Introduction to Neurolinguistics

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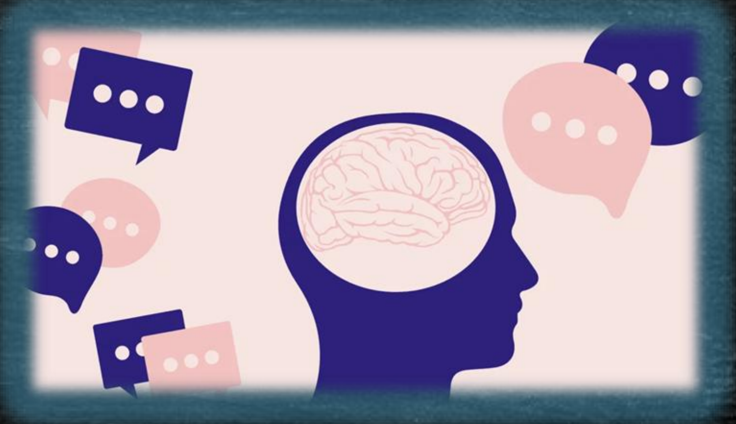
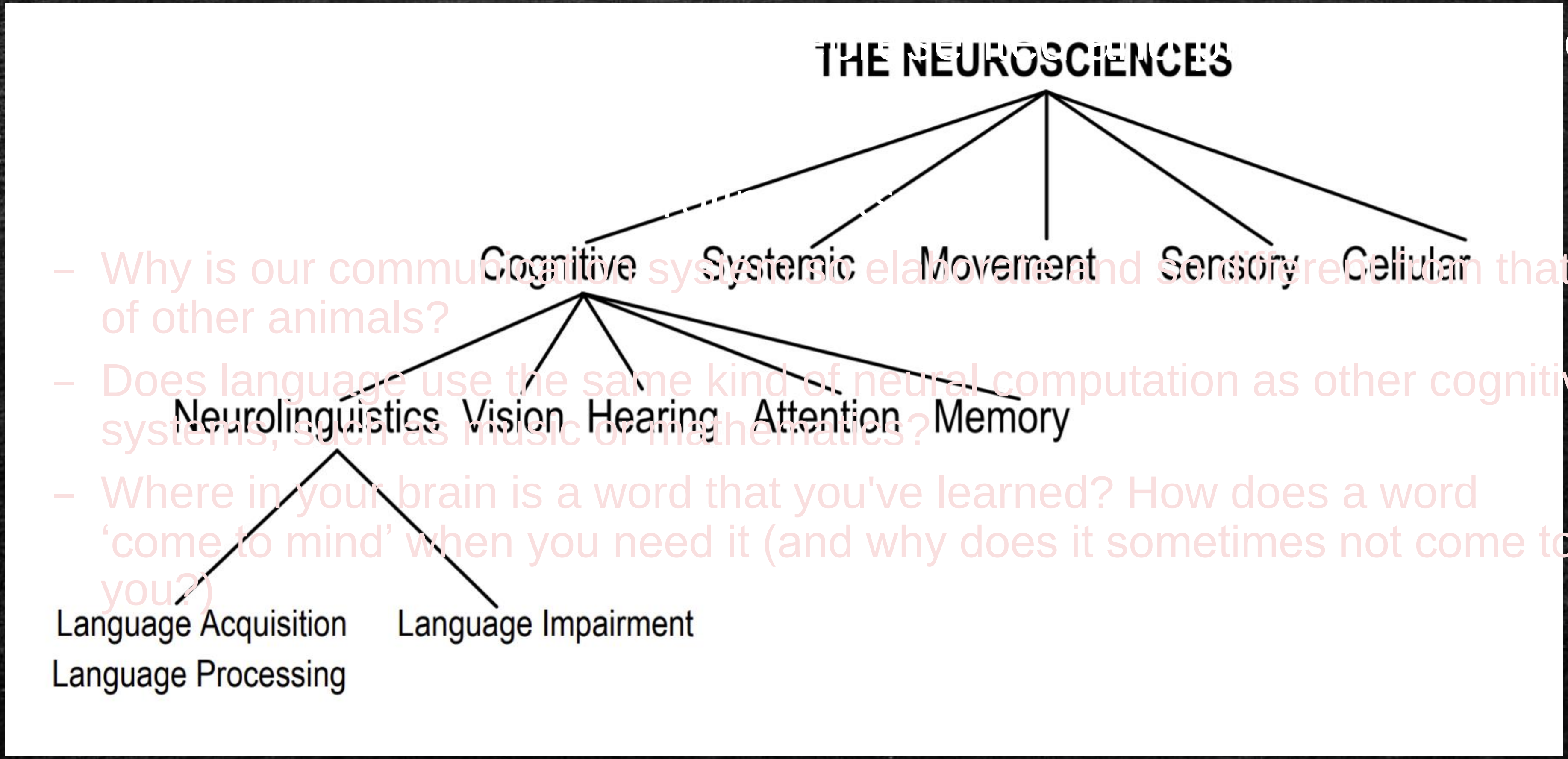
Roadmap

- What is Neurolinguistics?
- Introduction to the Nervous System
- Language Representation in the Brain
  - Early Models
  - New techniques
- Language Processing in the Brain
- Developmental Neurolinguistics (Language Acquisition)



What is Neurolinguistics?



- Why is our communication system so elaborate and so different from that of other animals?
- Does language use the same kind of neural computation as other cognitive systems, such as music or mathematics?
- Where in your brain is a word that you've learned? How does a word ‘come to mind’ when you need it (and why does it sometimes not come to you?)

The Nervous System- The Basics

- Misconceptions about the Brain:

※ We use only some portion of the neurons.

✓ We use all of the neurons in our brains.

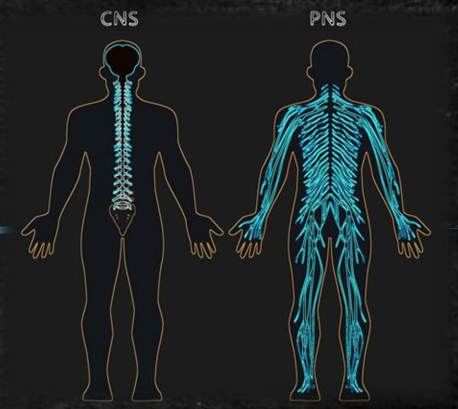
※ The brain declines as you get older.

✓ Though some cognitive functions do decline as you get older, plenty of your mental skills (e.g. cognitive control, comprehension) actually improve with age.

※ The brain does not change through out life.

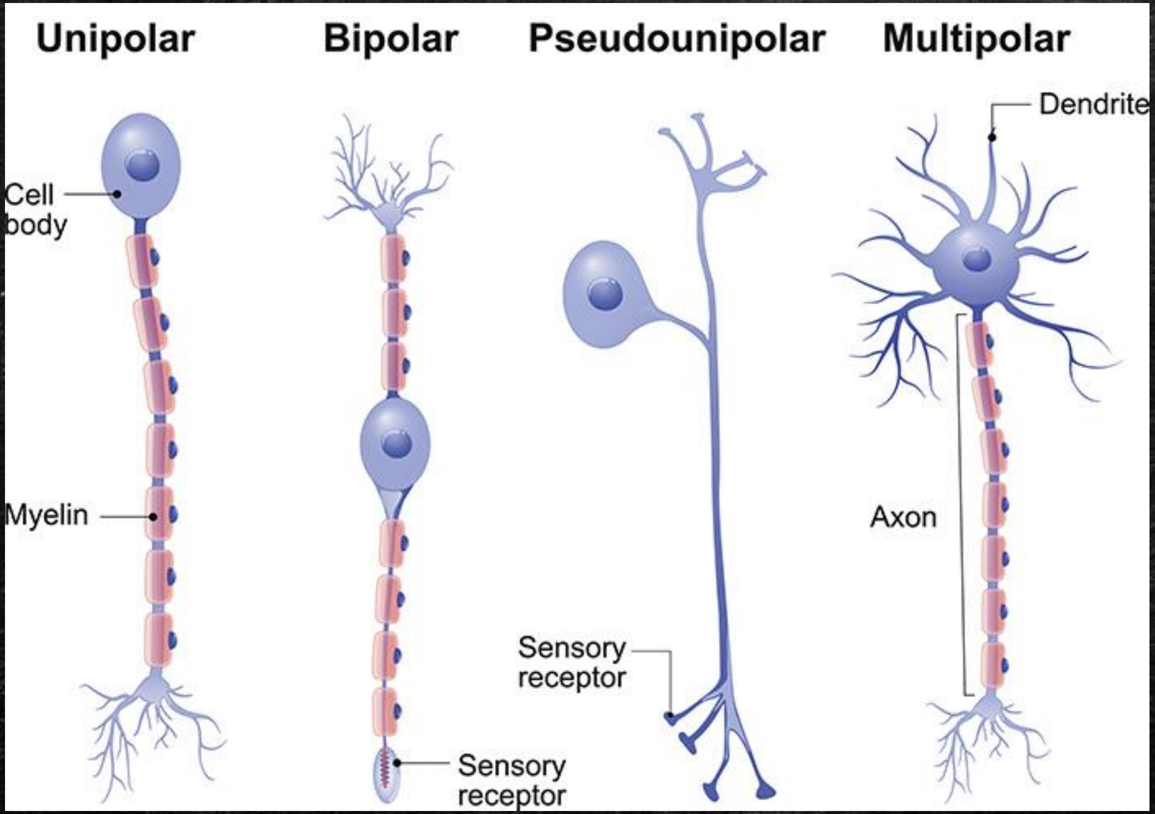
✓ The brain is constantly changing (neuroplasticity) through out life.

