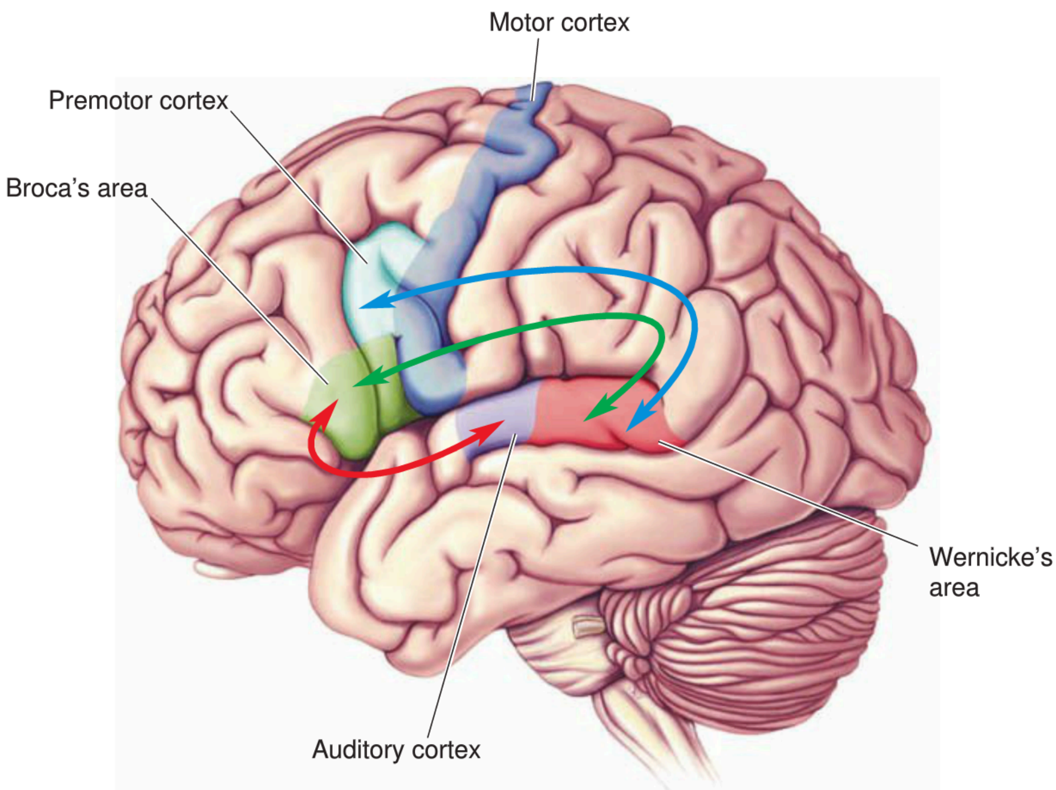
Lecture 38. Language

Prof. Melissa Warden

Pre-Lecture Preparation

Watch Video 38-1: Language circuits in the brain
Understand this figure:



Required Reading

Be able to explain the following figures from Bear et al.: p.687, Fig. 20.1; p.692, Fig. 20.5; p.696, Box 20.2; p.697, Fig. 20.6 and Table 20.1; p.704, Fig. 20.9; p.707, Fig. 20.13; p.708, Fig. 20.14; p.712, Fig. 20.18

Optional Reading

1. Phonetic feature encoding in human superior temporal gyrus. Mesgarani N, Cheung C, Johnson K, Chang EF.

Learning Objectives

1. To learn how the sounds of speech (the phonetic elements of language) are generated by the vocal tract

2. To understand the genetic underpinnings of language
3. To learn the complimentary roles of specialized language areas in the brain (Broca's area and Wernicke's area) and to understand how damage to these areas affects speech
4. To learn the concept of hemispheric dominance for speech and language.

Lecture Outline

Current estimates are that the capacity for human language evolved relatively recently, about 100,000 years ago. While animals use a great diversity of sounds and behaviors to communicate, none of these come close to the elaborate and flexible system of language used by humans. In this lecture, we will discuss the neural mechanisms of speech production and comprehension, from grammar and fluent speech to meaning.

