Language and the Brain

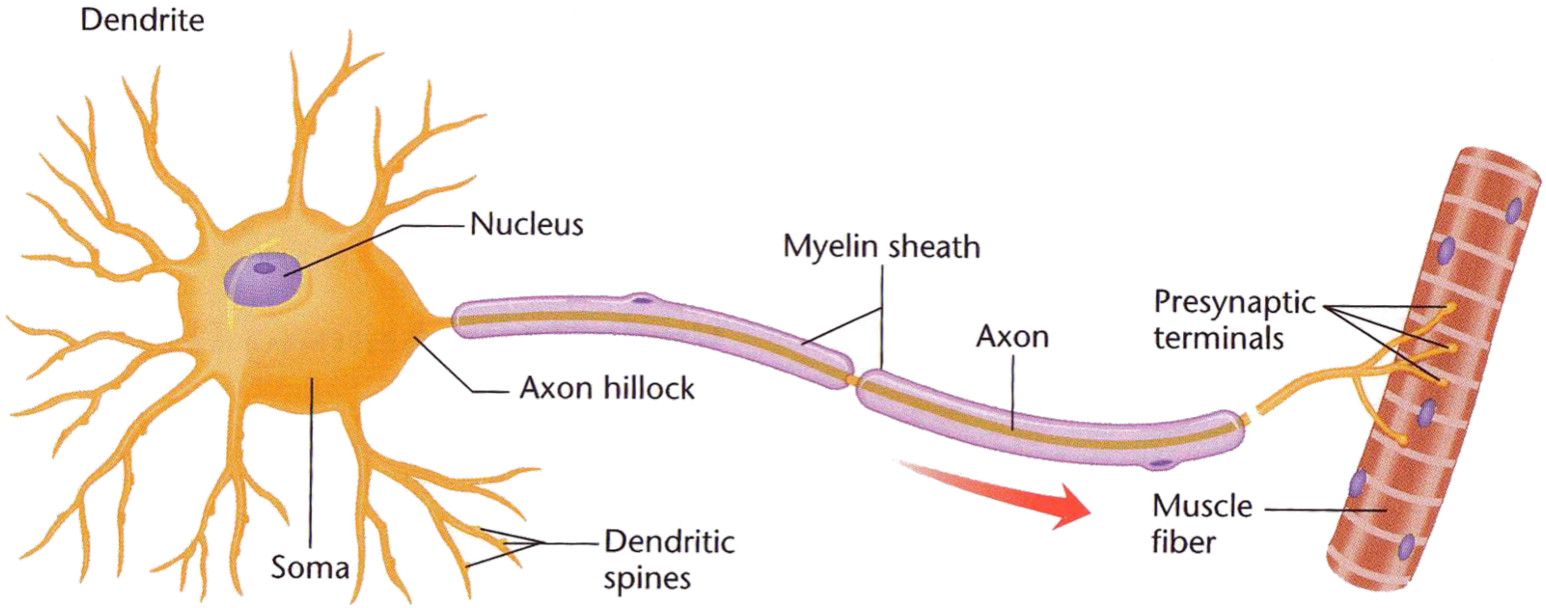
LIGN 170, Lecture 16

Neurons

- Cells which receive information and transmit it to other cells
- Approx. 100 billion neurons in the adult human brain
- Cell bodies range in size from .005mm to .1mm in mammals

Structure of a neuron

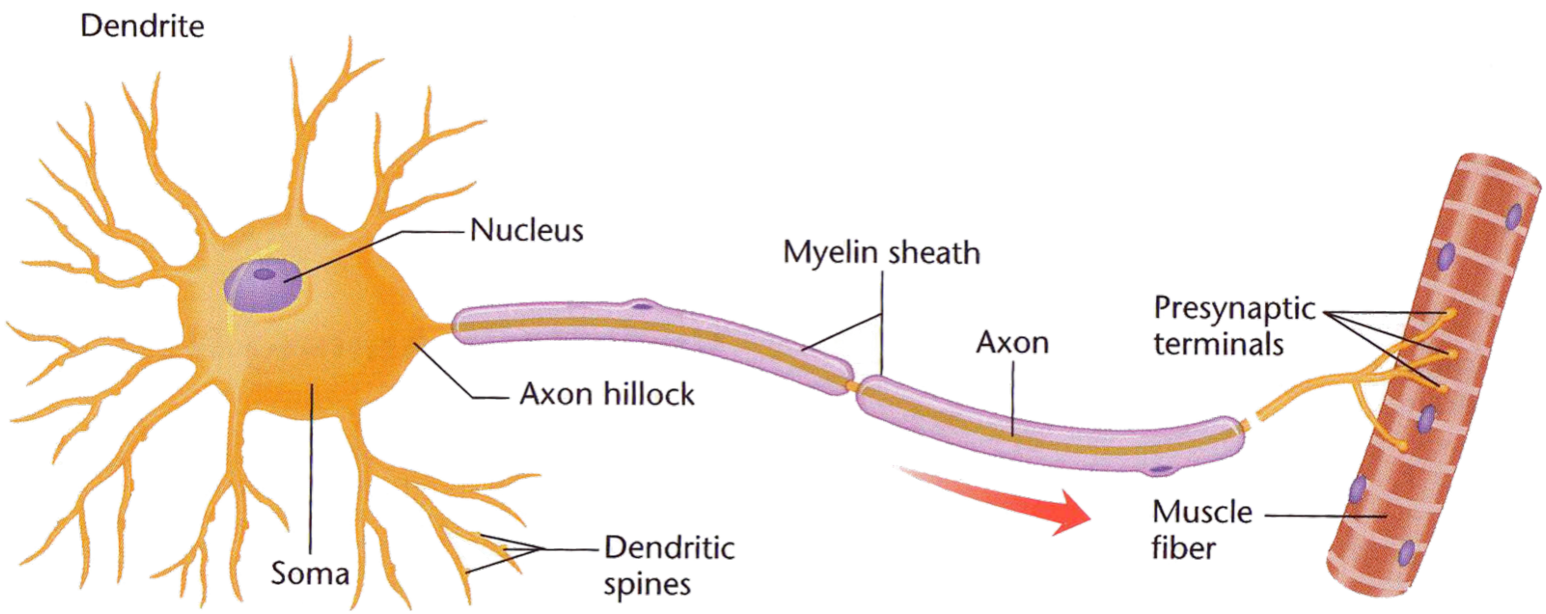
- Dendrites (Input)
- Soma or cell body (Additional input)
- Axon & presynaptic terminals (Output)

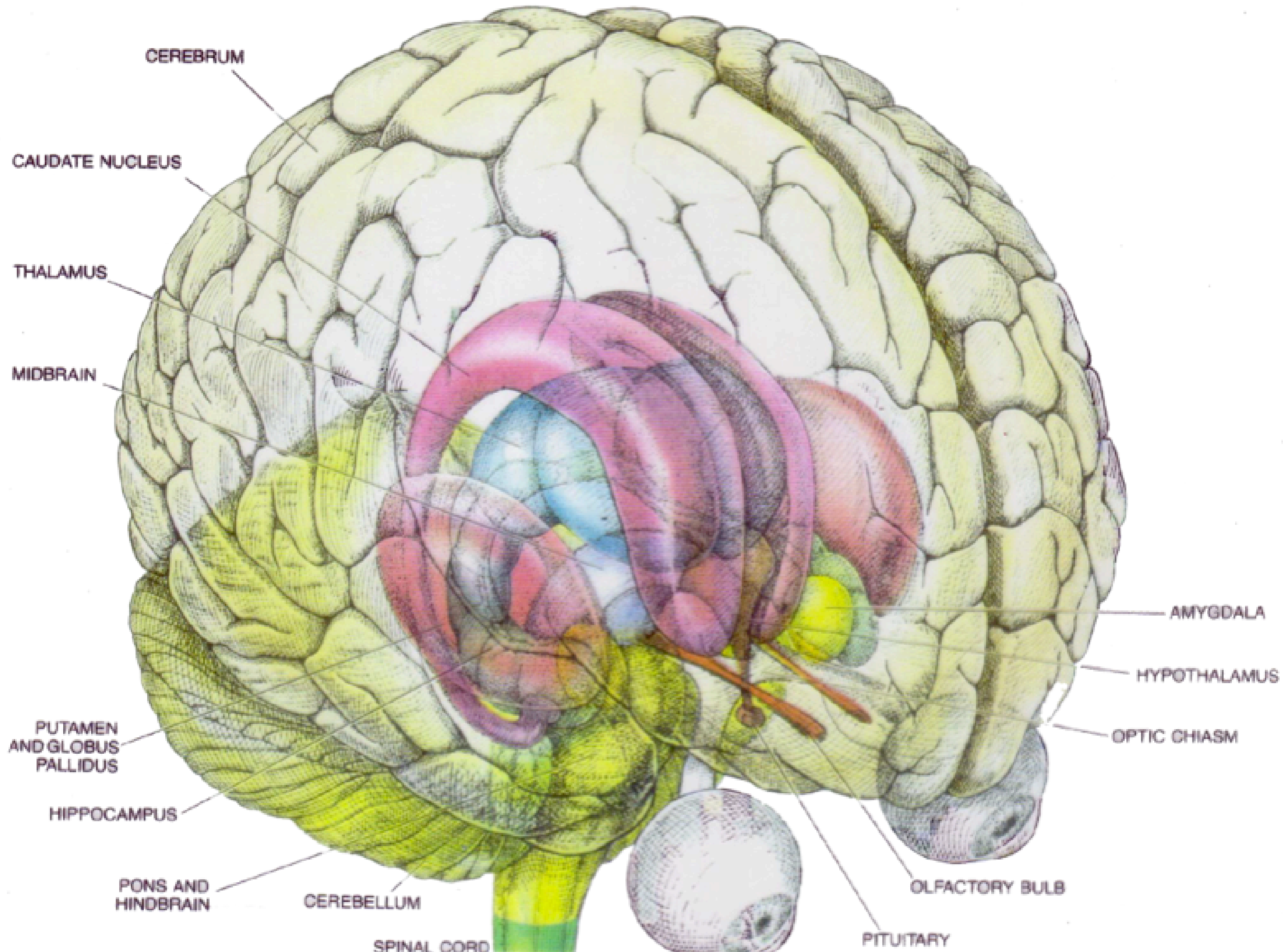


Information transfer in the brain

- Electrical
  - The cell membrane of a neuron maintains a disparity between the electrical charge inside & outside the cell
  - A neuron “fires” an action potential when that disparity reaches a critical point
- Chemical
  - Action potential triggers the release of neurotransmitters from axons, which change electrical disparity of next neuron