The Nervous System- The Facts

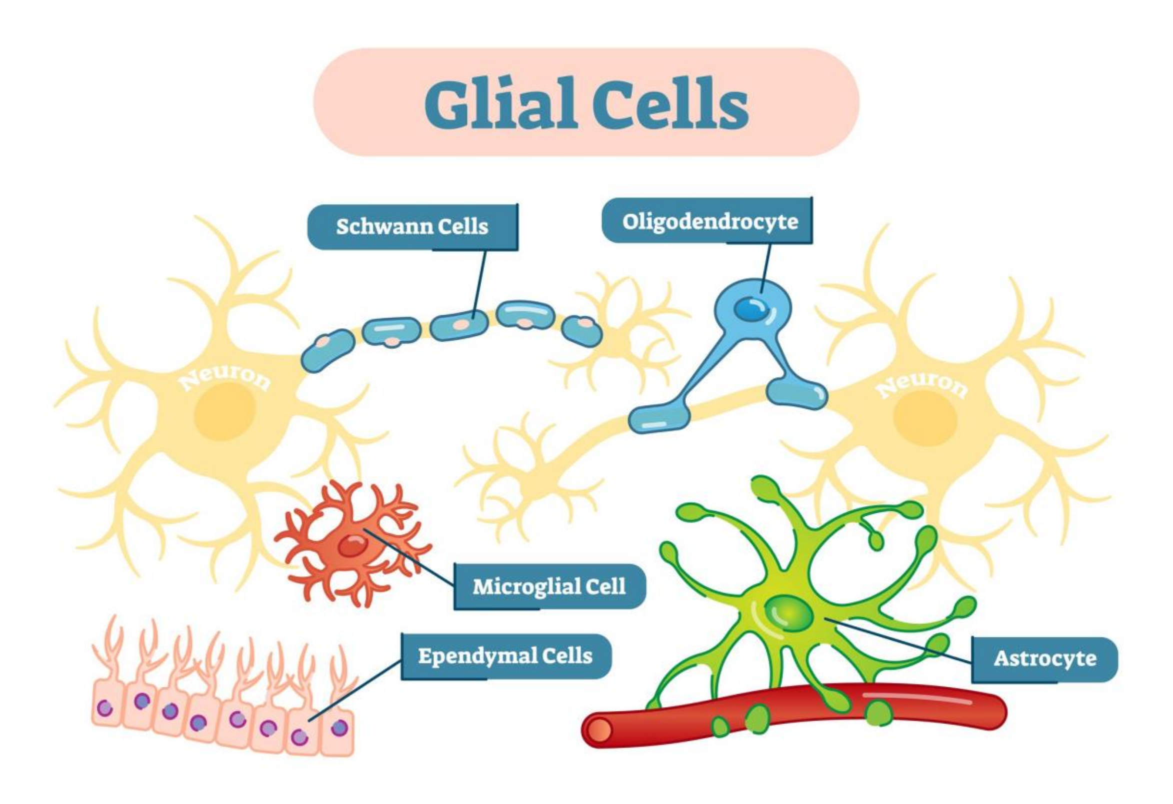


- A human brain contains roughly 86 billion nerve cells, or neurons.
- The nervous system keeps our bodies in sync by communicating with all other parts of our bodies, like the cardiovascular system, the gastrointestinal system, the immune system.
- Neurons talk to each other using both electrical and chemical signals.
- Your nervous system is filled with circuits made up of neurons that relay messages around your brain and body. They're responsible for everything you think, do, say, and feel.

The Nervous System – The Cells



Neurons

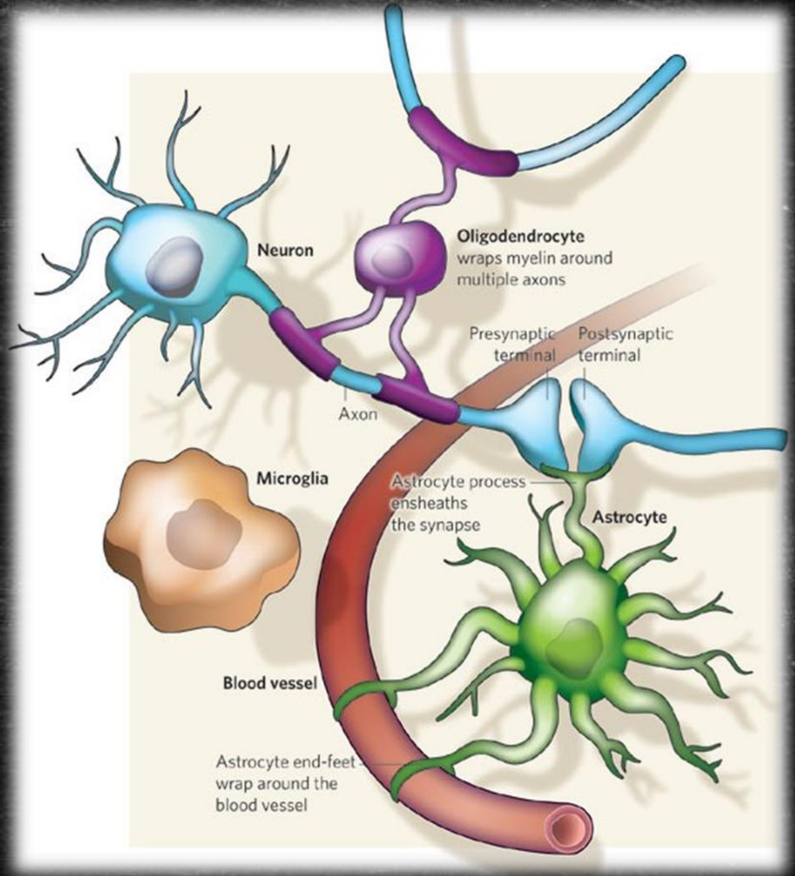


Glial Cells

Glial Cells

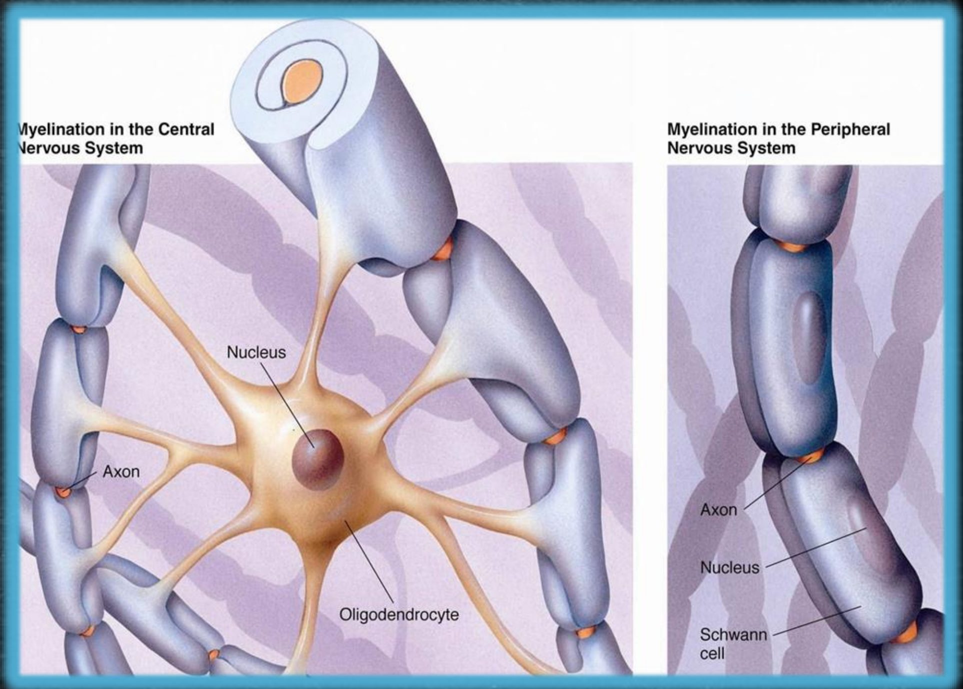
- Central Nervous System
  - Astrocytes
  - Microglial Cells
  - Oligodendrocytes