1. Language generation
    a. The mechanics of speech generation by the vocal tract
    b. The characteristics of human language; phonemes, words, grammar

2. Evidence for a specific genetic requirement for language
    a. FoxP2 and verbal dyspraxia

3. Language areas specialized for different functions in the brain
    a. Broca's area lesions and non-fluent, but meaningful speech
    b. Wernicke's area lesions and fluent, but non-meaningful speech
    c. Information flow through language regions of the brain

4. Hemispheric dominance in speech and language
    a. The left hemisphere usually specializes in language
    b. Split-brain epilepsy patients can understand with the right hemisphere but cannot respond with speech

Study Questions

1. How is it possible for a split-brain human to speak intelligibly if the left hemisphere controls speech? Isn't this inconsistent with the fact that the left hemisphere must direct motor cortex in both hemispheres to coordinate movements of the mouth?

2. What does the Wernicke-Geschwind language processing model explain? What data are inconsistent with this model?

3. In what ways is the left hemisphere usually language dominant? What does the right hemisphere contribute?

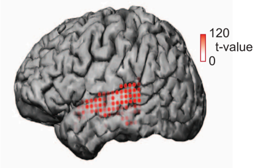
NEUROBIOLOGY AND BEHAVIOR II: INTRODUCTION TO NEUROSCIENCE

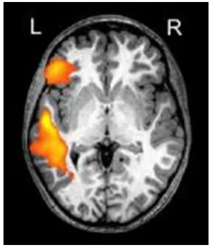
BioNB 2220

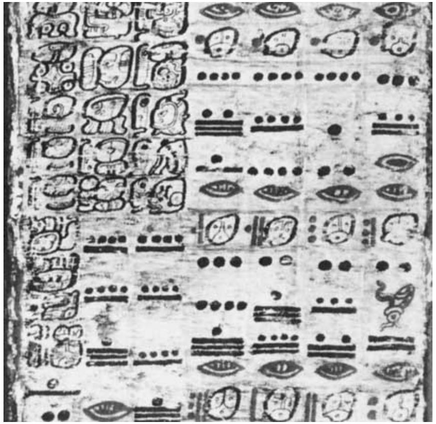
Lecture 38: Language

April 29, 2019

Melissa R. Warden, PhD







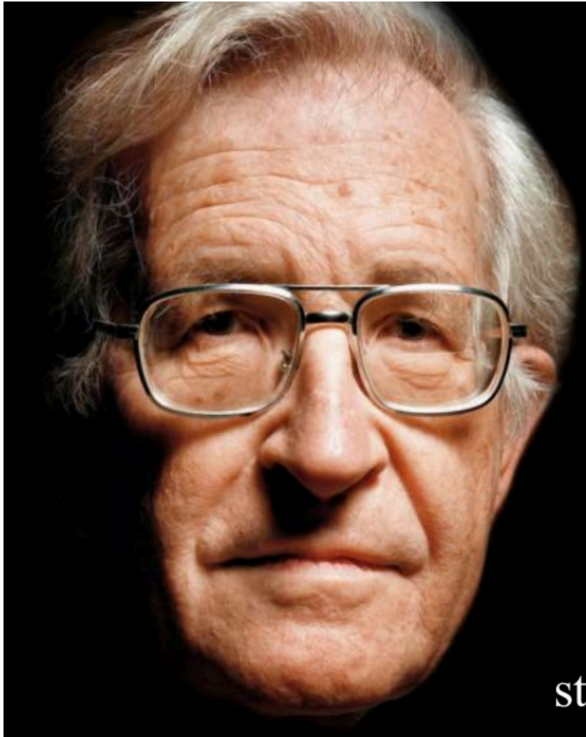
What is language?

What ~~is~~ language?

What ISN'T language?

What ~~is~~ language?

Animal communication



NOAM CHOMSKY

Acquiring language cannot be reduced to simply developing an inventory of response to stimuli, because every sentence that anyone produces can be a totally new combination of words.