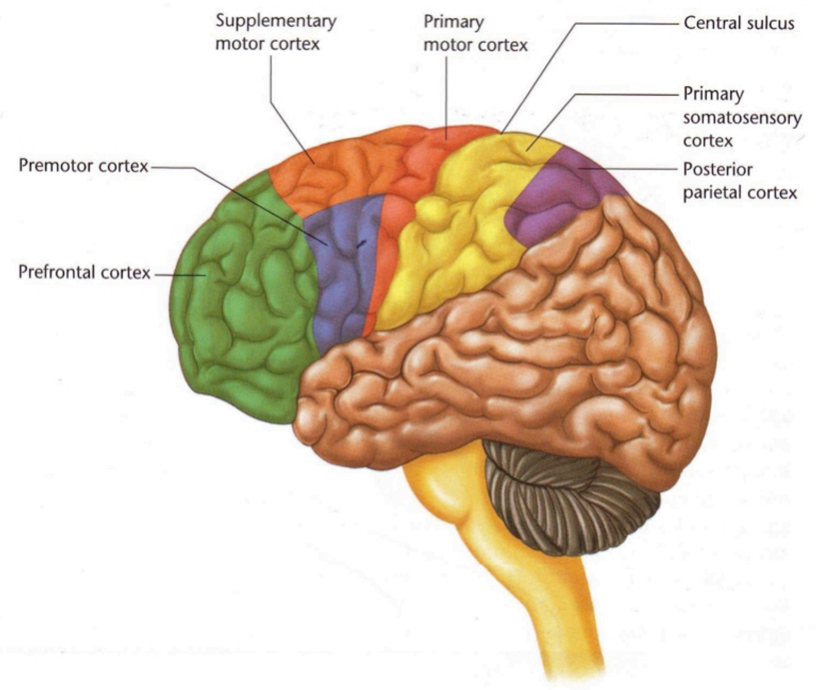
Information transfer



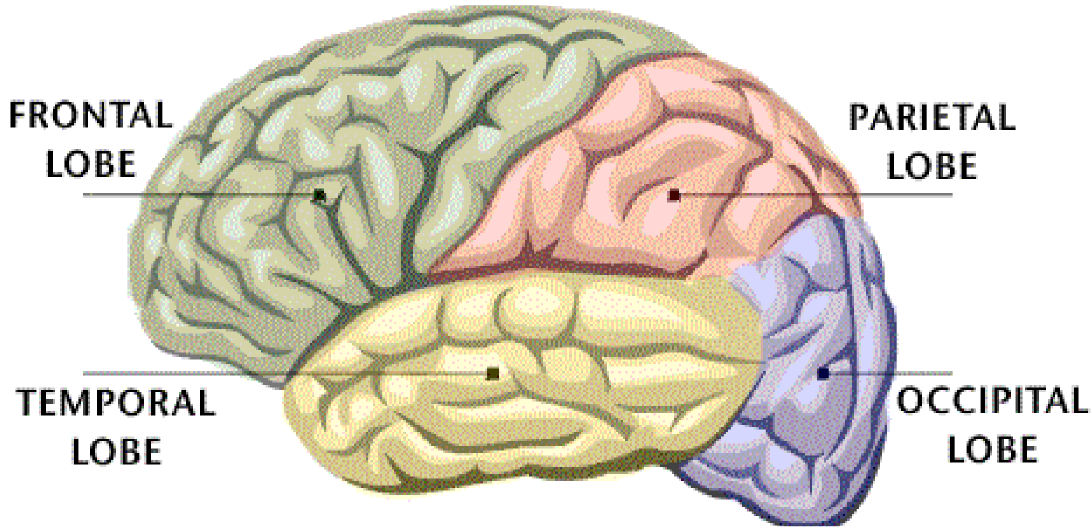

CEREBRUM
CAUDATE NUCLEUS
THALAMUS
MIDBRAIN
PUTAMEN AND GLOBUS PALLIDUS
HIPPOCAMPUS
PONS AND HINDBRAIN
CEREBELLUM
SPINAL CORD
AMYGDALA
HYPOTHALAMUS
OPTIC CHIASM
OLFACTORY BULB
PITUITARY

Cerebral cortex (a.k.a. neocortex, cerebrum)

- Essentially a big disk scrunched up into our skulls
- Two hemispheres
    - Connected by corpus callosum

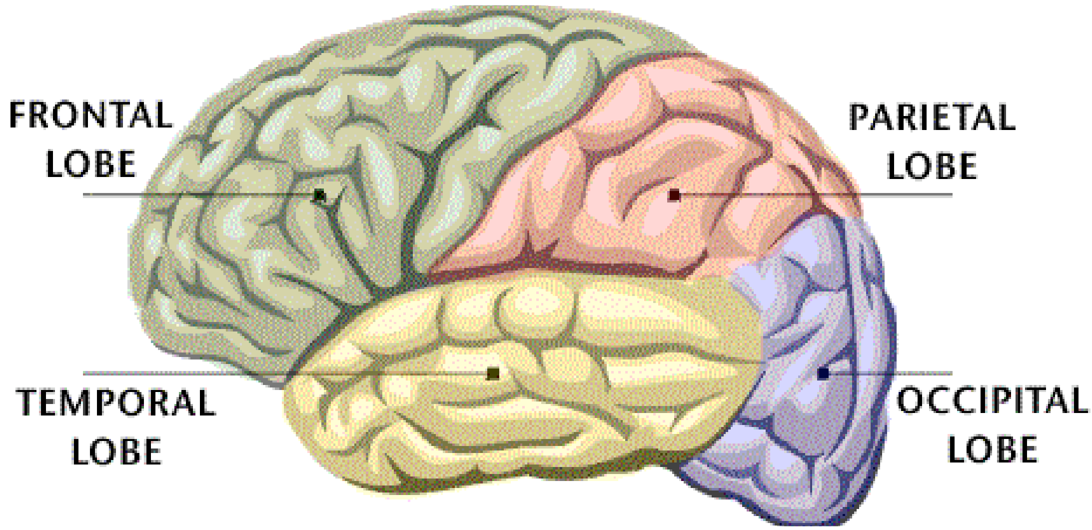


Four cerebral lobes



Four cerebral lobes

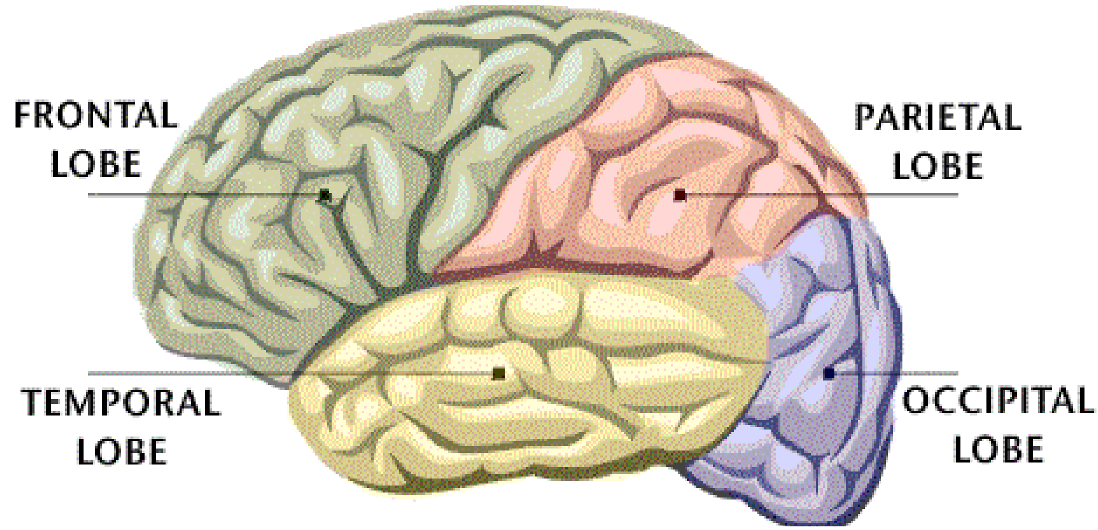
- Frontal contains:
  - Primary motor Cortex
  - Prefrontal cortex



- Important for: Integrating information
  Working memory
  Context-dependent behaviors
  Language

Four cerebral lobes

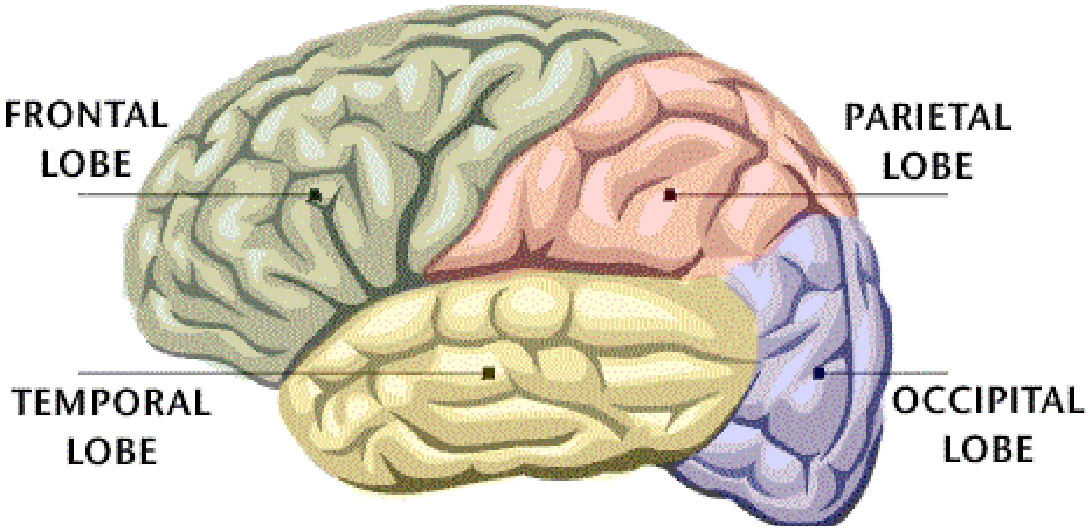
- Temporal contains:
  - Auditory processing (including language)



  - Higher-order visual processing (e.g. face recognition)
  - Emotional behaviors (e.g. suppression of fear/anxiety)