- Peripheral Nervous System
  - Schwann Cells



Oligodendrocytes and Schwann Cells

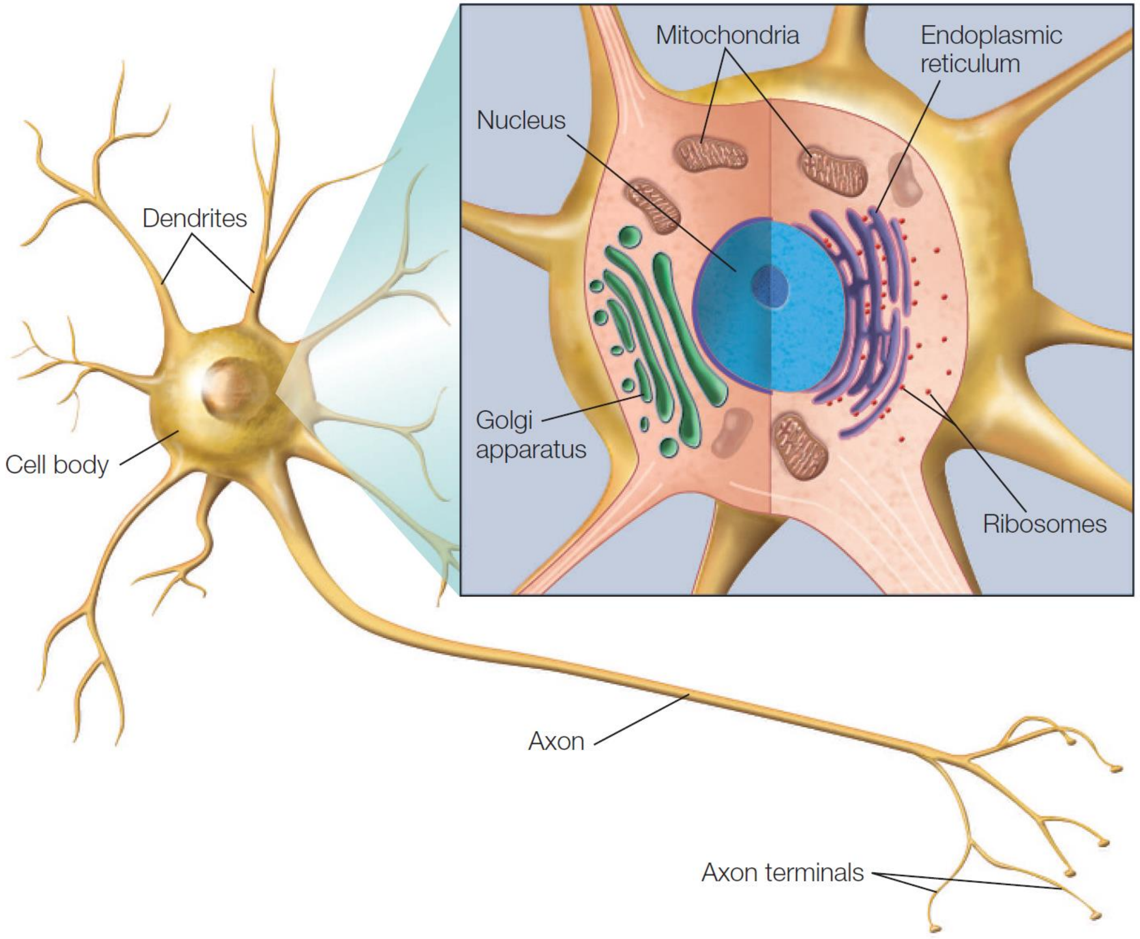
- Oligodendrocytes and Schwann cells form the fatty substance called **myelin** in the nervous system.
- Myelin is a good electrical insulator, preventing loss of electrical current across the cell membrane.
- It increases the speed and distance that information can travel along a neuron.



Neurons

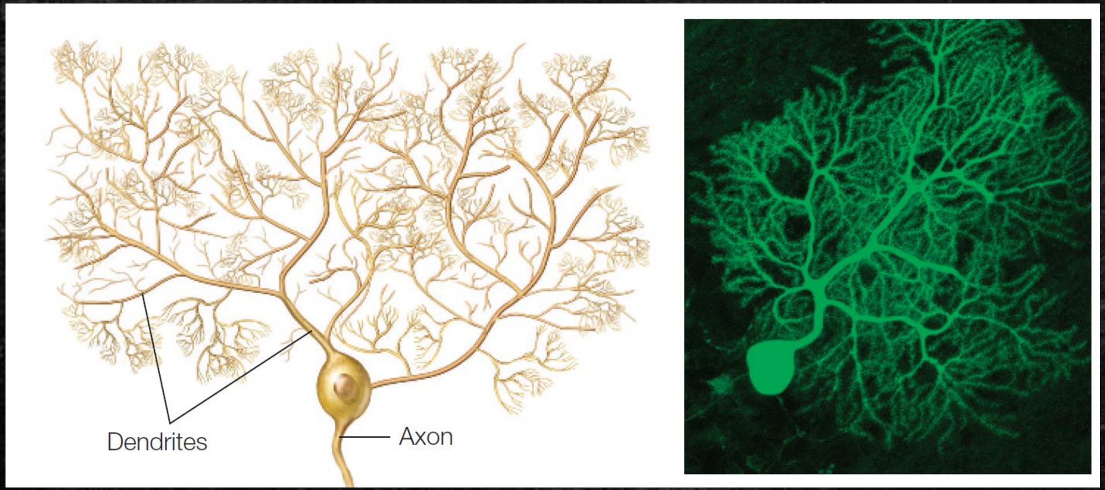
Source: Cognitive Neuroscience: The Biology of the Mind by Michael Gazzaniga, Richard Ivry and George Mangun, W.W. Norton, 1998.

FIGURE 2.4 Idealized mammalian neuron.
A neuron is composed of three main parts: a cell body, dendrites, and an axon. The cell body contains the cellular machinery for the production of proteins and other macromolecules. Like other cells, the neuron contains a nucleus, endoplasmic reticulum, ribosomes, mitochondria, Golgi apparatus, and other intracellular organelles (inset). The dendrites and axon are extensions of the cell membrane and contain cytoplasm continuous with the cytoplasm inside the cell body.

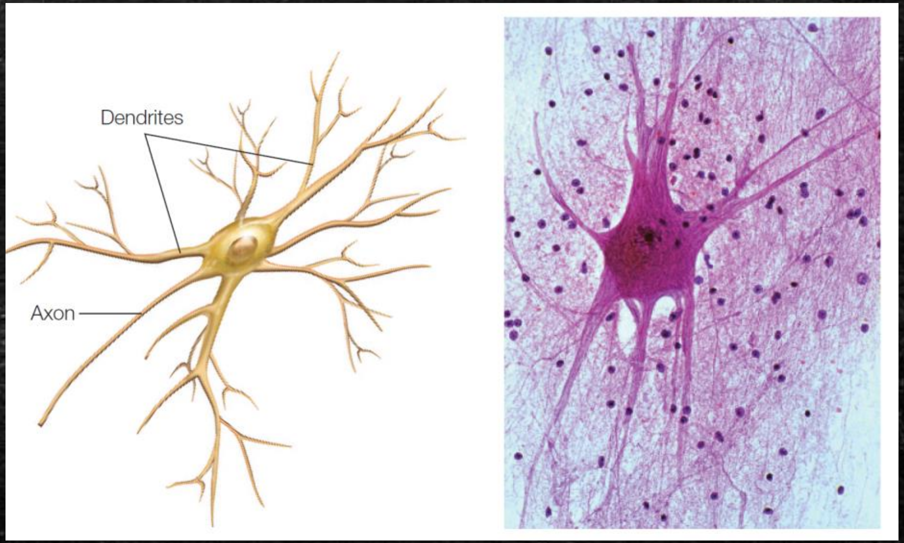


Neurons - Dendrites

- Dendrites are branching extensions of the neuron that receive inputs from other neurons.



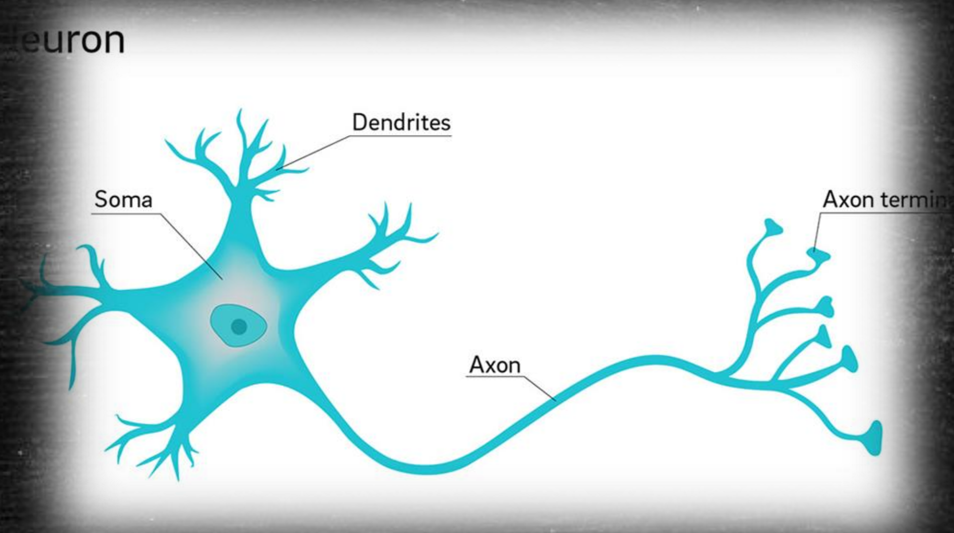
Purkinje cells



Spinal motor neurons

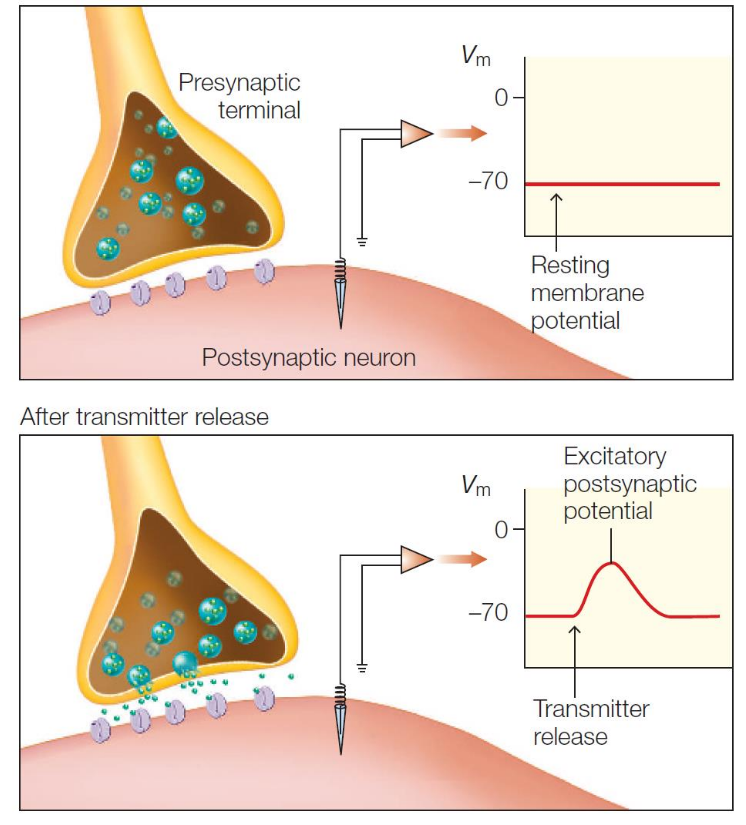
Neurons - Axons

- The **axon** is a single process that extends from the cell body.
- Electrical signals travel along the length of the axon to its end, the axon terminals, where the neuron transmits the signal to other neurons or other targets.