Word order matters

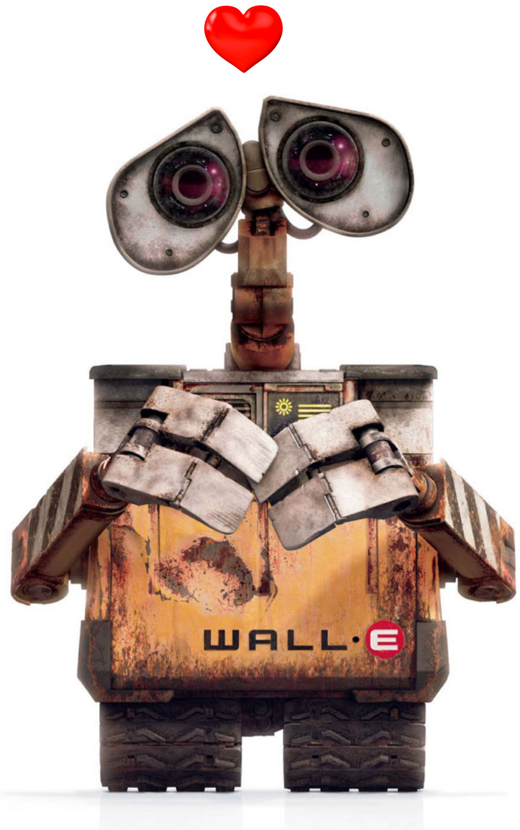
You like it

It likes you

If you can't be with the one you love, love the one you're with. --Billy Preston

I go where I please, and I please where I go. --Duke Nukem

I am stuck on band-aid, because band-aid's stuck on me. --Band-aid commercial



Unique features of human language

Animal signs convey a limited set of ideas

- Threat is nearby
- I am the best and you should mate with me

Human language:

- Also maps sounds to meaning
- Also uses a finite set of elements (words)
- But elements can be combined to yield an infinite array of expressions (sentences)

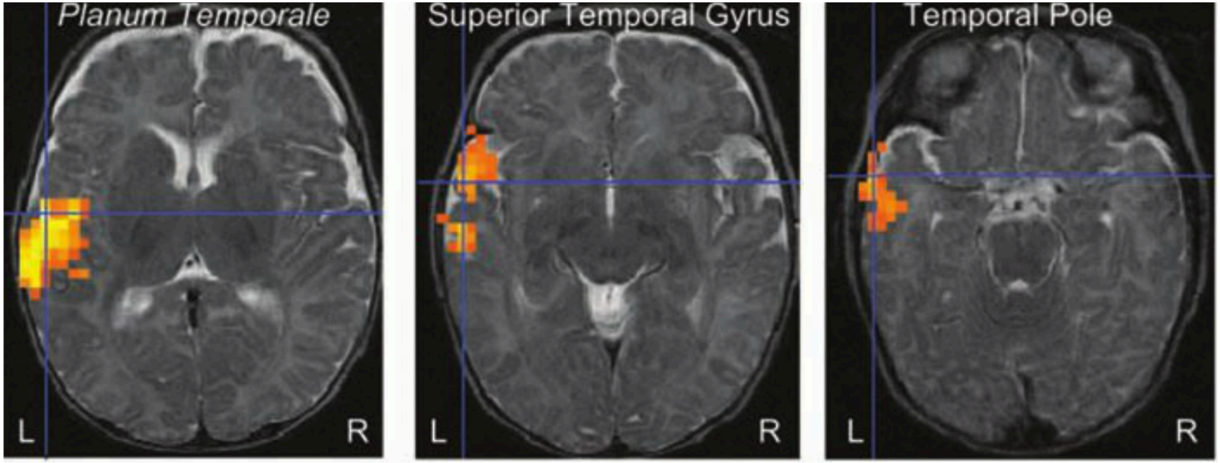
Colorless green ideas sleep furiously

We can study sound production and sound meaning in animals, but *syntax* remains a challenge. May be related to sequencing ability.