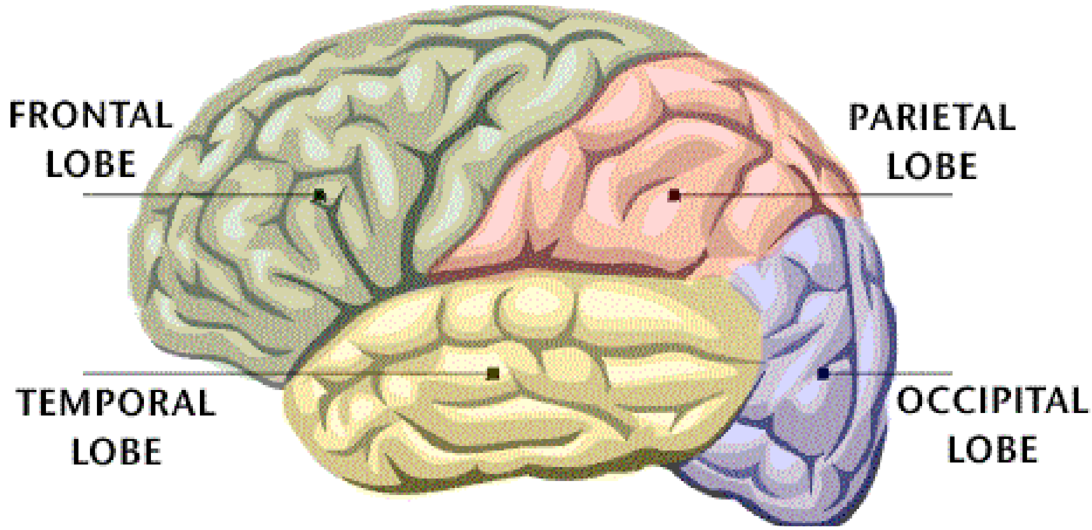
Four cerebral lobes

- Parietal contains:
  - Primary somato-sensory cortex

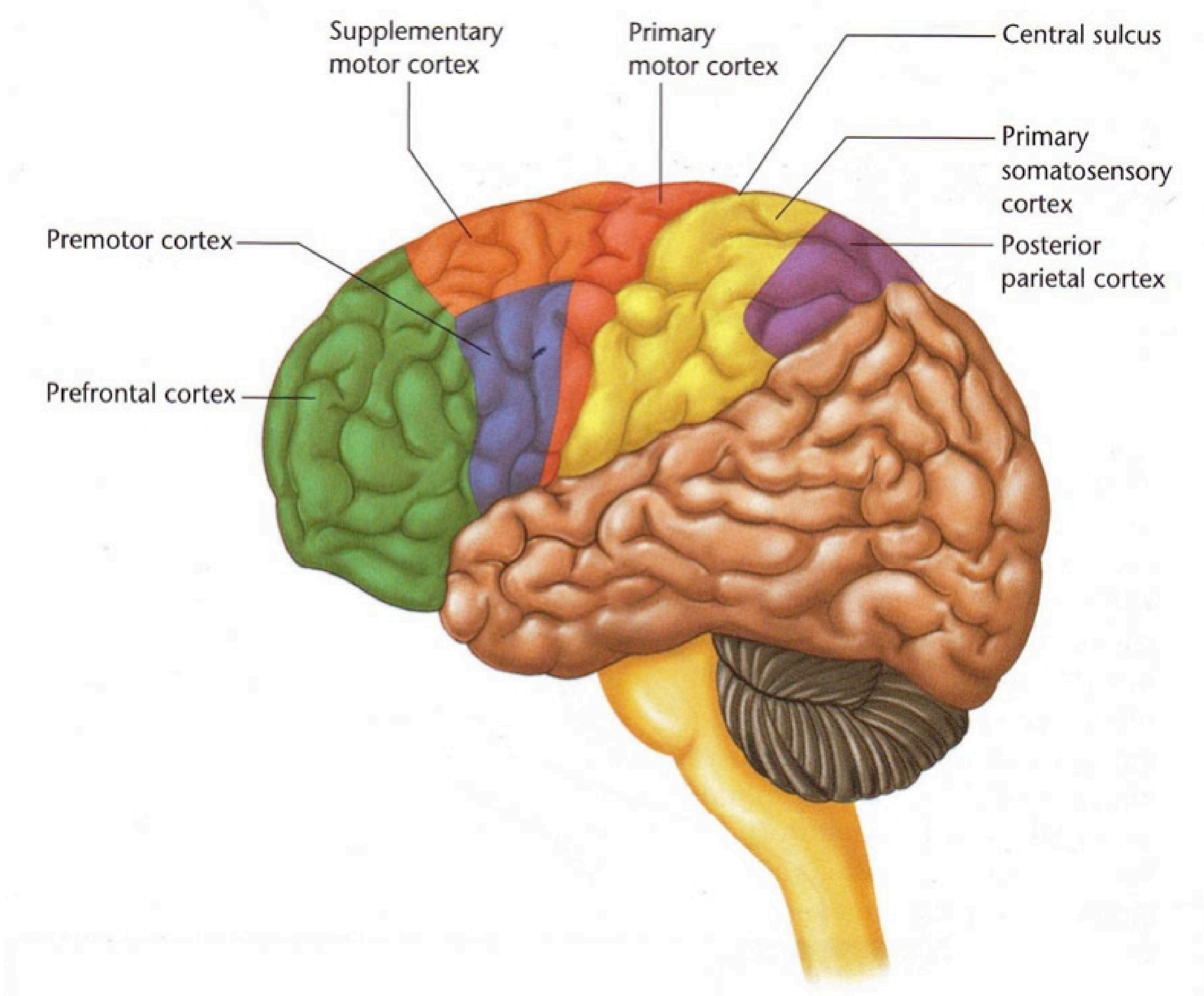


Four cerebral lobes

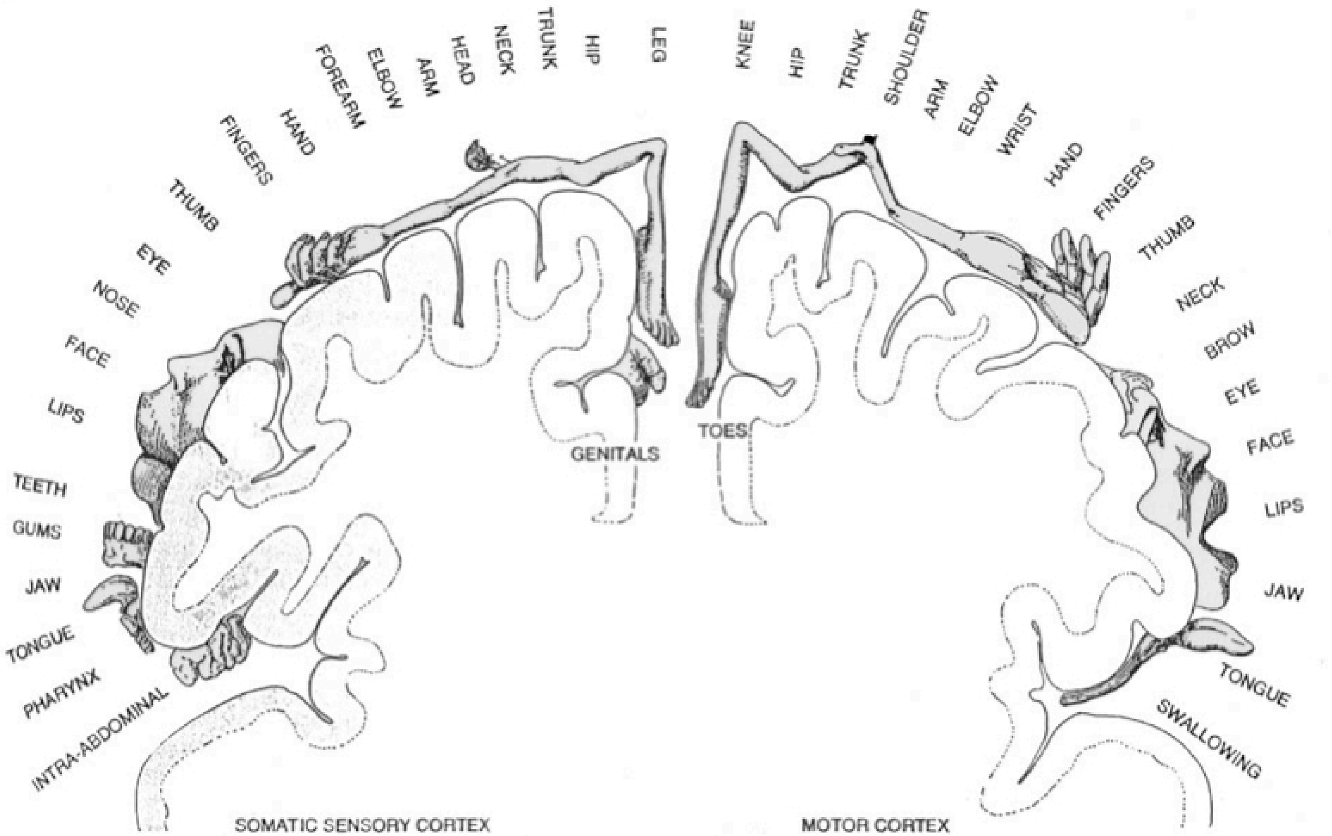
- Occipital contains:
  - Primary visual cortex



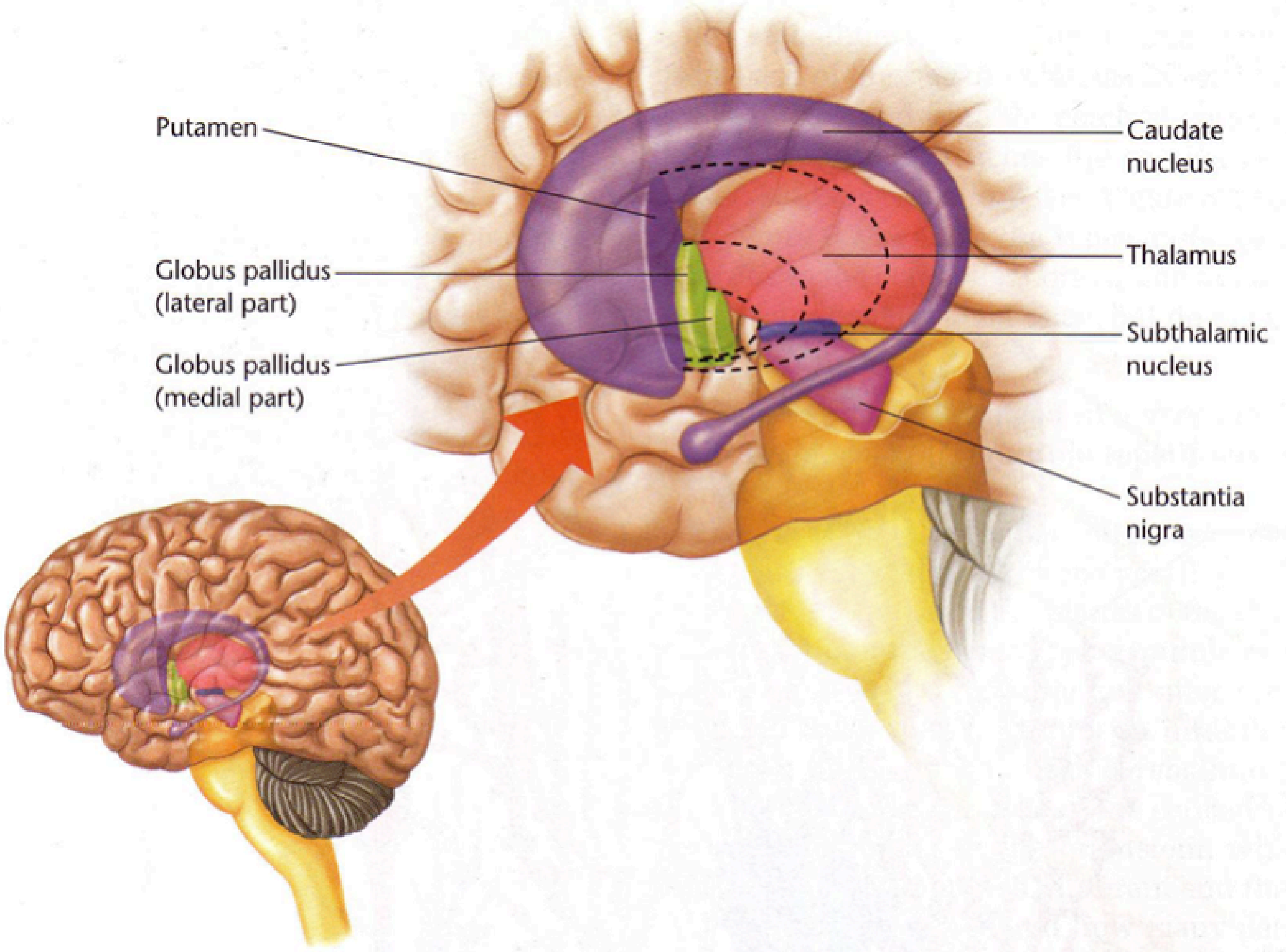
Some major functional areas



Somatotopic maps



Language below the cortex: The basal ganglia



The Binding Problem

- How do all these parts work together as a whole?
- How do various sensations (visual, auditory) come together into a unified experience?
- One hypothesis: synchronization of neural activity via inferior parietal cortex and parts of basal ganglia

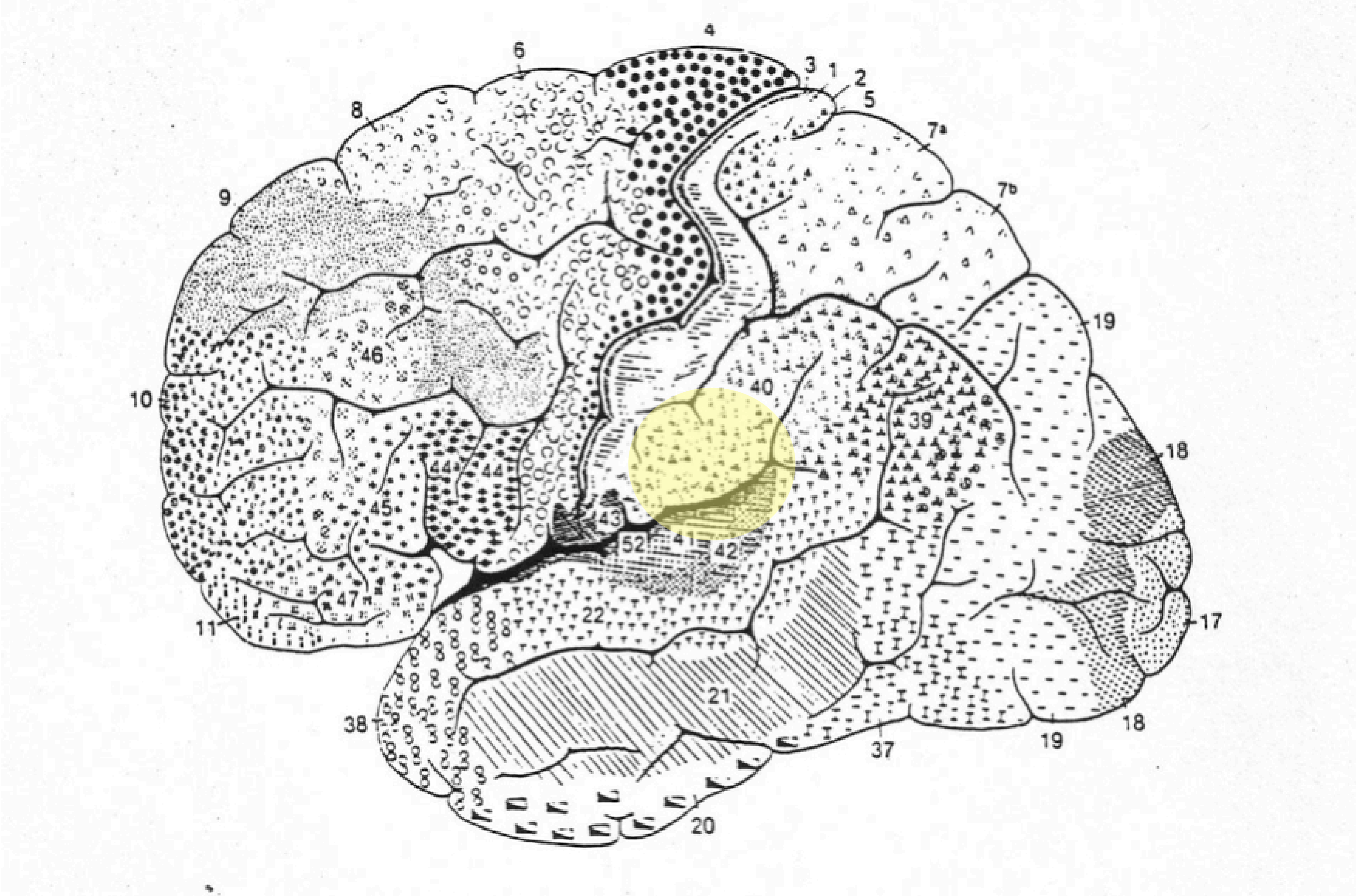
Summary

- Neurons use electrical and chemical signals to function
- There are two hemispheres in the cortex and four major regions
  - The temporal and frontal lobes are involved in language processing
- The subcortical Basal Ganglia are also involved in language
- Some regions of cortex contain maps of sensory/motor representations