Synaptic Transmission

- Neurons communicate with other neurons and cells at specialized structures called synapses, where chemical and electrical signals can be conveyed between neurons.



Quick Quiz 1

Which of the following are specialized population of macrophages (immune cells) that are found in the central nervous system?

A) Schwann Cells

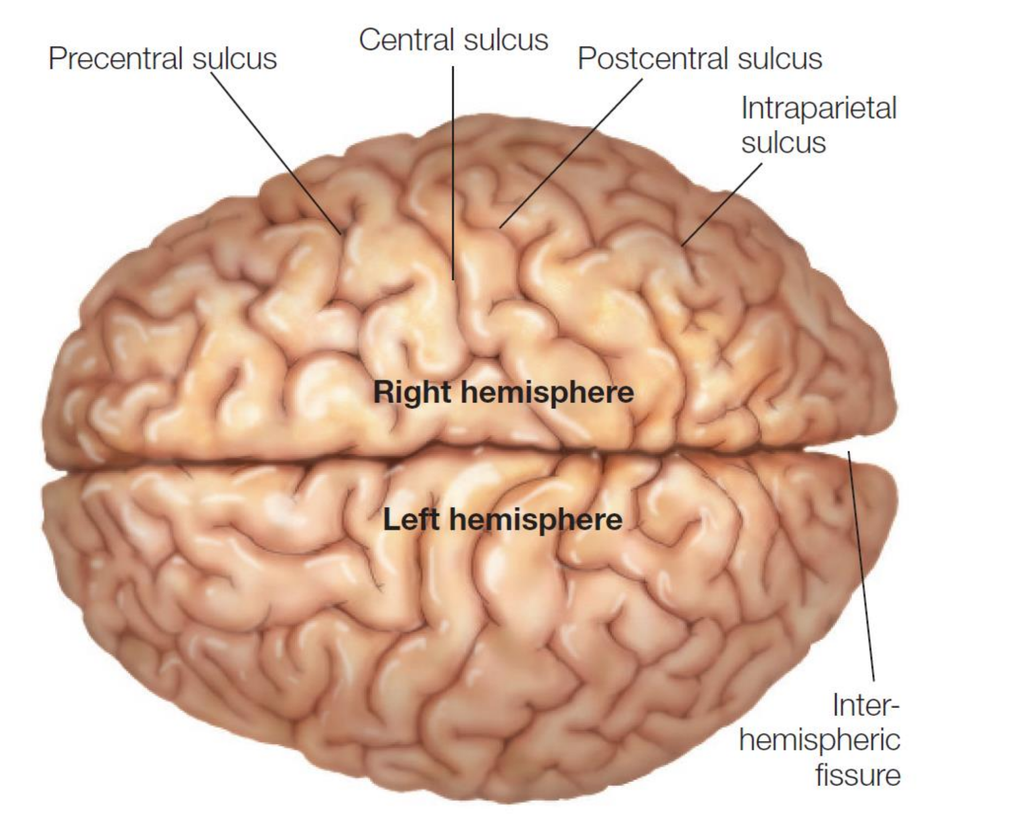
B) Epithelial Cells

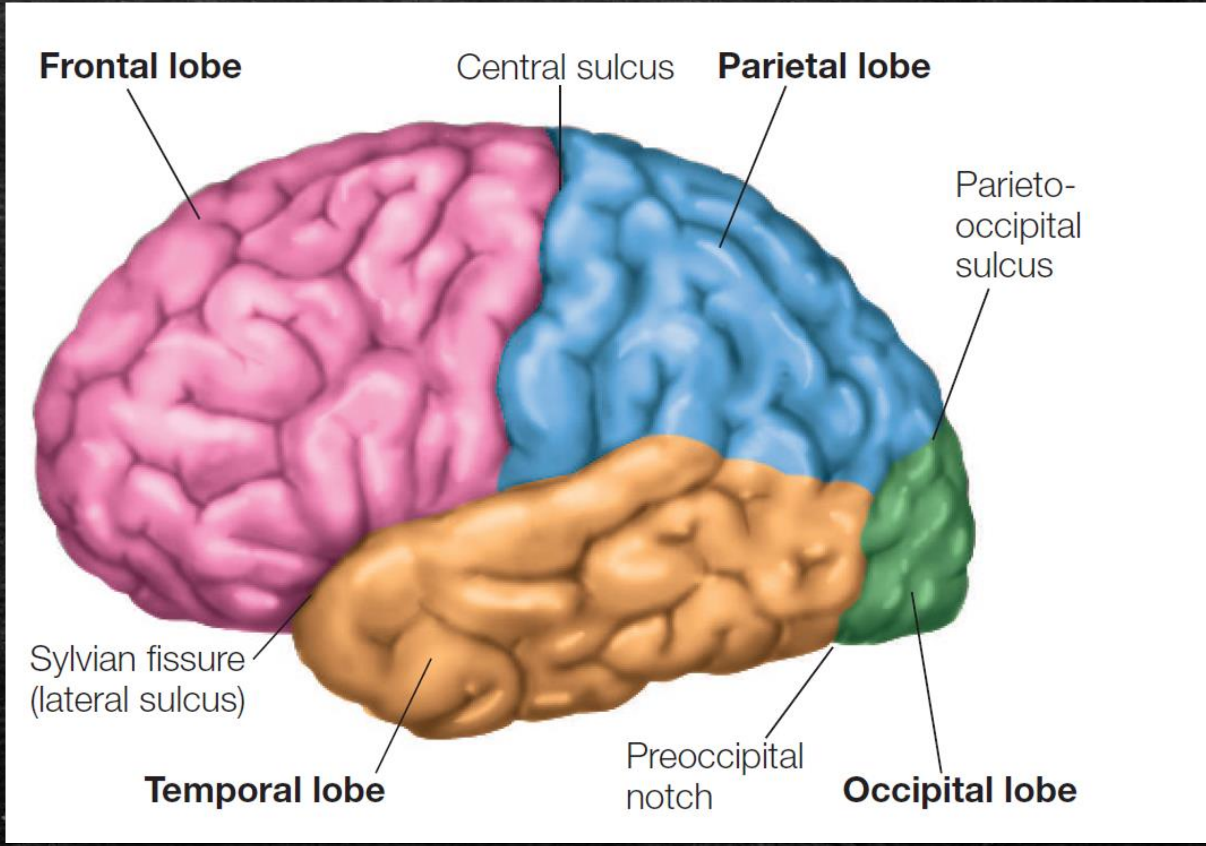
C) Microglial Cells

D) Purkinje Cells

E) Astrocytes

The Cerebral Cortex





Language Representation in the Brain(LIGN 180)

- How to study?

Aphasia – A broad term referring to the collective deficits in language comprehension and production that accompany neurological damage, even though the articulatory mechanisms are intact.

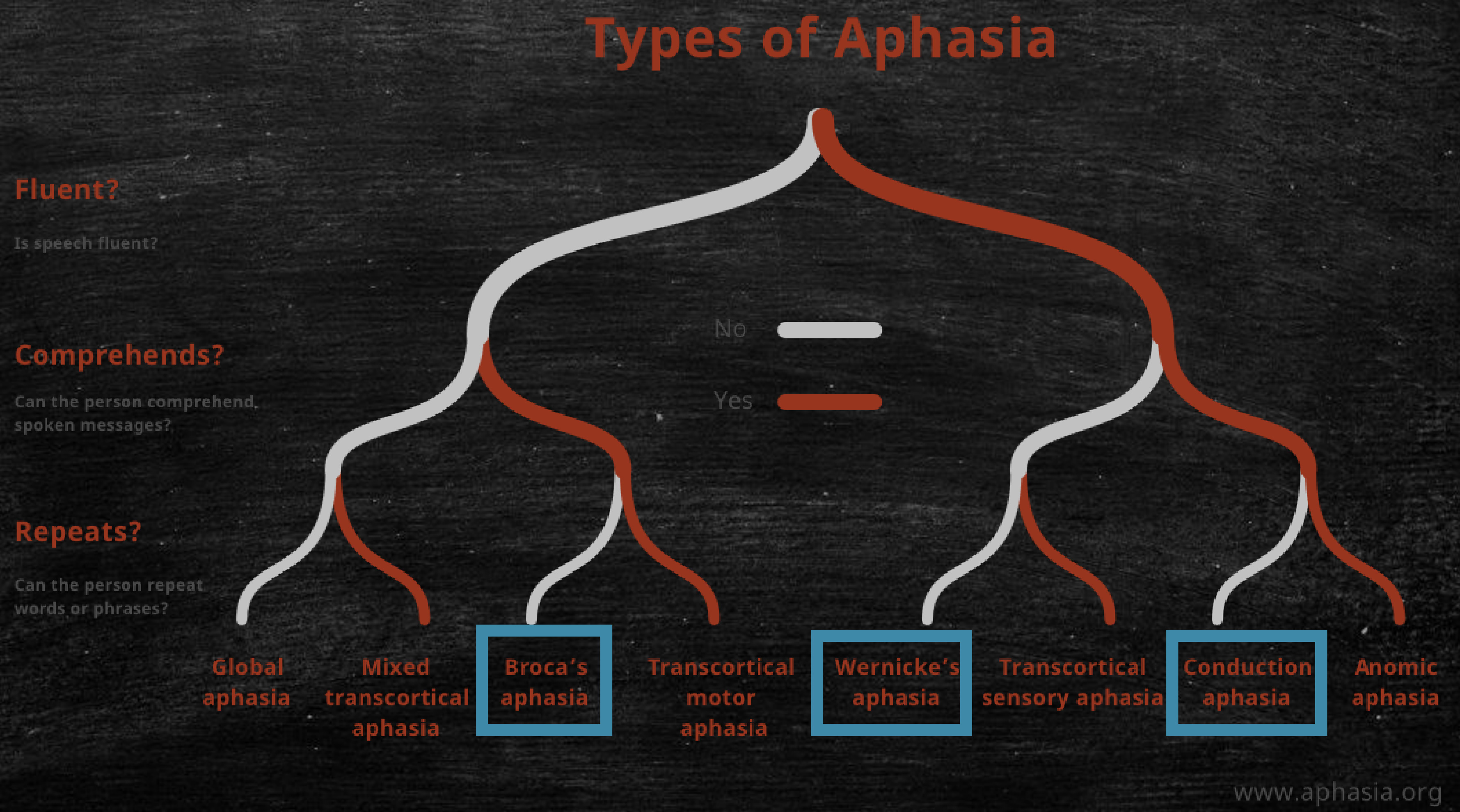
Genetics - The KE family and FOXP2 Gene

Neuroimaging Studies

AND OTHER TECHNIQUES….

