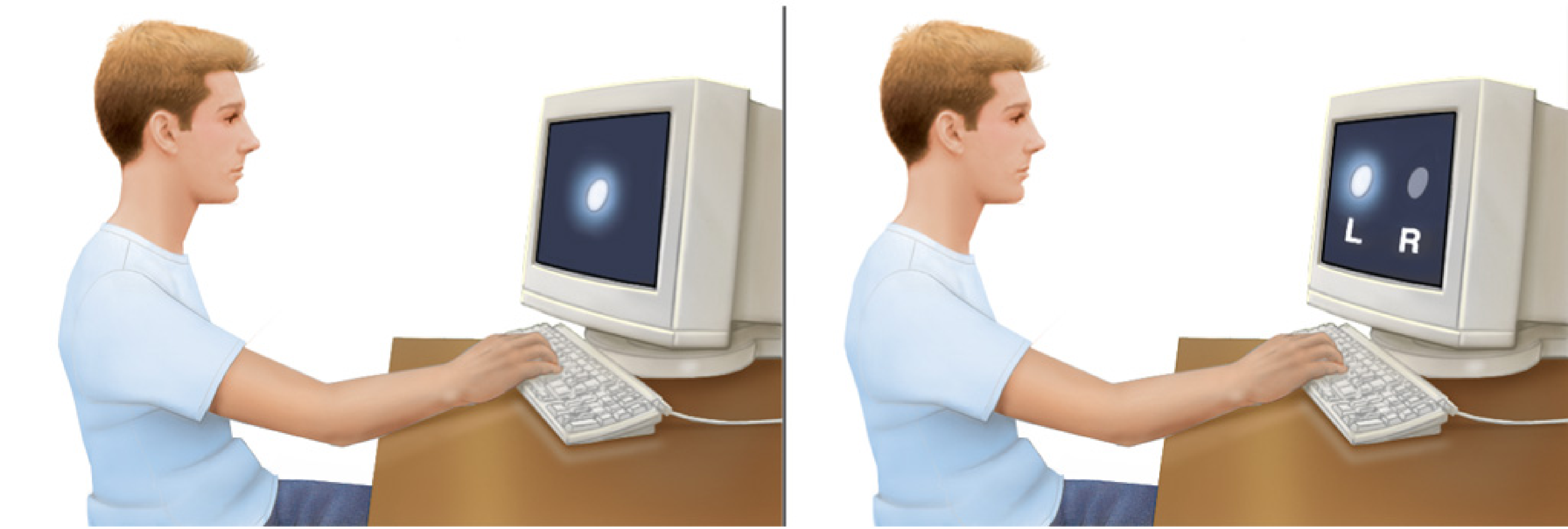
Method	Method type	Invasiveness	Brain property used
EEG/ERP	Recording	Non-invasive	Electrical
Single-cell (and multi-unit) recordings	Recording	Invasive	Electrical
TMS	Stimulation	Non-invasive	Electromagnetic
MEG	Recording	Non-invasive	Magnetic
PET	Recording	Invasive	Hemodynamic
fMRI	Recording	Non-invasive	Hemodynamic

The Methods of Cognitive Neuroscience

- Electrical methods: measure electrical activity of neurons
  - Single-cell recording
  - Multi-unit recording
  - Scalp EEG/ERP
- Hemodynamic methods: measure bloodflow changes produced by increased metabolic demands of neural firing
  - PET (glucose tracer)
  - fMRI (oxygenated hemoglobin)
  - fNIRS (oxygenated hemoglobin)
- Lesion methods: stroke, neurodegenerative diseases, surgery
- Non-invasive brain stimulation: TMS, tDCS

Subtraction Method

Behavioral subtraction (Donders, 1868)

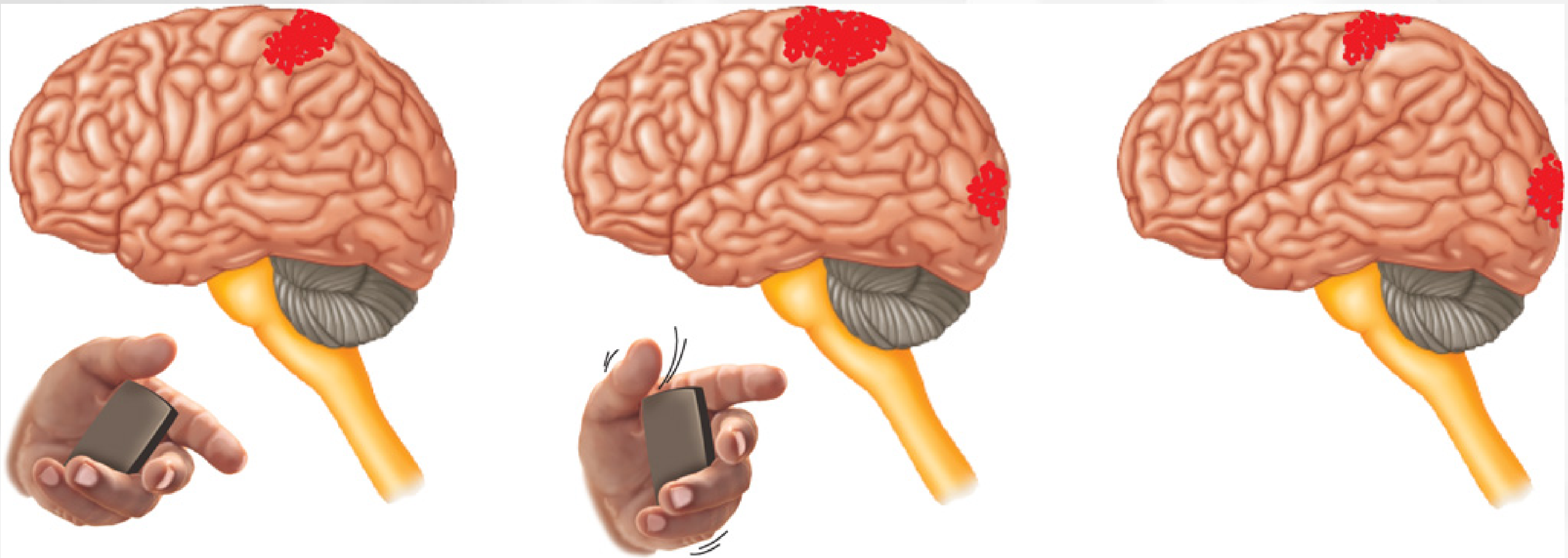


(a) Press J when light goes on.

(b) Press J for left light, K for right.

Subtraction Method

Neural subtraction



(a) Initial condition—hold object

(b) Test condition—manipulate object

(c) Activity associated with manipulating object

Next time

How do neuroscience findings help to understand cognitive processes?