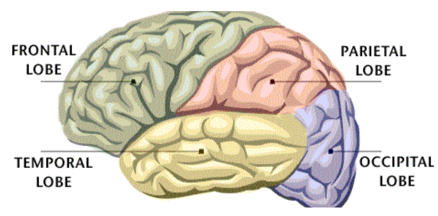
Lateralization

- Two hemispheres of cortex are not the same
- Anatomical differences
  - Subtle differences in cellular structure
  - Visible differences in region sizes
    - Temporal Lobe
      - Planum temporalis is longer and more narrow in left hemisphere than right
      - Heschl's gyrus - different angles

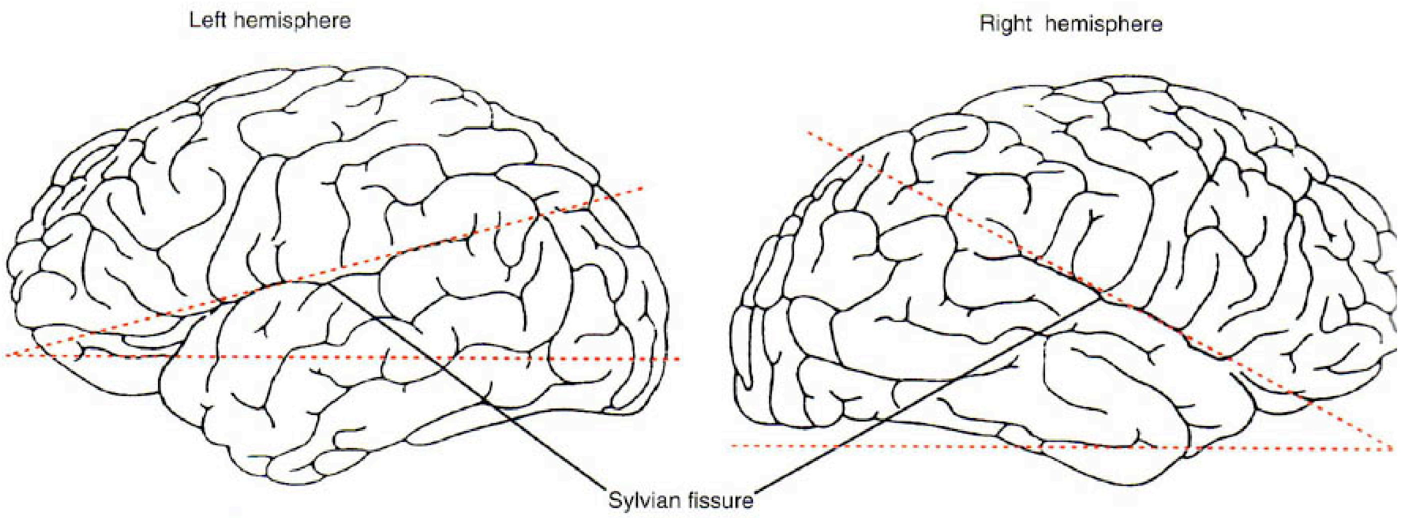
Near Brodmann 42



Lateralization



- Sylvian Fissure
  - Longer and at shallower angle in left hemisphere



Lateralization

- Functional Differences
  - Somatosenory, visual and auditory maps differ between hemispheres in many animals
  - Hand Dominance
    - Right-handed vs. left-handed
      - Also true for non-human primates
  - Language
    - Most of language processing takes place in left hemisphere

Lateralization

- May be dependent on inter-hemispheric communication
  - In one study, severing the corpus callosum in animals of different species resulted in loss of asymmetry

Lateralization

Function	Left	Right
Audition	Sounds related to language	Music, environment
Memory	Categories	Specific exemplars
Vision	High spatial frequencies	Low spatial frequencies

Lateralization

Target stimulus

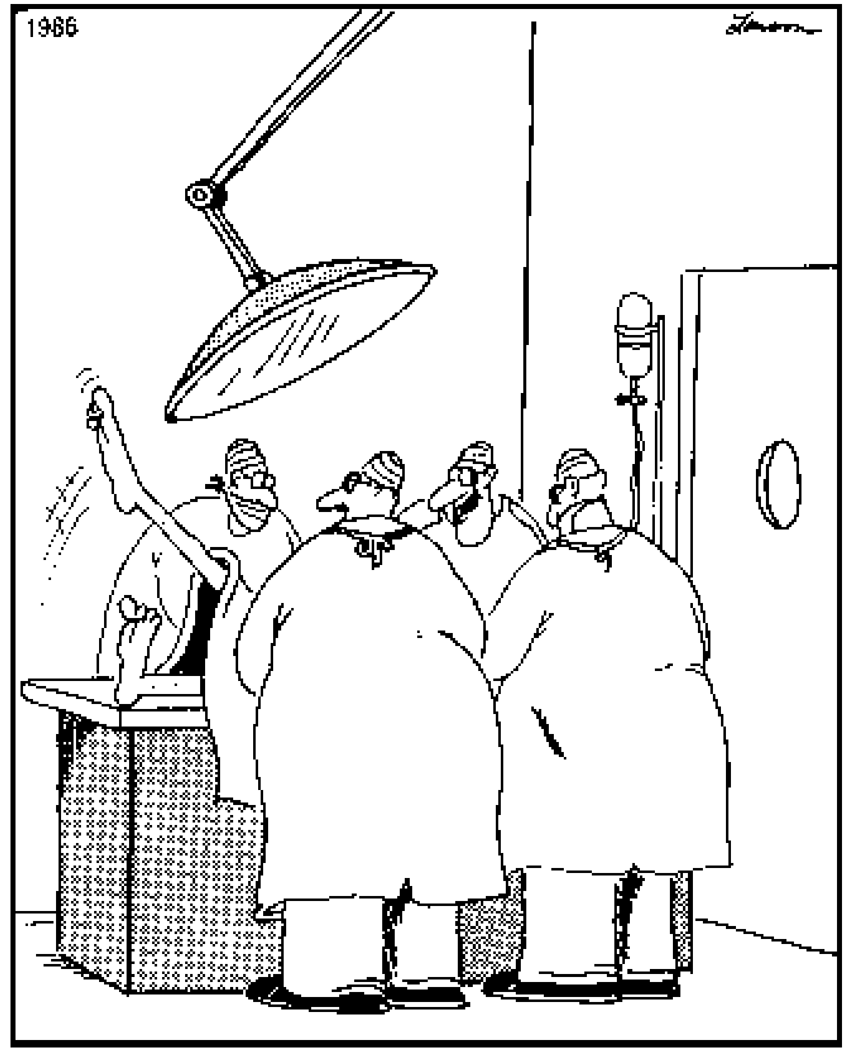
Left hemisphere

- Better ability to process temporal information
  - Understanding spoken language requires understanding rapid, serial auditory input
    - Timing/Sequence of language is important
    - Some language disorders may be due to problems with this timing ability

Handedness and language

- Functional & structural asymmetries often less pronounced in left-handed people
  - Language is more likely to be right-lateralized or bilateral
  - Family handedness counts, too
    - RH with close LH family: better ability of right hemisphere to acquire language
    - LH with LH family: more likely to be right or bilateral

Some methods for studying the brain



"Whoa! *That* was a good one! Try it, Hobbs — just poke his brain right where my finger is."

Invasive vs. non-invasive

- Invasive
  - A foreign object/substance is introduced into the brain
  - The skull is opened for direct access to the brain
- Non-invasive
  - Nothing is added to the brain
  - The skull is not opened

Invasive methods - Electrical

- Sub-dural recording
  - Dura Mater (”tough mother”) is a thick membrane between the skull and cortical surface
  - Electrodes are placed below the dura (but not inserted into cortex)
  - Electrical activity of populations of neurons is recorded

Invasive methods - Electrical

- Sub-dural stimulation
  - "Awake neurosurgery"
  - Electrical current is applied to brain sites
  - At the right threshold, this disrupts functioning of neurons near stimulation site (temporarily)
  - Apply behavioral tests to see if stimulated area is required for particular function/behavior

Invasive methods - Chemical

- Wada test
  - Barbituate sodium amytal (or similar) is injected into right or left carotid artery
  - Causes temporary anesthesia in cortex on same side as injection
    - 1 - 2 minutes per injection
  - Behavioral tests can then show if a given function is lateralized (e.g. can the subject still speak?)

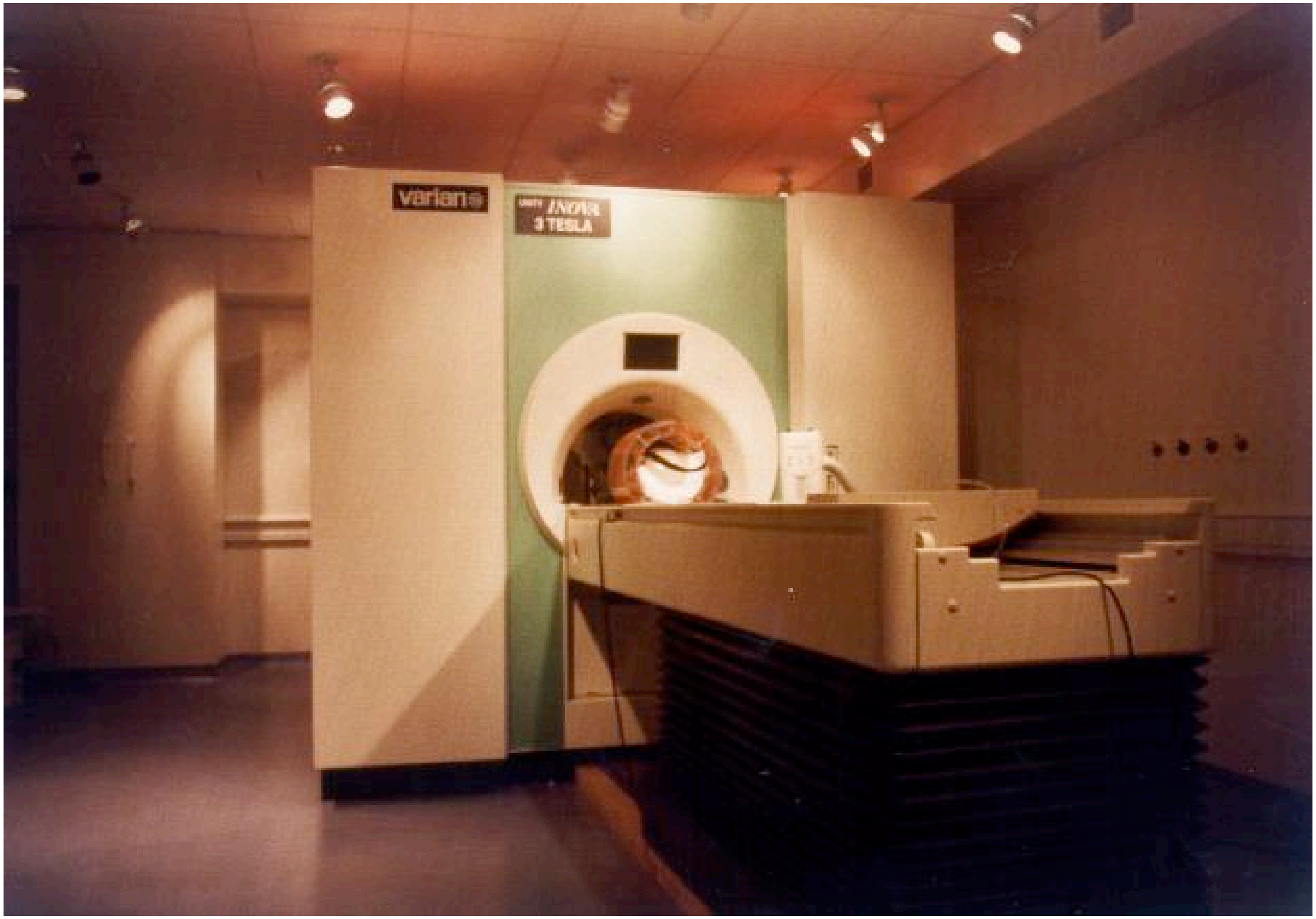
Invasive methods - Blood flow

- Positron Emission Tomography (PET)
    - Mildly radioactive glucose or oxygen are injected into the blood stream
        - Oxygen-15 is often used in cognitive studies (2 minute half-life)
    - Both are used as energy sources by the brain - and so are taken up in greater amounts by areas that are active during a given (e.g. cognitive) task
    - Detectors monitor location of radioactive emissions in the brain - localizing areas that are most active during task
    - Temporal resolution: 45 seconds
      Spatial resolution: 4mm