Aphasia

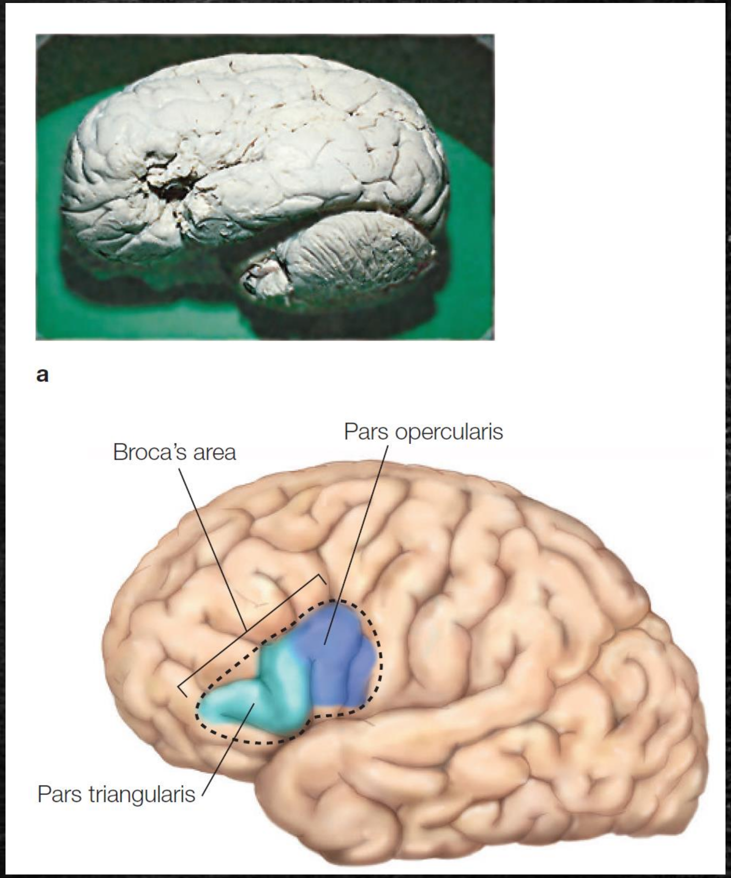
Aphasia



Types of Aphasia
Fluent?
Is speech fluent?
Comprehends?
Can the person comprehend spoken messages?
Repeats?
Can the person repeat words or phrases?
No
Yes
Global aphasia
Mixed transcortical aphasia
Broca's aphasia
Transcortical motor aphasia
Wernicke's aphasia
Transcortical sensory aphasia
Conduction aphasia
Anomic aphasia
www.aphasia.org

Broca's Aphasia (Deficits in Syntax)

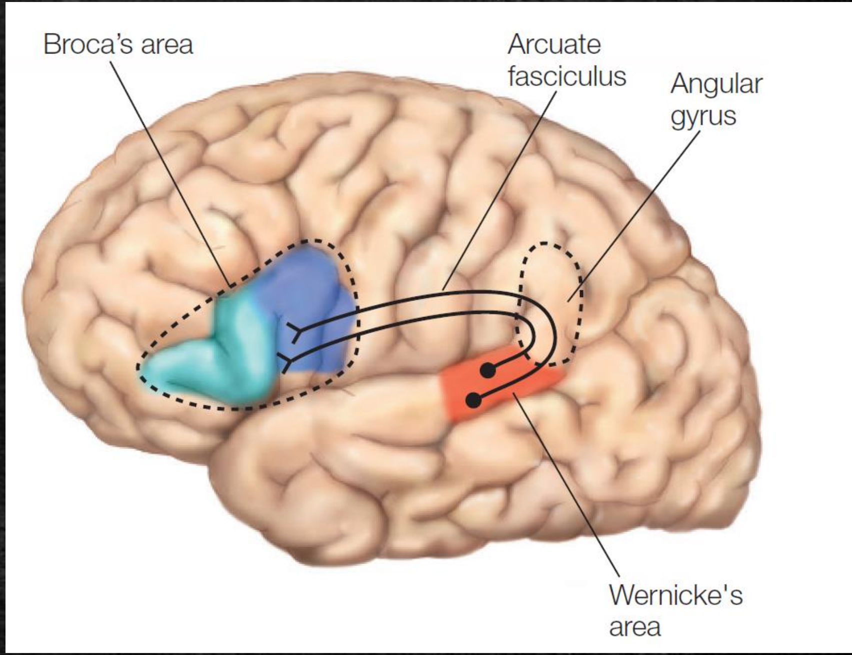
- First clearly described by the Parisian physician Paul Broca in the 19th century.
- In the most severe forms of Broca's aphasia, single utterance patterns of speech are often observed.
- The speech of patients with Broca's aphasia is often telegraphic (containing only content words, comes in uneven bursts, and is very effortful)
- **Broca's aphasia patients are aware of their errors and have a low tolerance for frustration.**



Broca’s Aphasia

Wernicke's Aphasia

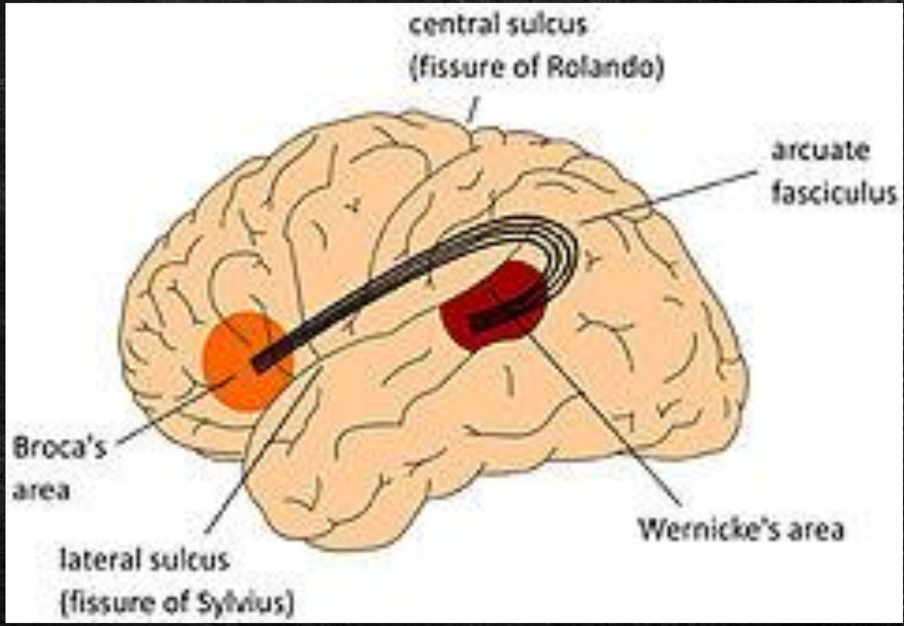
- First described fully by the German physician Carl Wernicke.
- Patients with this syndrome have difficulty understanding spoken or written language and sometimes cannot understand language at all.
- Although their speech is fluent with normal prosody and grammar, what they say is often nonsensical.