Nim Chimpsky

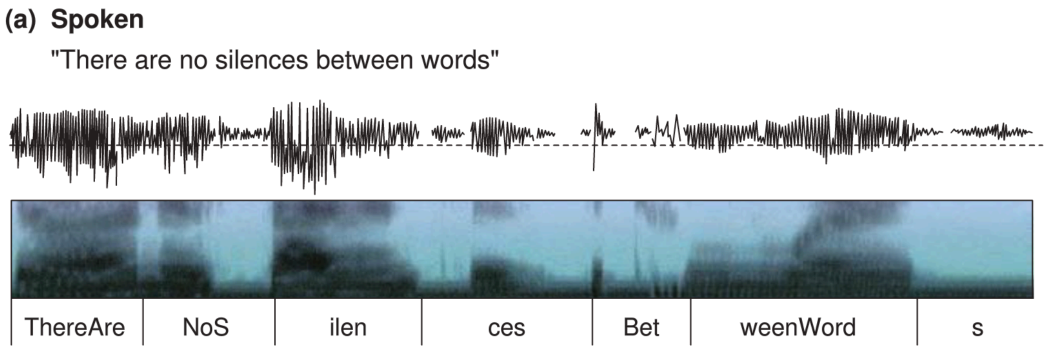
Humans are hard-wired for syntax

Children learn the sound patterns of words and phrases before they can produce words



Brain activity in a 3-month-old infant listening to speech

Word boundaries are not obvious

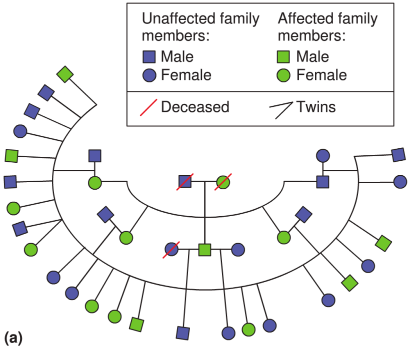


Genetic specialization for language

The FoxP2 gene and language

KE family

- Dyspraxia (difficulty controlling speech muscles, making speech sounds, sequencing sounds, controlling breathing)
- Speech unintelligible even to family members
- Grammar and language difficulties – expressive (speech) and receptive (listening)
- Learning difficulties



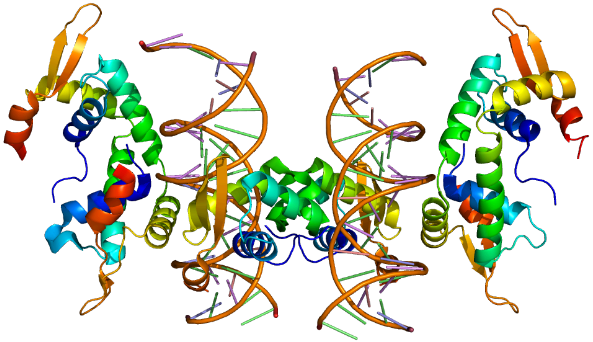
(a)

Impairments were due to mutations in a single gene: FoxP2

The FoxP2 gene and language

Mutation in this single gene can be devastating for language and speech. Mutations in only one allele cause severe language deficits (dominant).