Non-invasive methods - Blood flow

- functional Magnetic Resonance Imaging (fMRI)
  - A steady magnetic field aligns particles of interest (e.g. hydrogen atoms)
  - A radio-frequency pulse is given which adds energy and causes the particles to tip away from the steady field
  - The energy that is released during return to steady field state is measured

- functional Magnetic Resonance Imaging (fMRI) continued...
  - Oxygenated blood and deoxygenated blood have different magnetic properties, and distort the magnetic field somewhat
  - This distortion can be detected and used see where oxygenated blood is being concentrated
    - greater oxygenation = greater neural activity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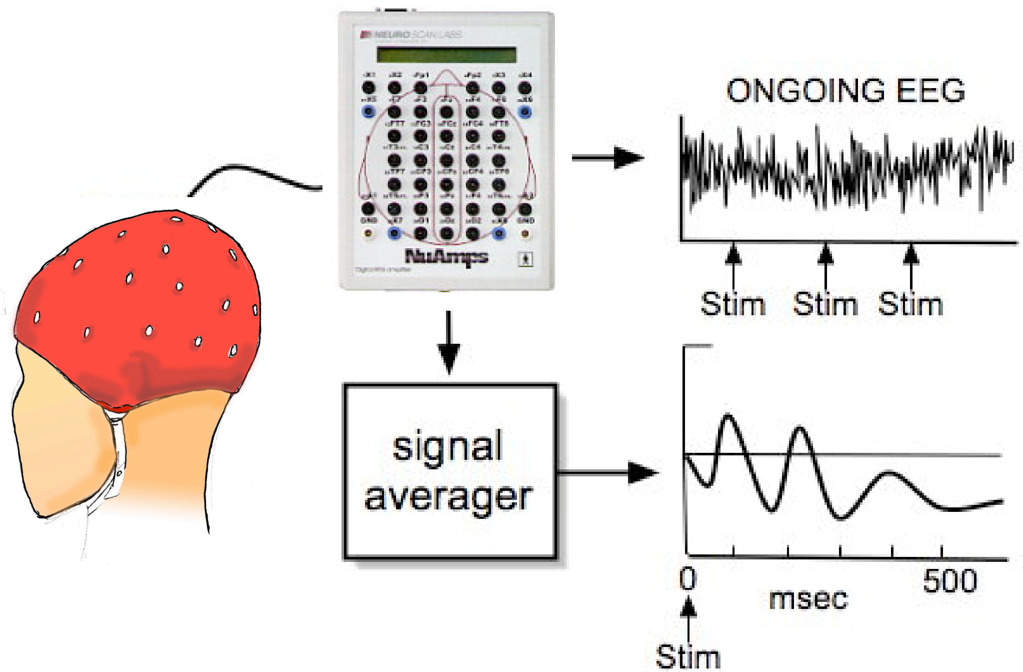
- functional Magnetic Resonance Imaging (fMRI)
  - Temporal resolution:
    - Dependent on blood-flow
    - Depends greatly on equipment and experiment design
      - Average: whole brain is scanned every 2-4 sec
      - Under ideal circumstances, resolution is on the order of 100msecs
  - Spatial resolution:
    - 1-2 millimeters with current technology

Non-invasive methods - Electrical

- Event-related brain potentials (ERPs)
  - Pyramidal cells in cortex firing synchronously generate an electrical field that can be measured
    - Electroenchephalogram (EEG)
  - Present stimuli to subject, time-lock EEG response and measure changes in electrical activity as a result of stimuli

Non-invasive methods - Electrical



Non-invasive methods - Electrical

- Temporal resolution:
  - Limited by technology
  - Most language studies: 3-5 milliseconds
  - Auditory studies: faster
- Spatial resolution: Largely unreliable

Acquired language disorders: Aphasia

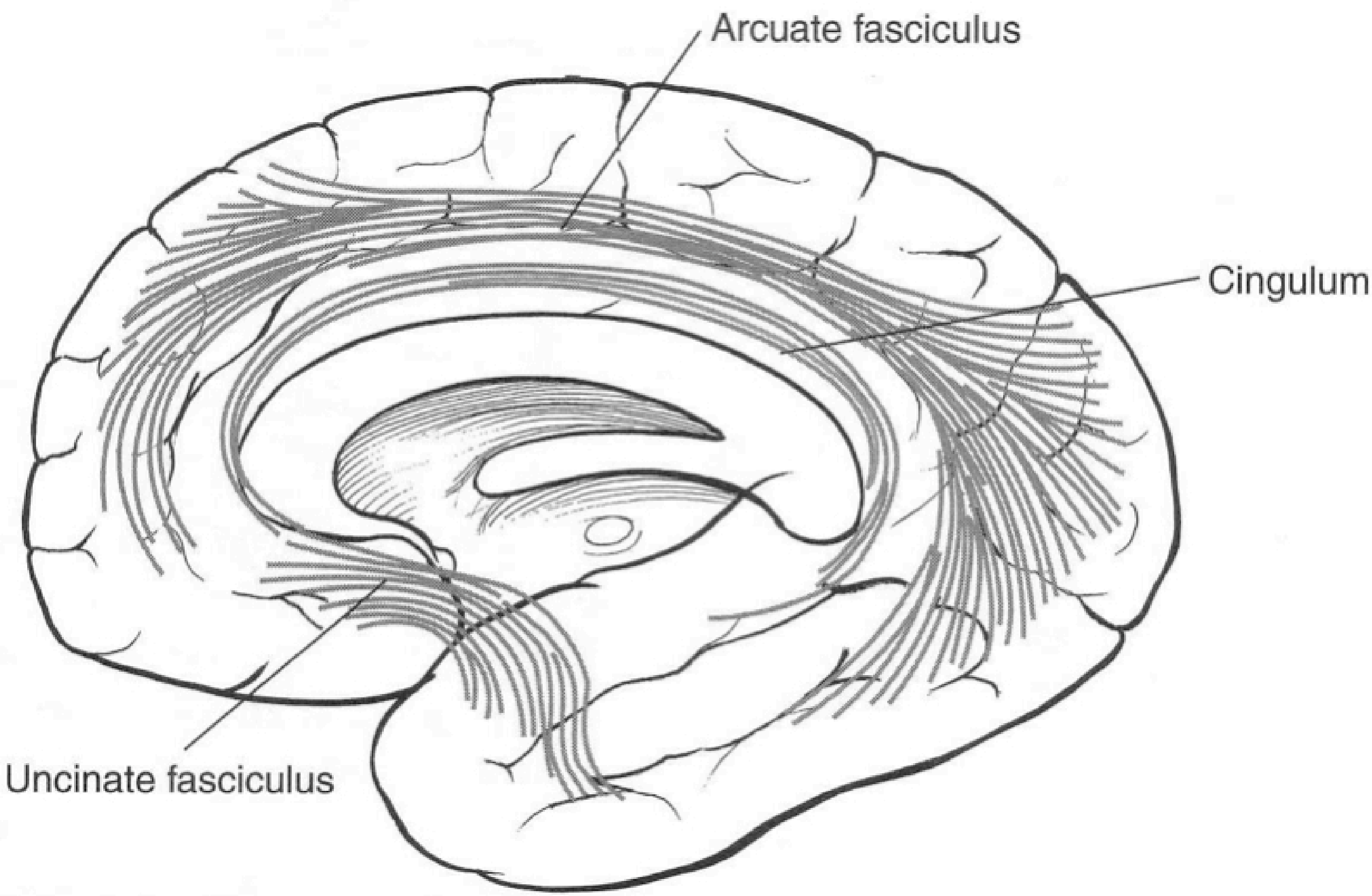
Grain of salt

- Dangers of mapping deficits to the brain
  - Functional deficit plus brain lesion does not necessarily equal localization of function
- Classic example:
  - If you take a resistor from a radio and it squawks - this does not mean that the resistor is a squawk suppressor

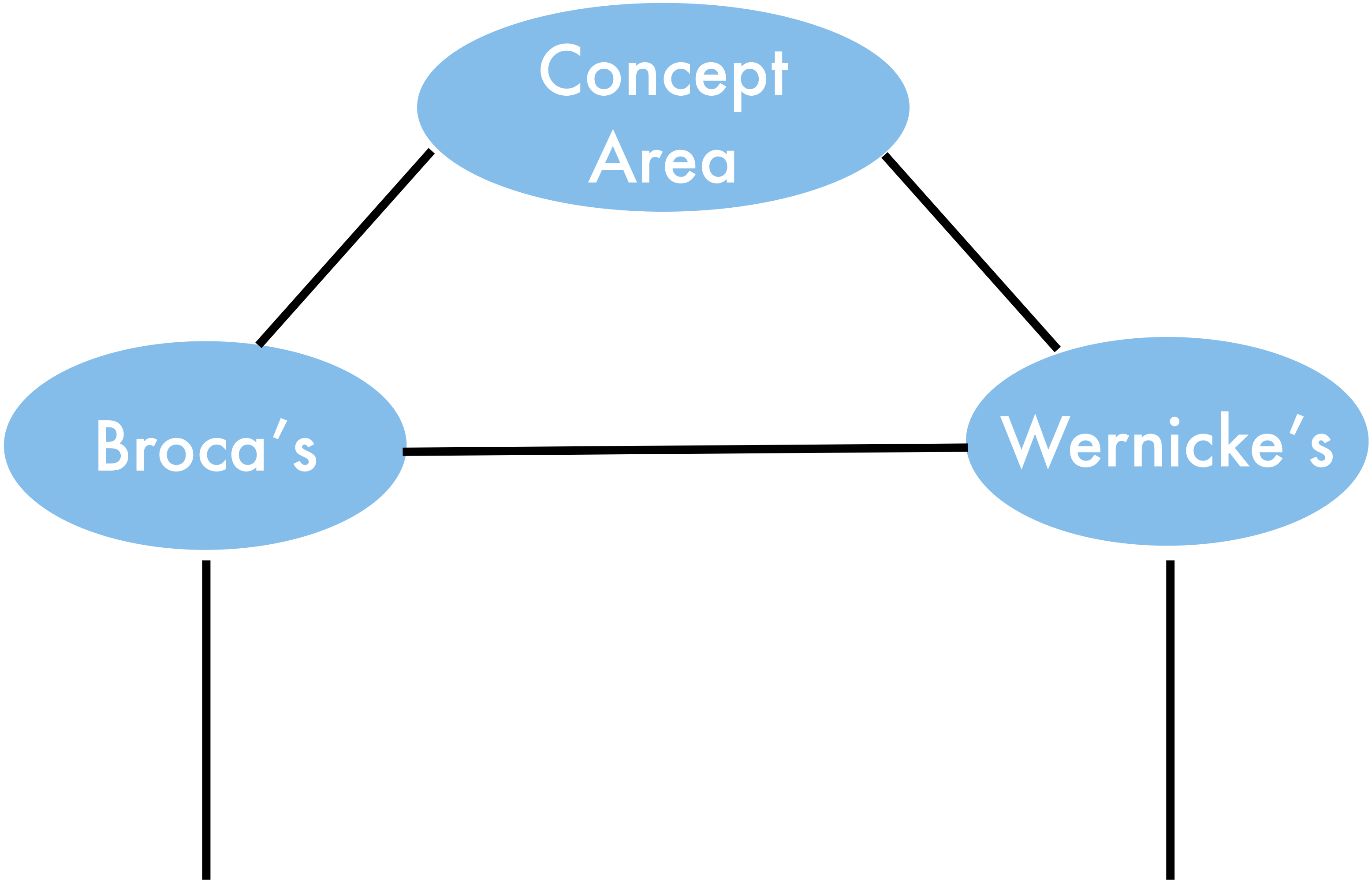
A bit of historical perspective

- Paul Broca
  - 1861, Paris, Patient Lebourge (” Tan “)
- Carl Wernicke
  - 1874 Paper
    - Proposed subtypes of aphasia & model
    - Described second aphasia
    - Predicted a third: Lesion of connection between Broca’s frontal area and his temporal one