Wernicke’s Aphasia

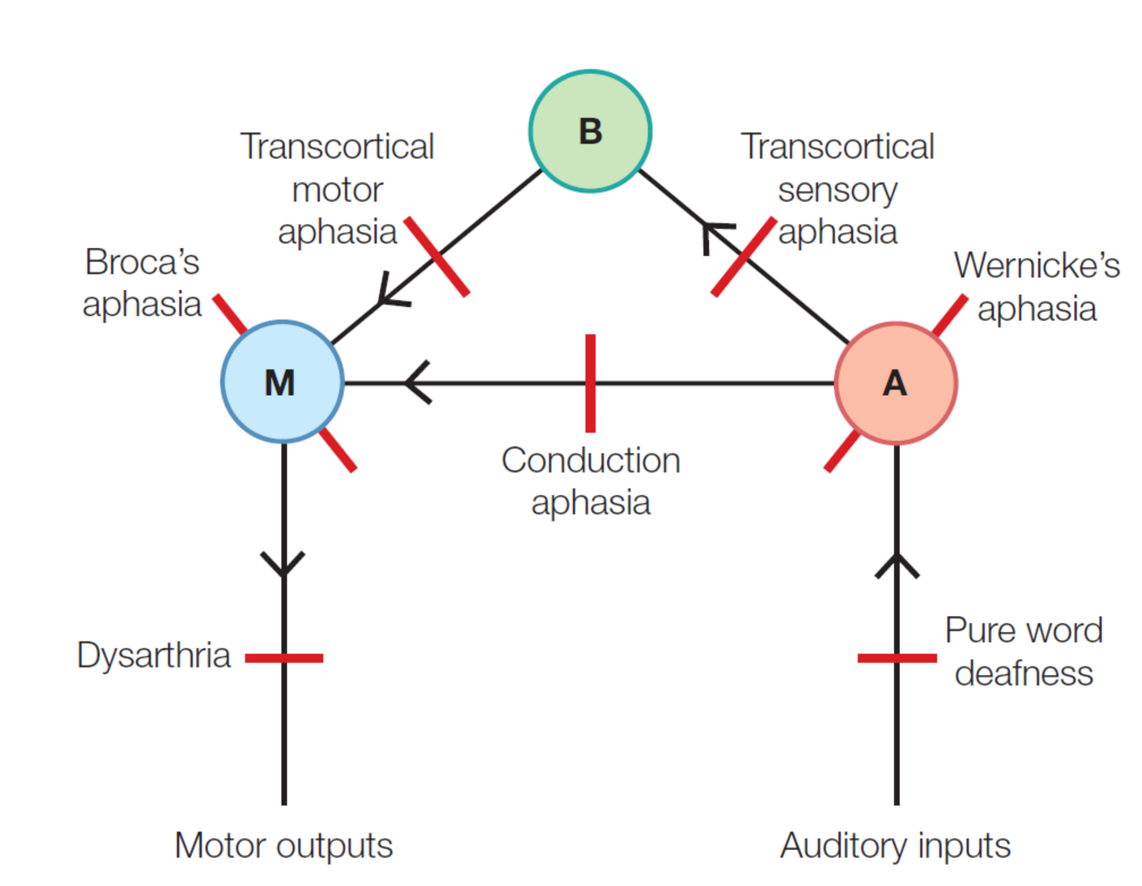
Conduction Aphasia

- Damage to **arcuate fasciculus**, the fiber tract connecting Wernicke's and Broca's areas, results in conduction aphasia
- Patients understand words that they hear or see , and they are able to hear their own speech errors but cannot repair them.
- They also have problems producing spontaneous speech, as well as repeating speech, and sometimes they use words incorrectly.



Conduction Aphasia

The Classic "Wernicke-Lichtheim-Geschwind" model



Limitations of Aphasia Studies

- Brain damage varies across people.
- Aphasia is atypical
- Brain damage affects more than just language
- Double dissociation rarely occur

Advances

Review

Broca and Wernicke are dead, or moving past the classic model of language neurobiology

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A R T I C L E   I N F O

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A B S T R A C T

With the advancement of cognitive neuroscience and neuropsychological research, the field of language neurobiology is at a cross-roads with respect to its framing theories. The central thesis of this article is that the major historical framing model, the Classic "Wernicke-Lichtheim-Geschwind" model, and associated terminology, is no longer adequate for contemporary investigations into the neurobiology of language. We argue that the Classic model (1) is based on an outdated brain anatomy; (2) does not adequately represent the distributed connectivity relevant for language, (3) offers a modular and "language centric" perspective, and (4) focuses on cortical structures, for the most part leaving out subcortical regions and relevant connections. To make our case, we discuss the issue of anatomical specificity with a focus on the contemporary usage of the terms "Broca's and Wernicke's area", including results of a survey that was conducted within the language neurobiology community. We demonstrate that there is no consistent anatomical definition of "Broca's and Wernicke's Areas", and propose to replace these terms with more precise anatomical definitions. We illustrate the distributed nature of the language connectome, which extends far beyond the single-pathway notion of *arcuate fasciculus* connectivity established in Geschwind's version of the Classic Model. By illustrating the definitional confusion surrounding "Broca's and Wernicke's areas", and by illustrating the difficulty integrating the emerging literature on perisylvian white matter connectivity into this model, we hope to expose the limits of the model, argue for its obsolescence, and suggest a path forward in defining a replacement.

Arcuate Fasciculus

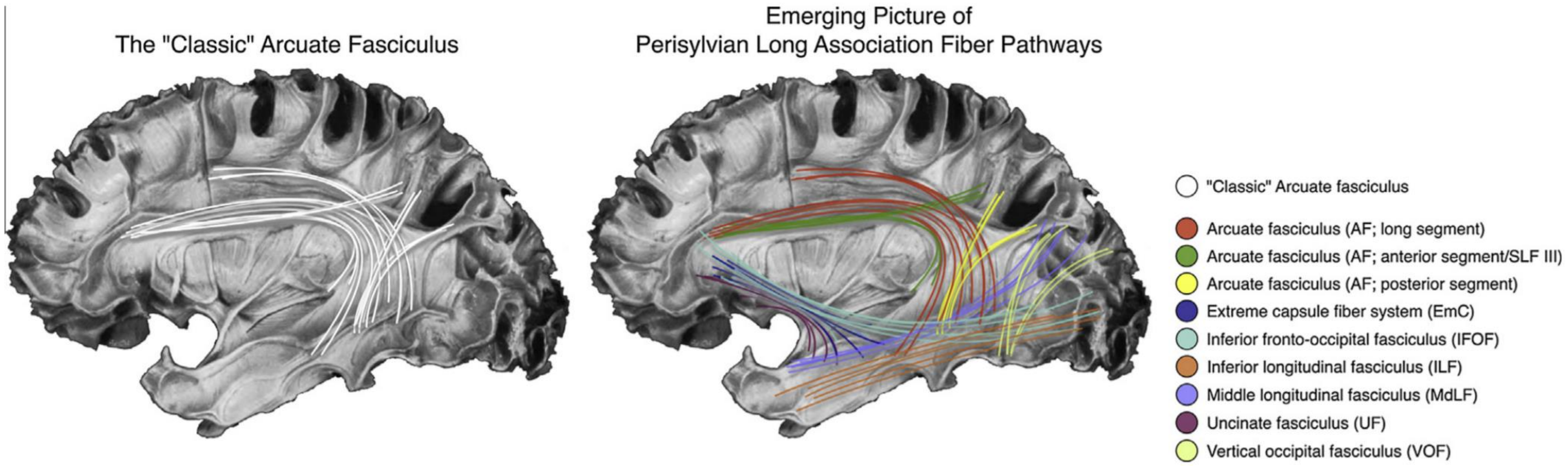


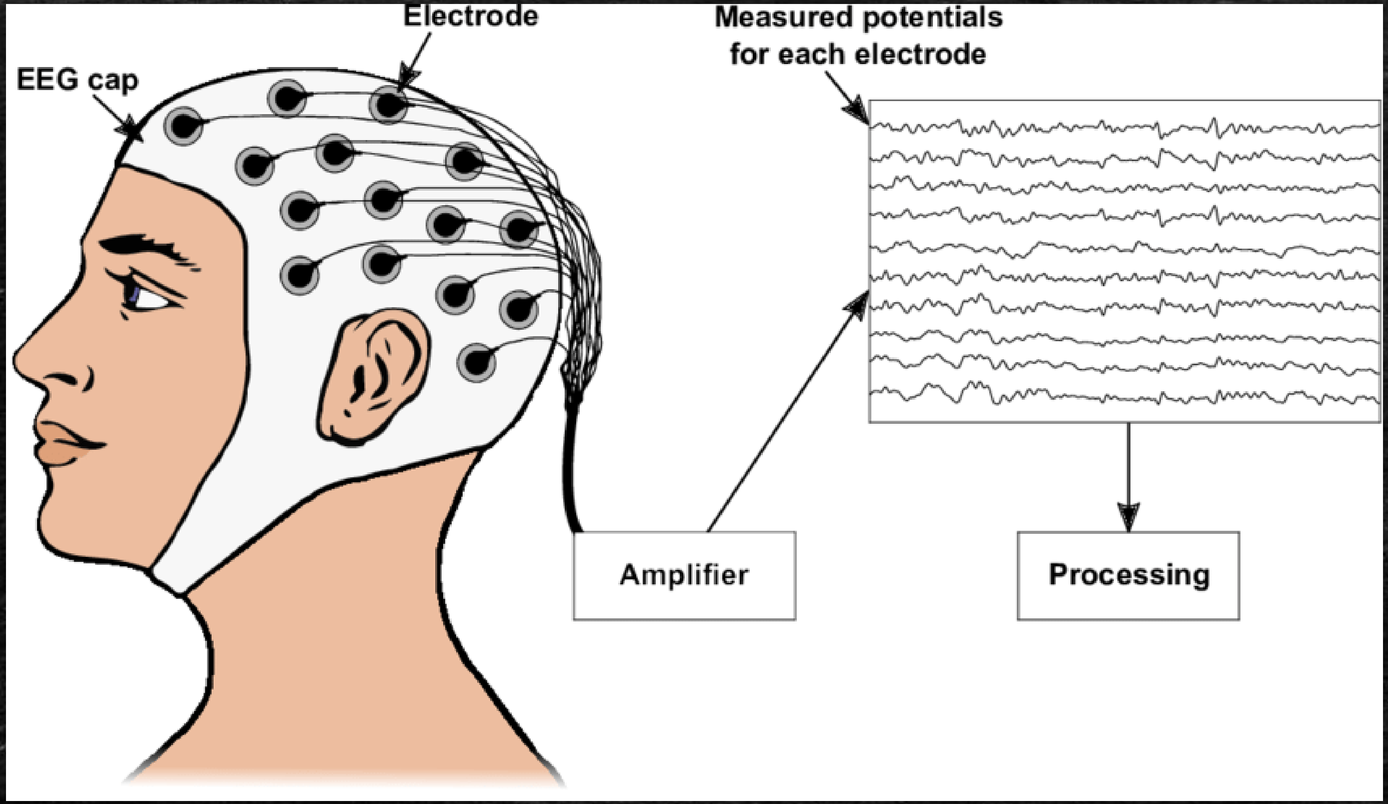
Fig. 4. An emerging picture of perisylvian long association fiber pathways supporting language. The image on the left shows the "classic" arcuate fasciculus. In the image on the right, the arcuate fasciculus is split into three components (Catani, Jones, & Ffytche, 2005). Additional fiber pathways discussed in the text are shown. SLF III = Superior longitudinal fasciculus, third subcomponent.

FOXP2 – Language and Gene

- A point mutation in FOXP2 co-segregates with a disorder in a family in which half of the members have severe articulation difficulties accompanied by linguistic and grammatical impairment.
- Although it is not likely that this gene is responsible for human language, the advancement of genetics and genomics provide us with tools to empirically evaluate the different hypotheses of the evolutionary origins of language.

Language Processing in the Brain

- Electroencephalography (EEG)

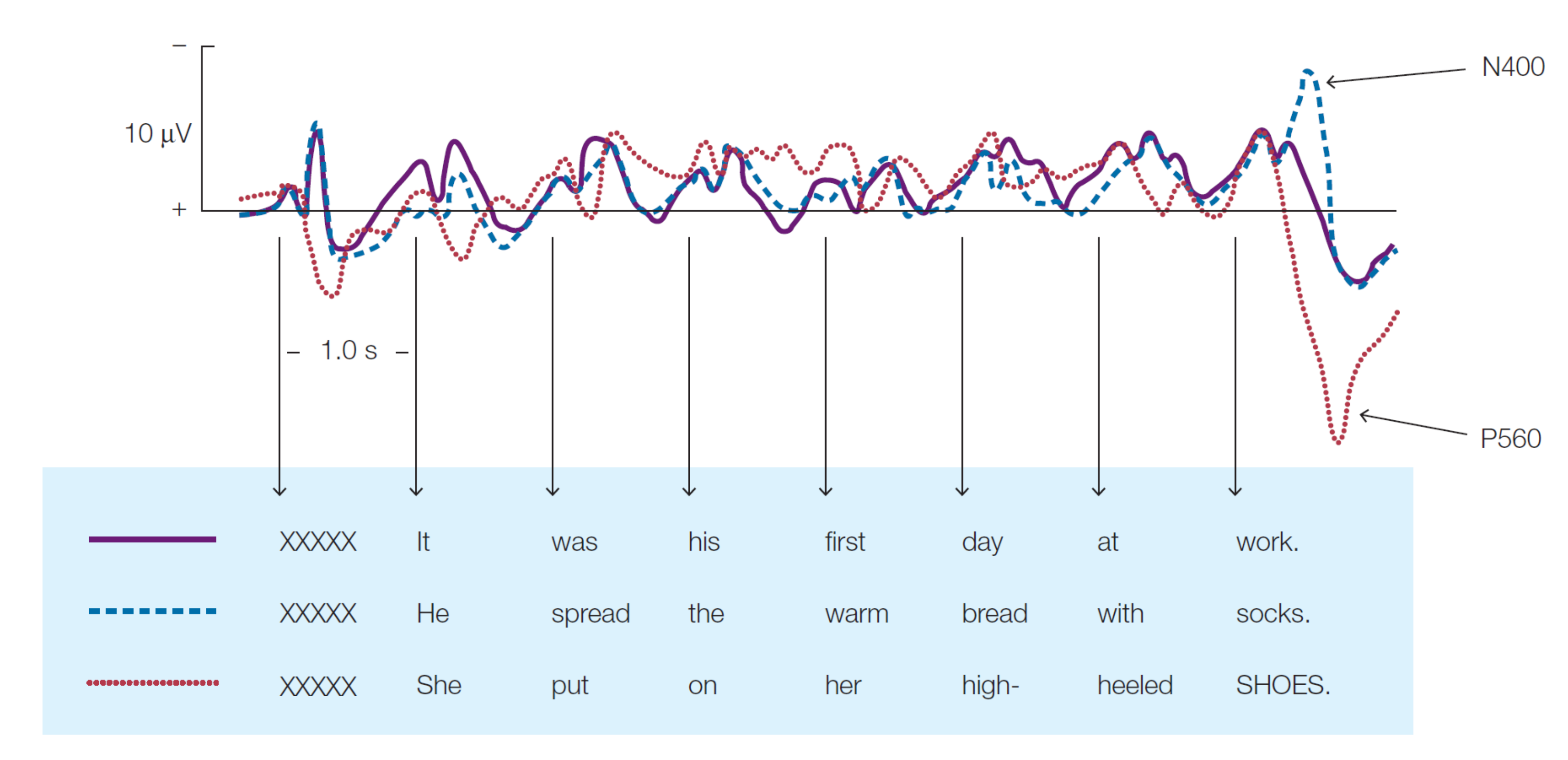


EEG Example

N400 and Semantic Processing

- First described Marta Kutas and Steven Hillyard at UC San Diego (1980)
- The name N400 indicates that it is a negative-polarity voltage peak in brain waves that usually reaches maximum amplitude about 400ms aft er the onset of a word stimulus that has evoked it.
- This brain wave is especially sensitive to semantic aspects of linguistic input.

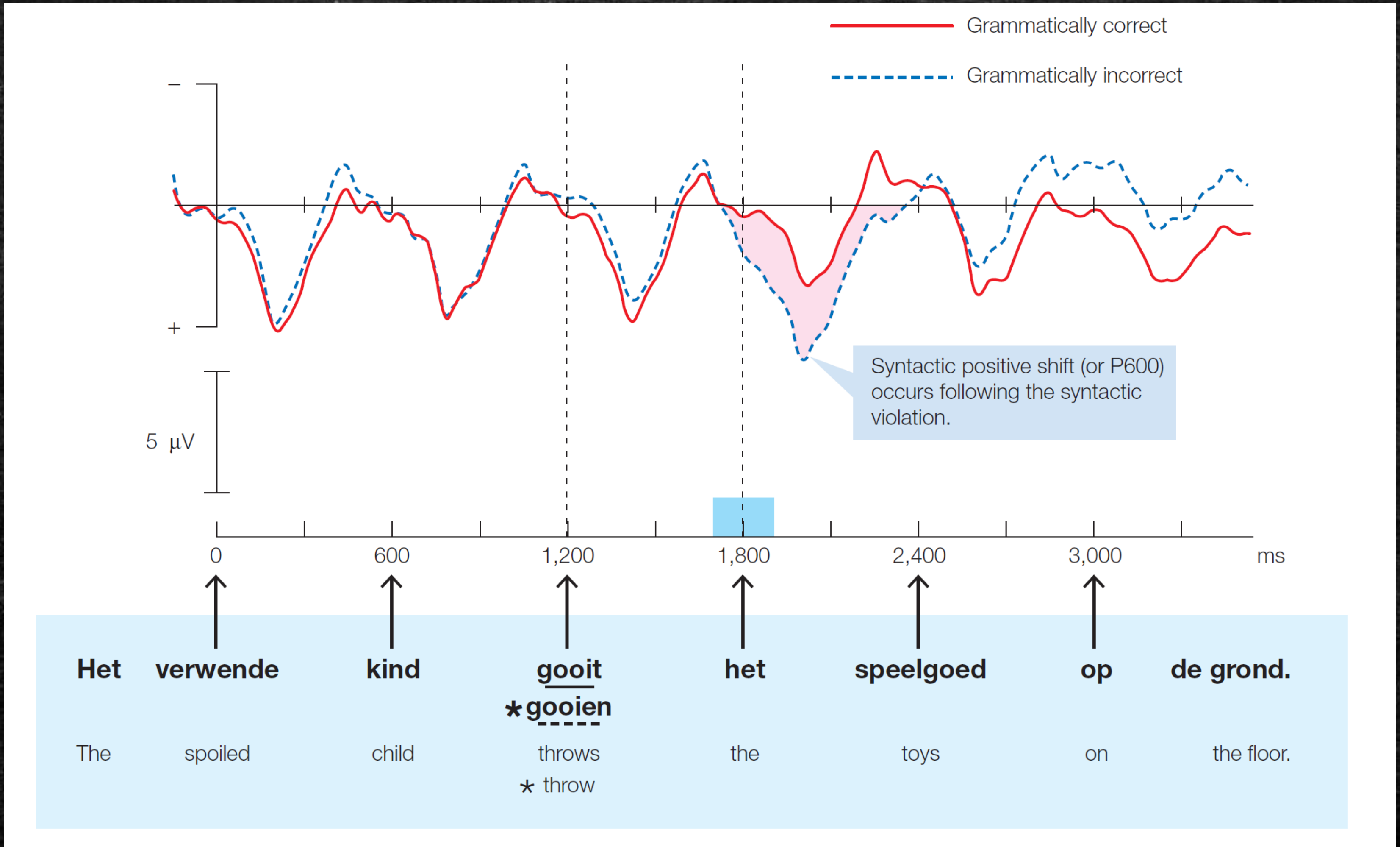
N400 and Semantic Processing



P600 and Syntactic Processing

- First reported by Lee Osterhout at the University of Washington and Phil Holcomb at Tuft s (1992), and by Peter Hagoort, Colin Brown, and their colleagues in the Netherlands (1993).
- Osterhout and Holcomb observed it at about 600ms aft er the onset of words that were incongruous with the expected syntactic structure.

P600 and Syntactic Processing



Quick Quiz

Patients with which of the following syndrome have difficulty understanding spoken or written language?

A) Broca's Aphasia

B) Wernicke's Aphasia

C) Conduction Aphasia

D) Anomic Aphasia

Quick Quiz 3

When hearing the following sentence: “I drink my coffee with cream and dog.” What brain response would you expect to have?

A) N400

B) P600

C) N200

D) P200

E) N600

F) P400

Quick Quiz 4

Which of the following sentence will elicit a P600 response?