Major fasciculi in the brain



Classic Model of Aphasia



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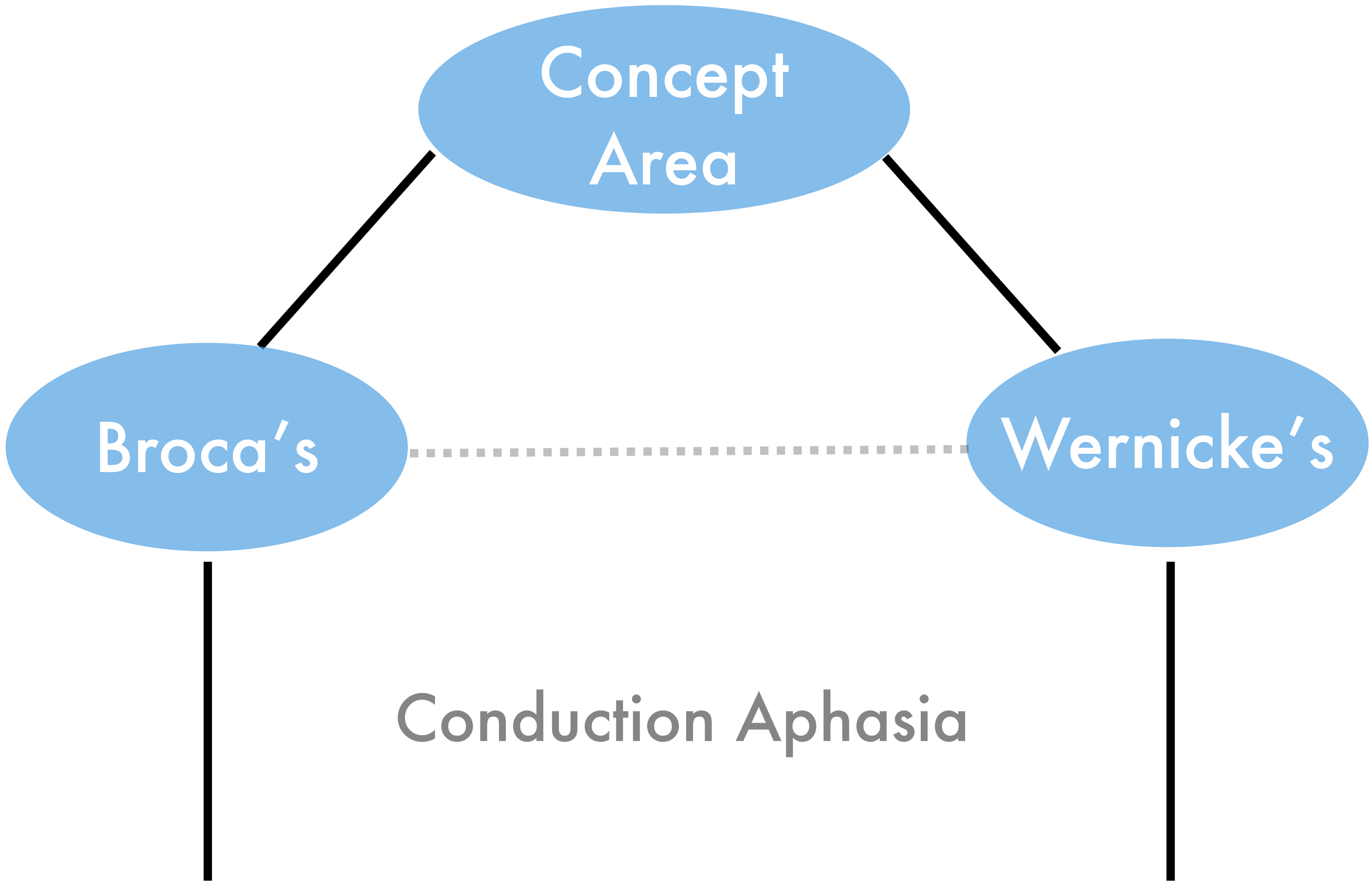

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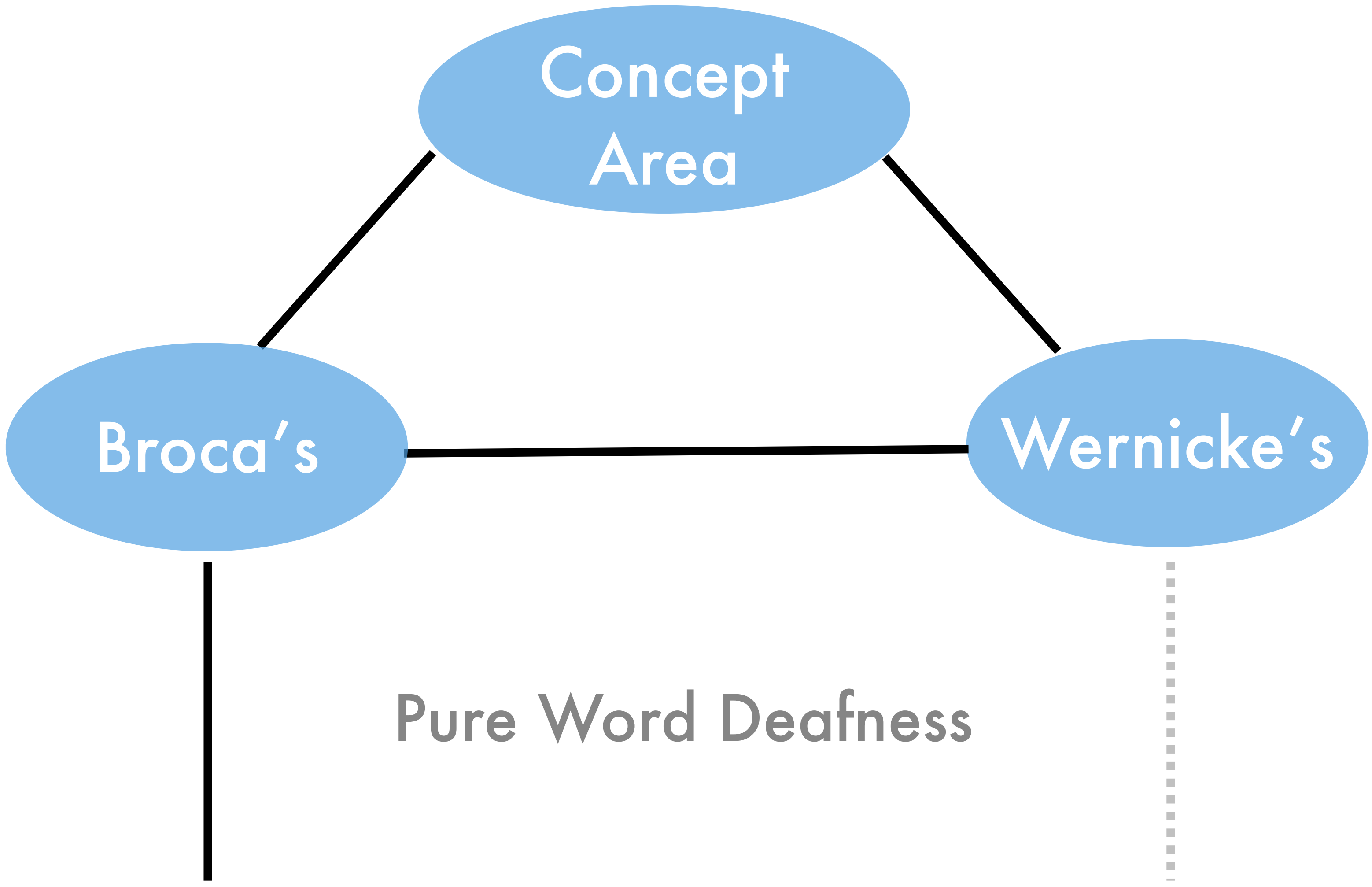

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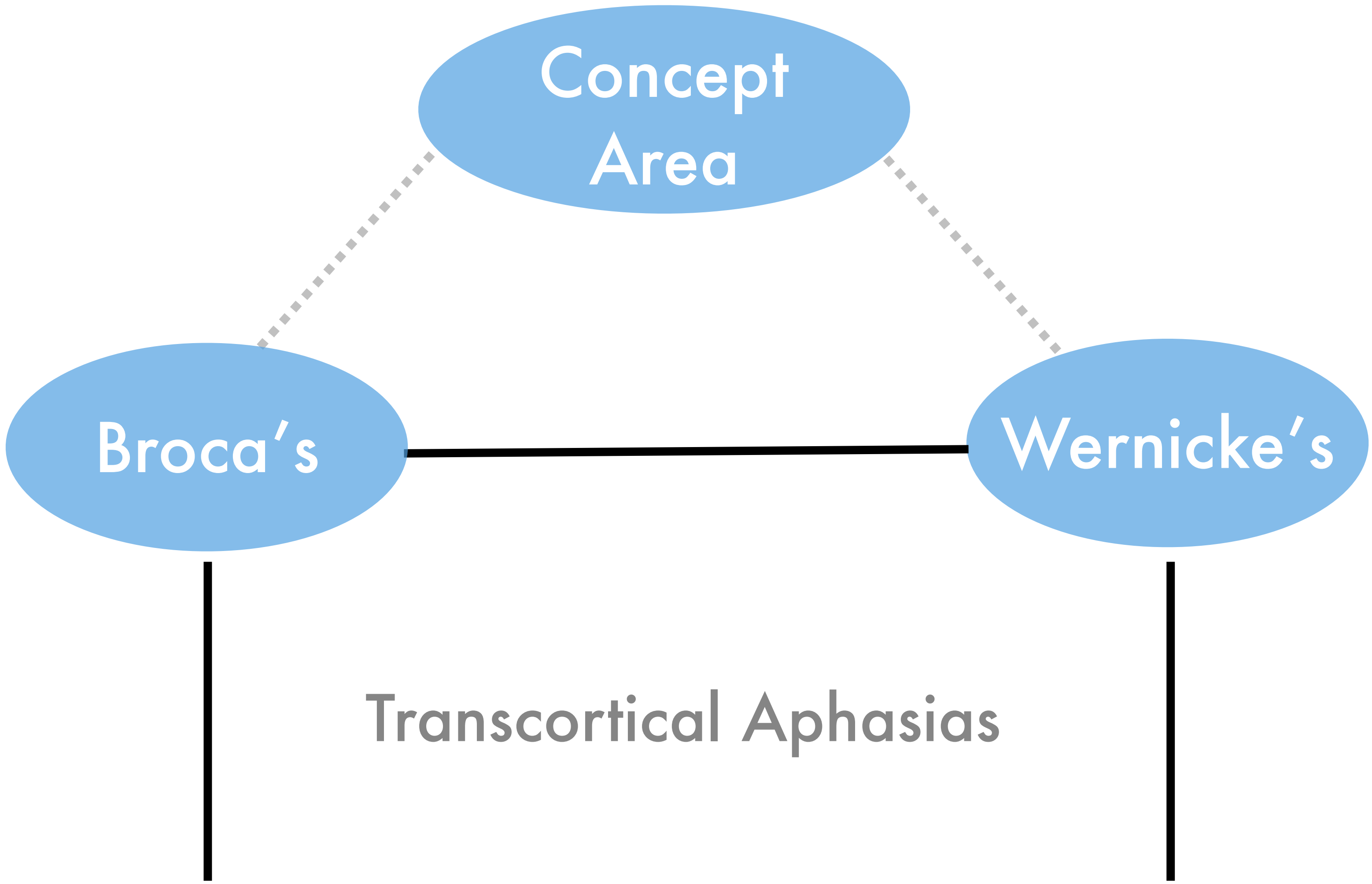
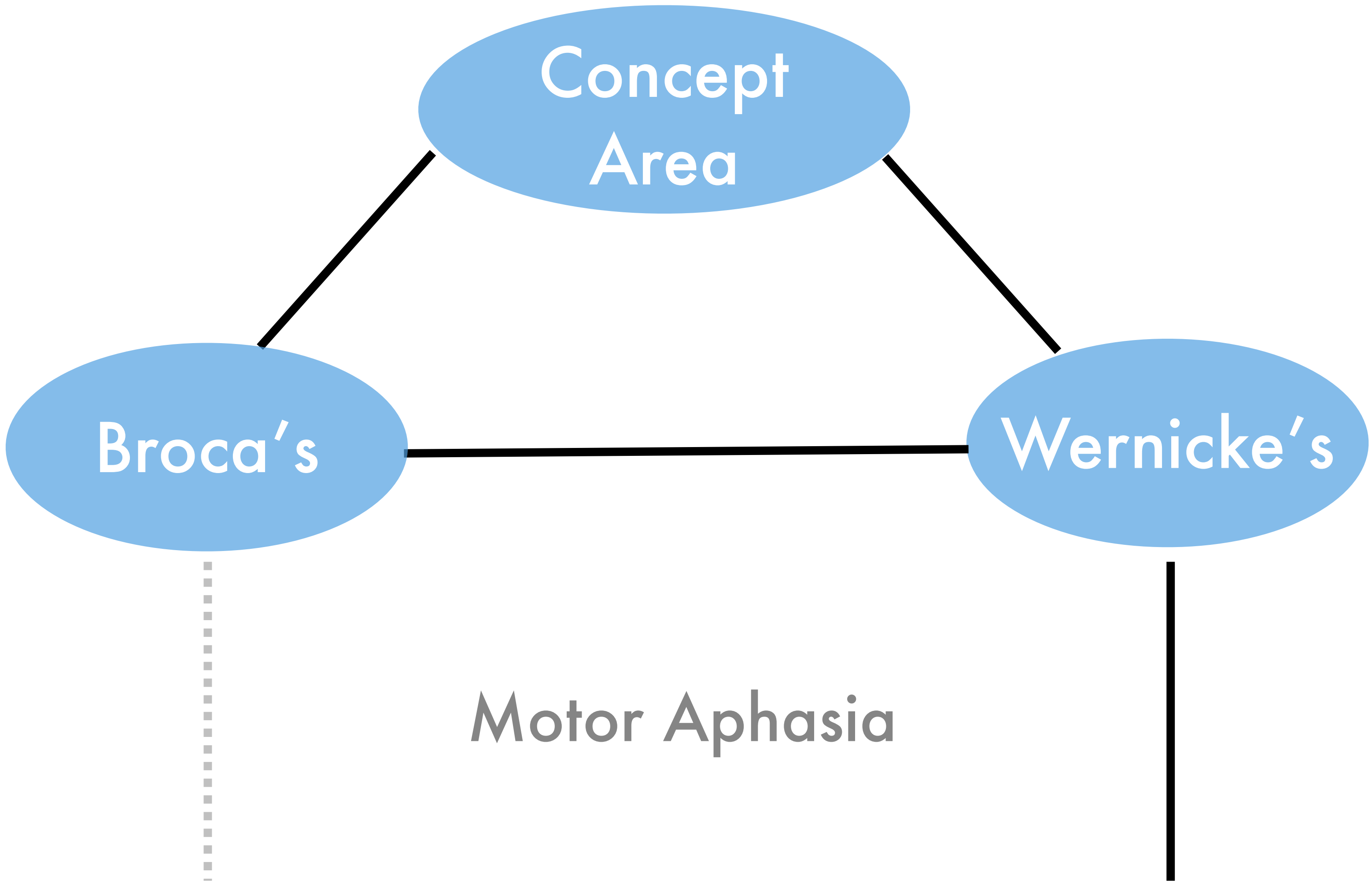