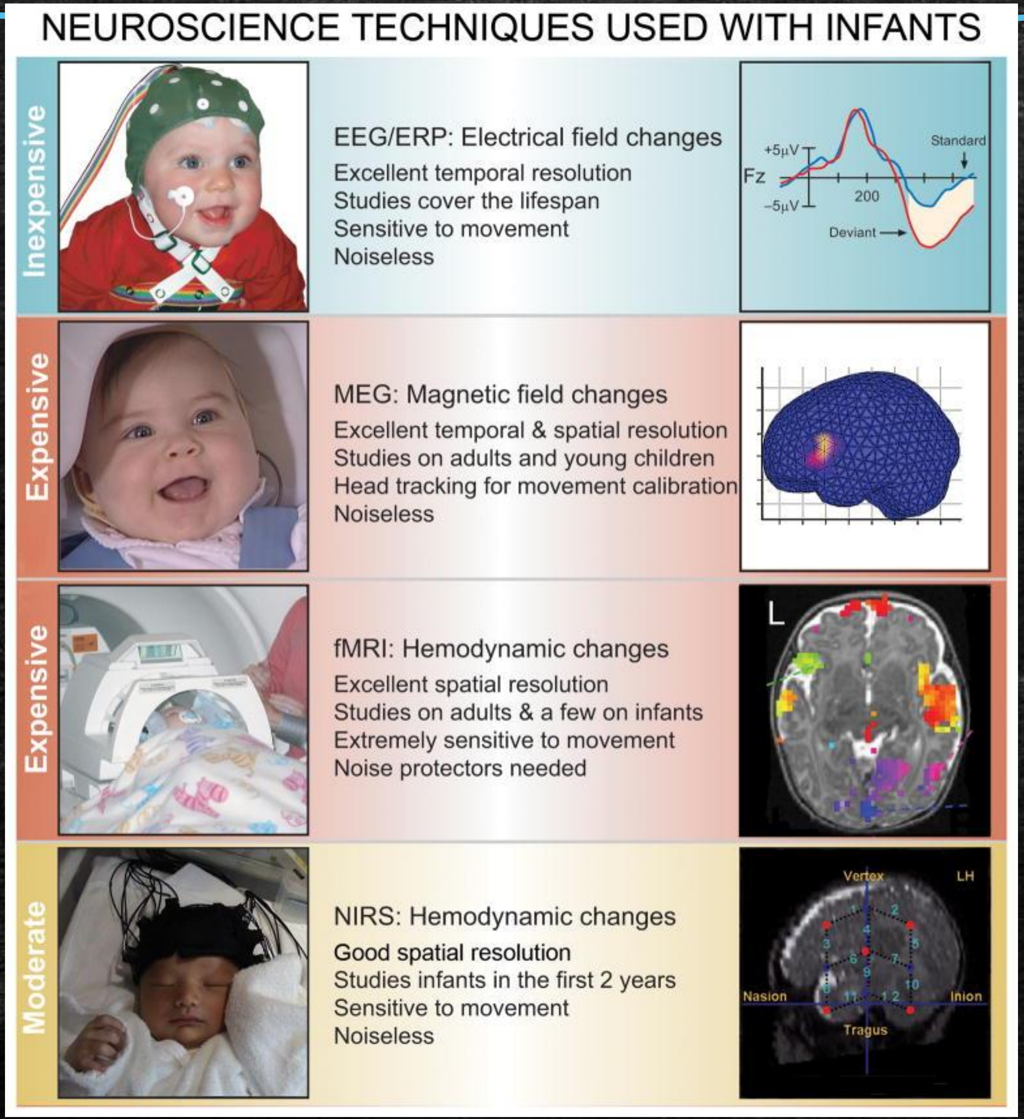
A) The child throw the toy.

B) The teacher wrote her name on the lake.

C) Students love neurolinguistics.

D) Biology is the scientific study of life.

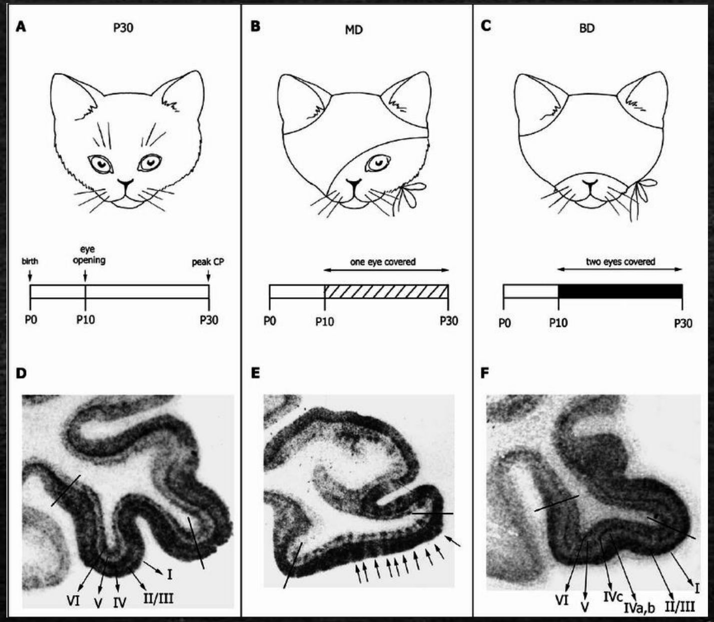
Language Development and the Brain



Kuhl P. K. (2010). Brain mechanisms in early language acquisition. *Neuron*, *67*(5), 713–727. https://doi.org/10.1016/j.neuron.2010.08.038

Language Development and the Brain

- The notion that a biologically determined period exists during which language acquisition must occur, if it is to occur at all, is known as the **critical period hypothesis.**
- There are also well-documented examples of critical periods across species.



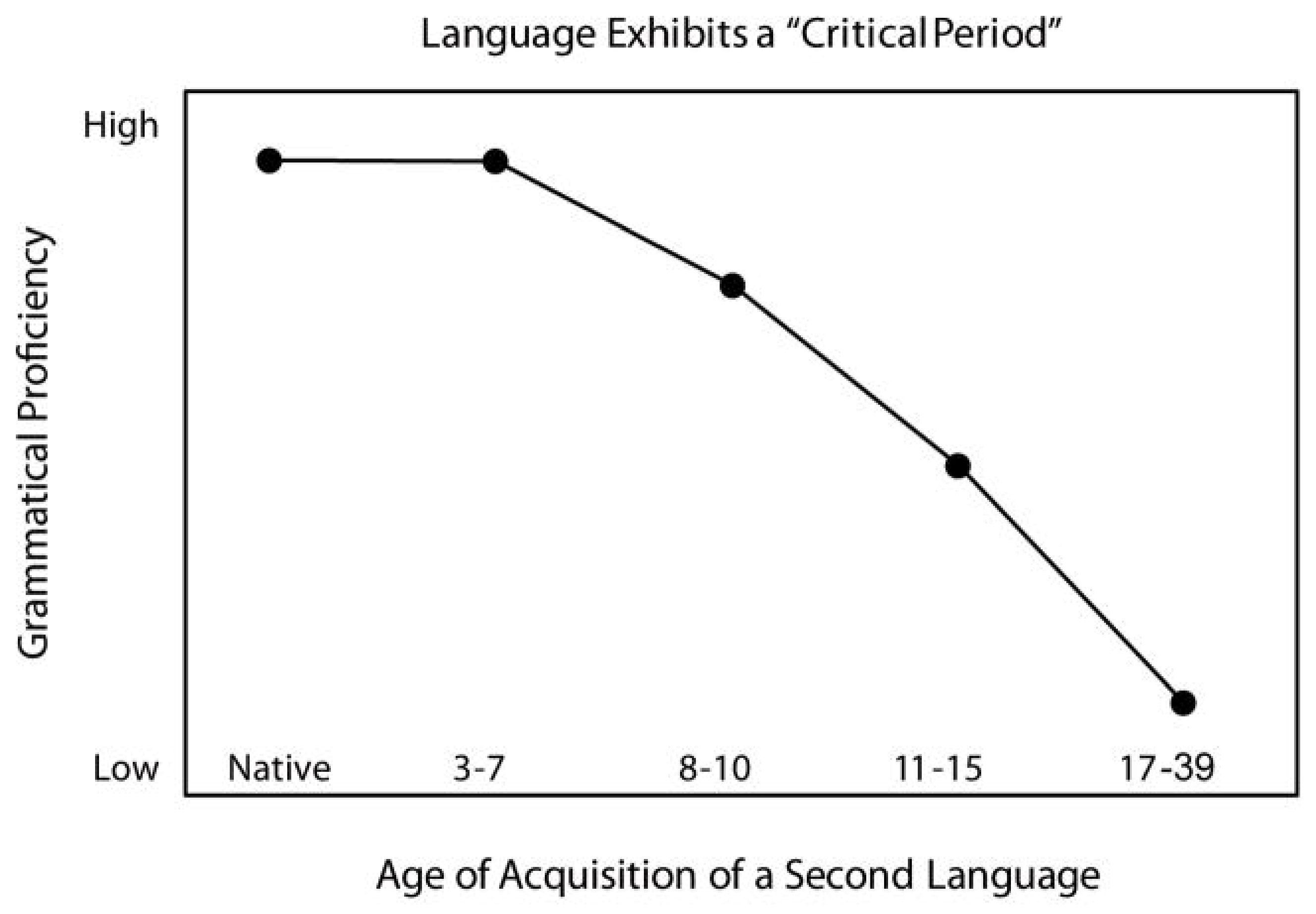
The case of Genie

Sentences produced by Genie:

- Mama wash hair in sink.
- At school scratch face.
- I want Curtiss play piano.
- Like go ride yellow school bus.
- Father take piece wood. Hit. Cry.

(Source: Curtiss, 1977., Hoff, 2013)

Language and the “Critical Period”



The Timing of Phonetic Learning