Classic Model of Aphasia



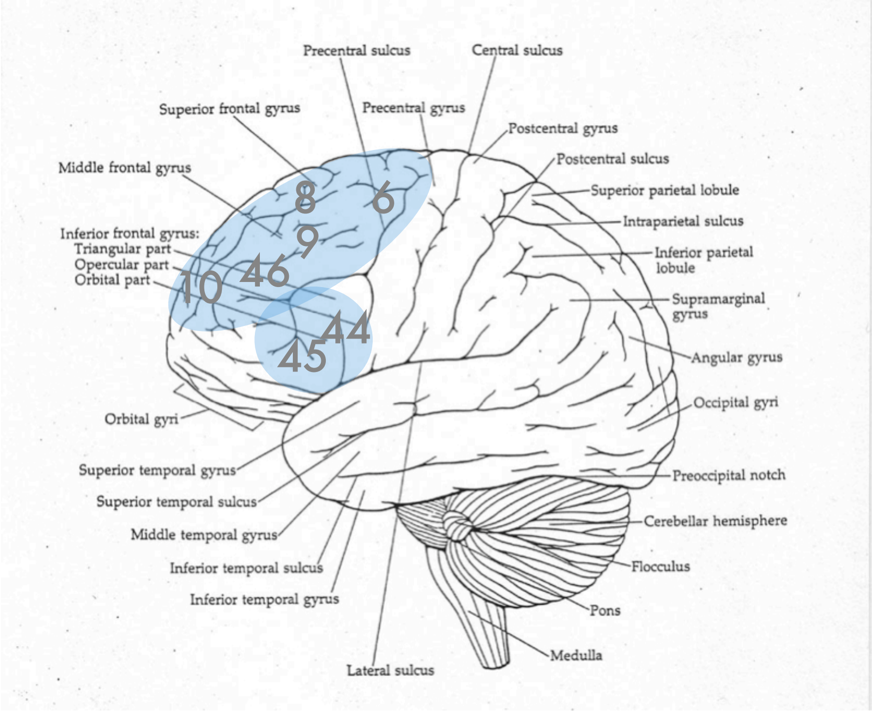
Motor Aphasia

A modern view

- Lichtheim´s model has been refined many times and is still conceptually important in the classification of aphasias
- Newer models of aphasia no longer focus on a few localized brain regions
  - The focus is on the interaction of networks of neurons encompassing both cortical and subcortical areas

Broca´s aphasia

- “True” Broca’s Aphasia
  - Damage to classical Broca’s area & white matter
  - Surrounding frontal areas
  - Basal ganglia
- Broca’s Area Aphasia
  - Damage limited to Broca’s area
  - Mild, temporary aphasia



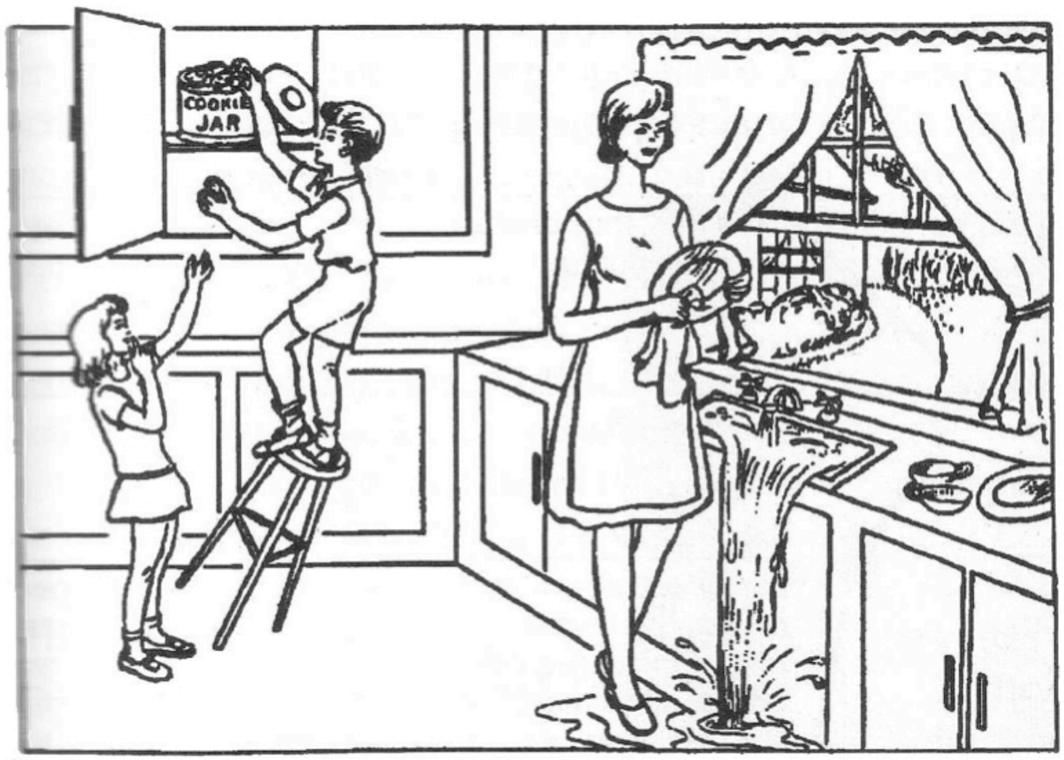
True Broca´s aphasia

- Nonfluent speech: effortful and slow
  - Lots of pauses
  - Difficulty with function words
    - conjunctions, prepositions
- Agrammatic speech
  - Lack of grammatical morphemes
    - Past tense, number agreement
- Difficulty with repetition

True Broca´s aphasia

- Phoneme distinguishing problems
  - Closely related phonemes (e.g. /p/ & /b/)
  - Comprehension problems
  - Difficulty understanding reversable passive sentences
    - The girl was kissed by the boy

Boston Diagnostic Aphasia Examination

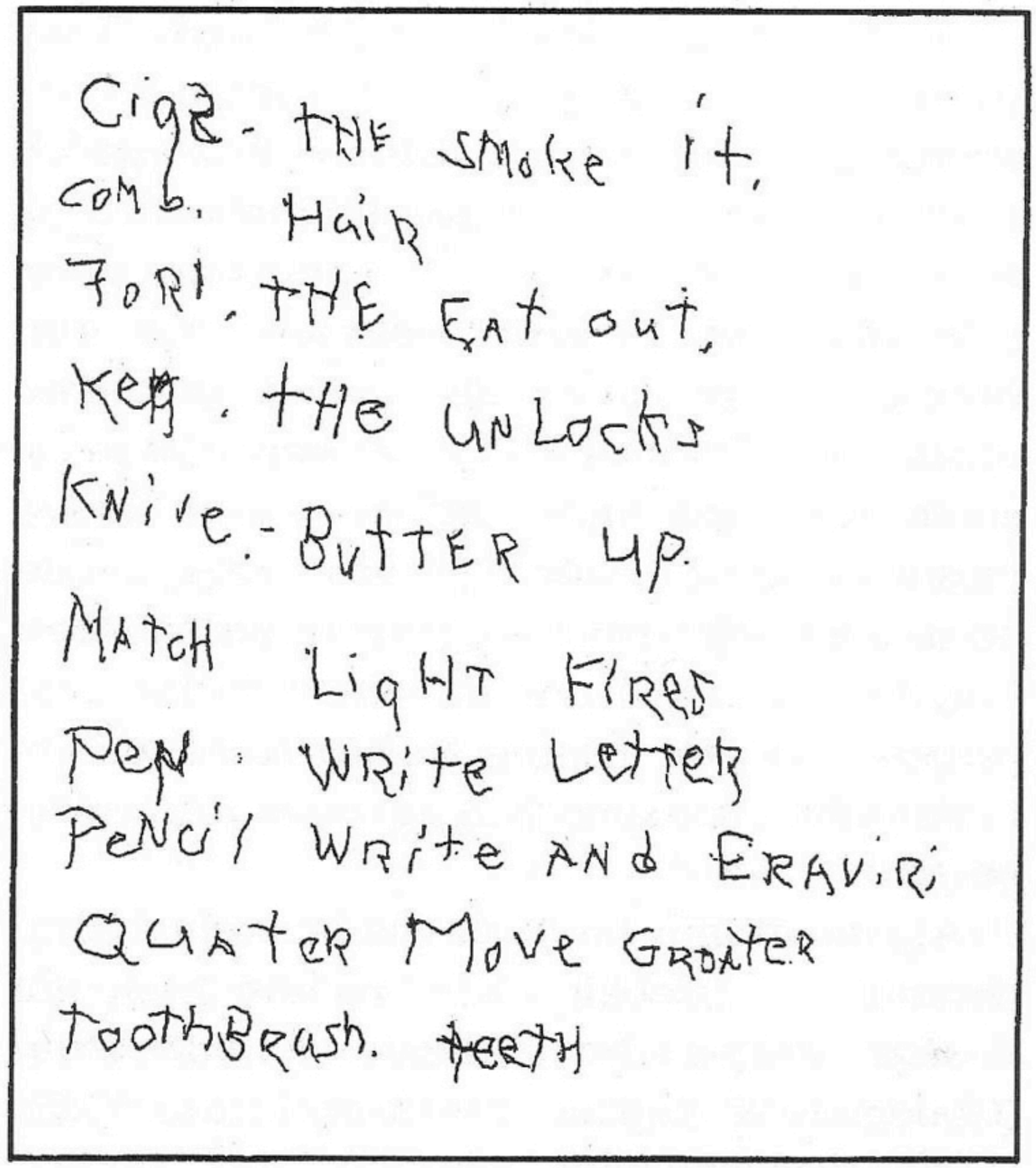


uh ... mother and dad ... no ... mother ... dishes ... uh ... runnin over ...water ... and floor ... and they ... uh ... wipin disses ...and ... uh ... two kids ... uh .. stool ... and cookie ... cookie jar ... uh ... cabinet and stool ... uh ... tipping over ... and ... uh bad ... and somebody ... gonna get hurt.

Porch Index of Communicative Ability

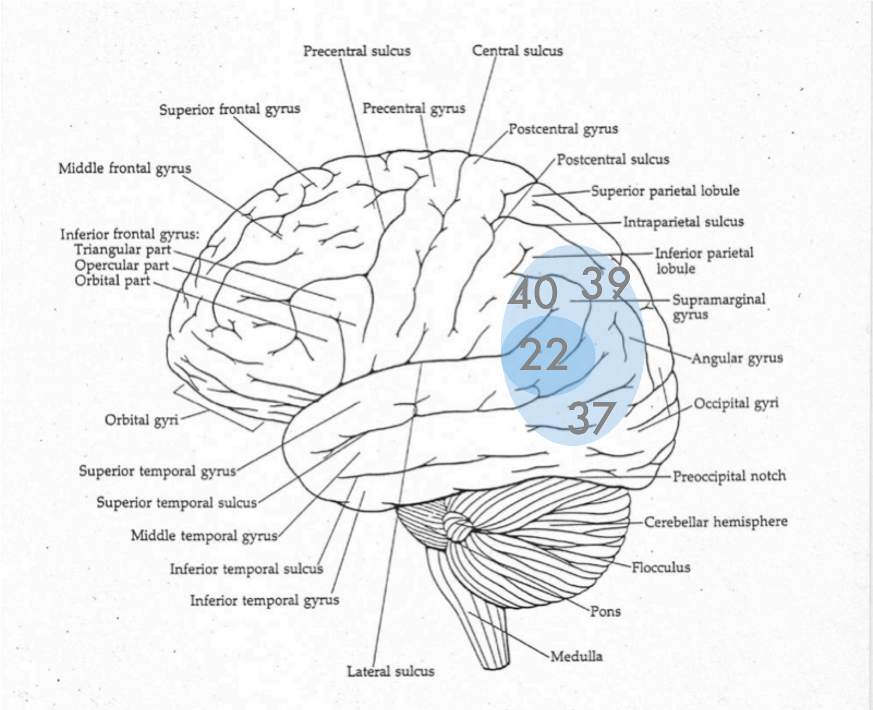
- What does one do with:

  cigarette
  comb
  fork
  key
  knife
  match
  pen
  pencil
  quarter
  tooth brush



Wernicke´s Aphasia

- Fluent speech
- Phonemic errors
- Substitution errors
- Neologisms
- Difficulty with repetition
- Difficulty with comprehension
- Poor short-term memory



Examples of Speech

- Clinician: *Tell me where you live.*
- Patient: *Well, it's a meender place and it has two.. two of them. For dreaming and pinding after supper. And up and down. Four of down and three of up.*

Examples of Speech

- Concluding an description of a shopping trip
- *I went down to the thing to do the other one and she was only the last one that ever did it, so I never did.*

Examples of Speech

- Describing what the patient had for breakfast:
- *This morning for - that meal - the first thing this morning - what I ate - I dine on - chickens, but little - and pig- pork- hen fruit and some bacon, I guess*

Porch Index of Communicative Ability

- What does one do with:

  cigarette
  comb
  fork
  key
  knife
  match
  pen
  pencil
  quarter
  toothbursh

6 That cigarette is not easy.

7 I do have a comb in my pocket all the time,

6 I go in the kitchen three times a day so I put the fork, knife-spoon in my

7 I do have keys in my pocket for Pickup or car, homes, school, church, want in the Building.

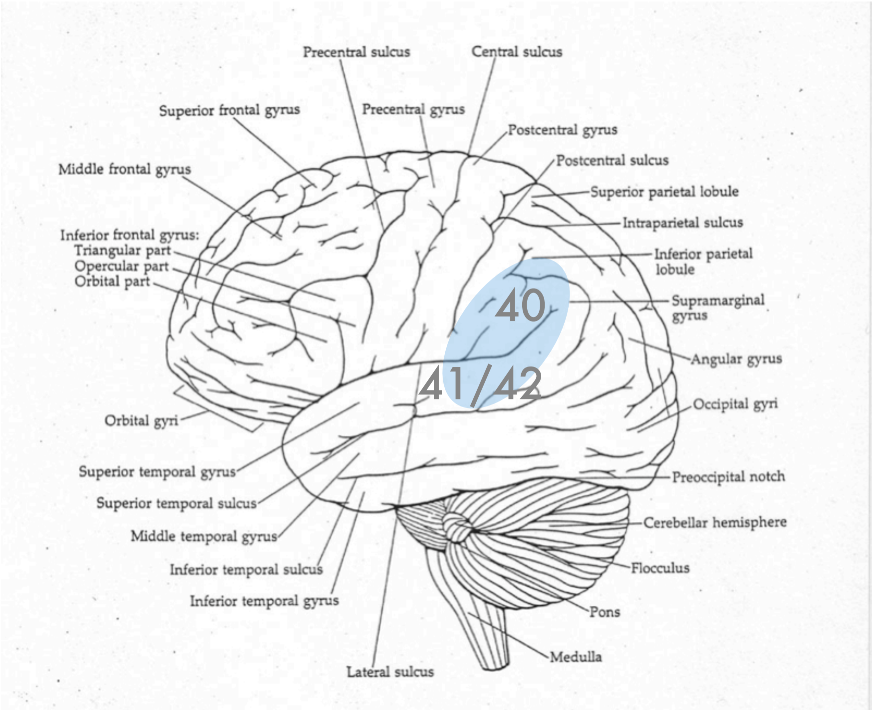
7 I do have pens-pencil in my pocket and even matches to.

1 I put the quarter in my pocket

12 I do brush the teeth every days

Conduction Aphasia

- Includes damage to the Arcuate Fasciculus with sparing of Broca´s and Wernicke´s areas
- Difficulty with repetition
- Phonemic errors
- Difficulty with "confrontation naming"



Repetition Errors

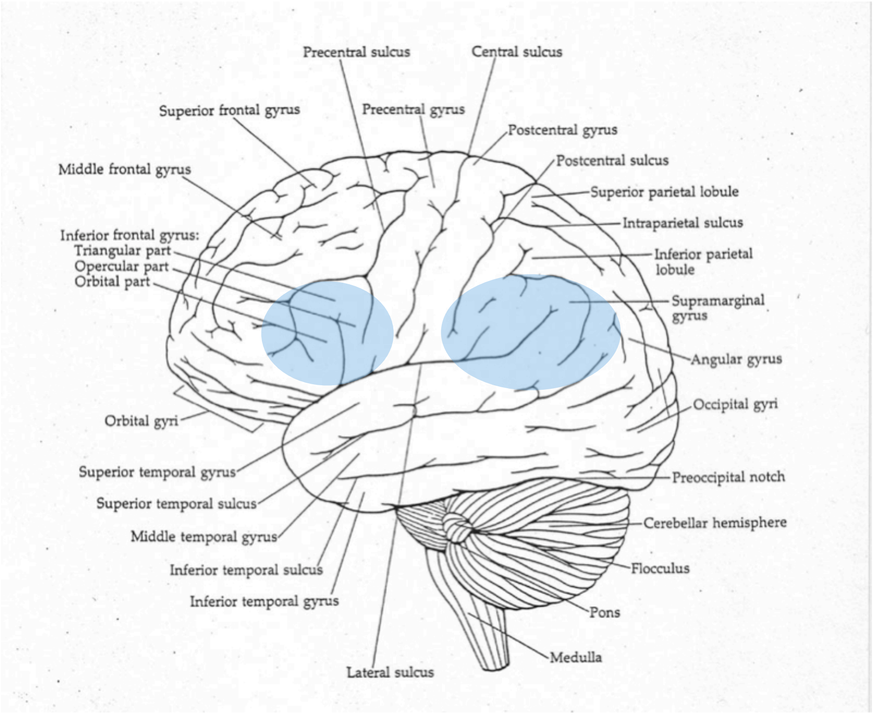
- **Clinician:** Now, I want you to say some words after me. Say 'boy'.
- **Patient:** Boy
- **Clinician:** Home
- **Patient:** Home
- **Clinician:** Seventy-nine
- **Patient:** Ninety-seven. No ... sevinty-sine... siventy-nice
- **Clinician:** Let's try another one. Say 'refrigerator'.
- **Patient:** Frigilator ... no? How about ... frerigilator.... no... frigaliterater .... aaah! It's all mixed up!

Phonemic errors

- Trying to say the word “circus”
- *It’s a kriskus … No, that’s not right, but it’s near. …Sirsis… No… This is very strange that I can’t say thsi word… How about kirsis? …No… I’ll have to by that. Kriskus? For some reason I can’t say it right now. But I’m close. Kirsis? No…*

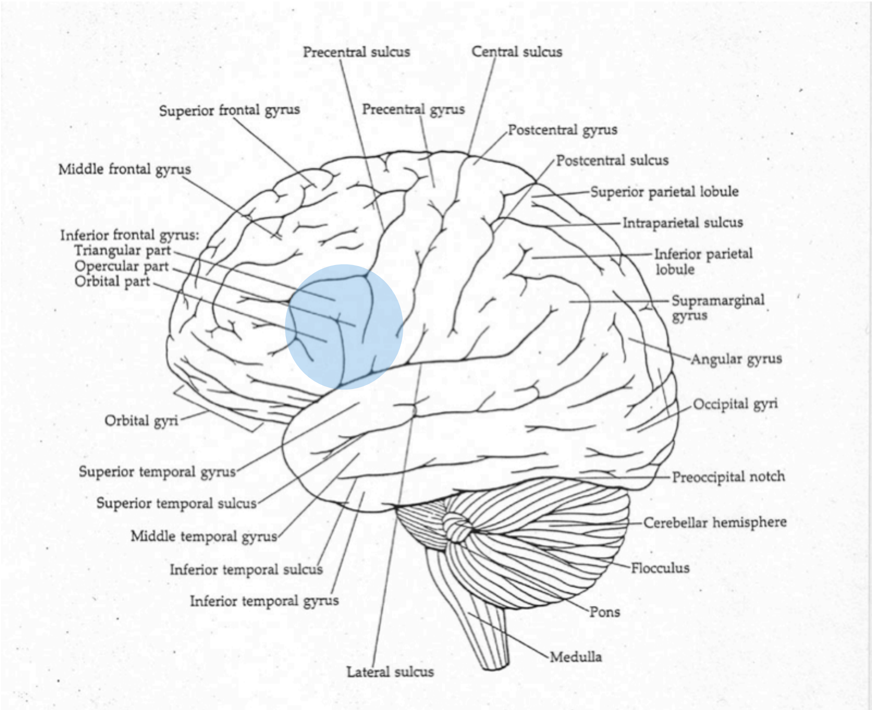
Global aphasia

- Also lesion in the Basal Ganglia
- Almost complete loss of language
- Automatic speech can be preserved
  - Expletives
  - Counting
  - Days of week
- Often accompanied by weakness on right side of face



Transcortical motor aphasia

- Broca's Area plus extensively into underlying white matter
- Largely mute
- Largely agrammatic
- Comprehension can be quite good
- Relatively intact repetition



Anomia

- Can result from damage in any areas discussion
- Often the final state after recovery from aphasias
- Overall, language skill is good
- Distinct word-retrieval problems
- Can be accompanied by mild signs of other aphasias

Alexia & agraphia

- Alexia: The inability to read
- Agraphia: The inability to write
- Can have alexia *without* agraphia
  - Connections between Wernicke's area and visual cortex are damaged
    - Left hemisphere cannot see the information, right cannot process it
  - Connections between Wernicke's area and motor planning/control regions remains intact