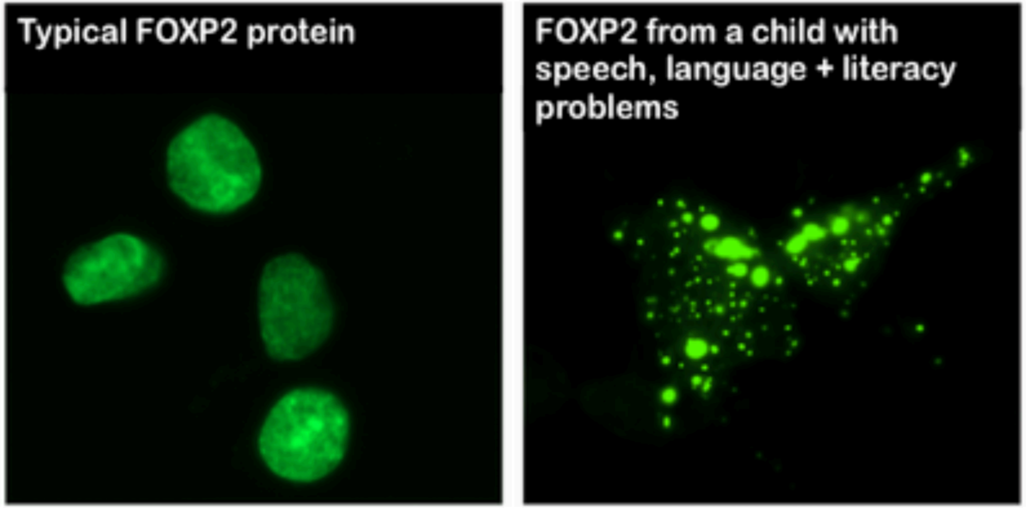
FoxP2 is a transcription factor – controls the expression of hundreds of other genes related to synaptic plasticity



FoxP2 protein

Normal and abnormal FOXP2

Nuclear FoxP2

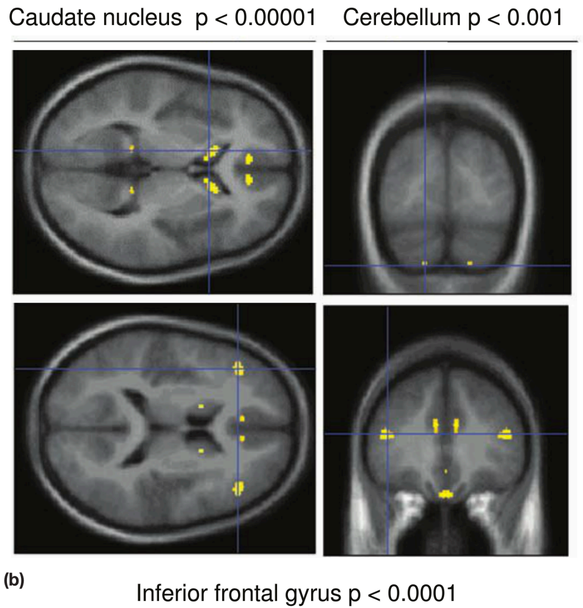


Cytosolic FoxP2

FOXP2 probed with a fluorescent marker
FOXP2 is a transcription factor, and localizes to the nucleus

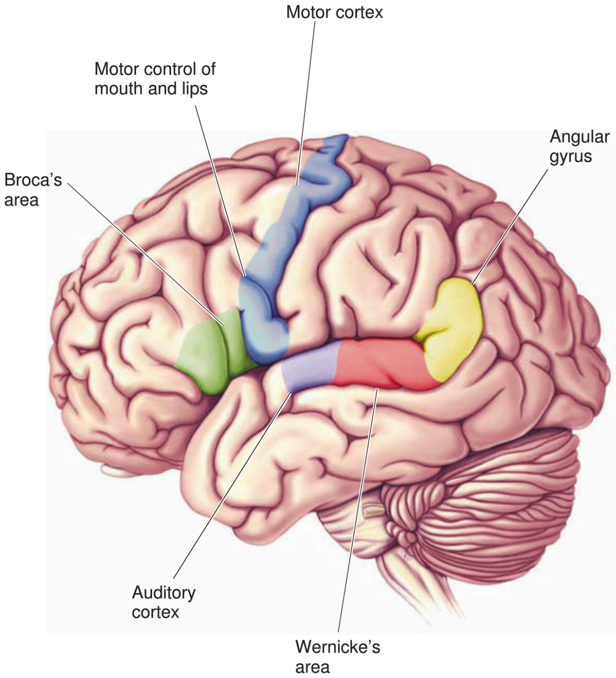
FoxP2 mutations in the KE family

Reduced gray matter in caudate nucleus of the striatum, cerebellum, and language areas in the frontal lobe



Specialized language areas of the brain

Language areas in the left hemisphere



Localization of function determined by lesions

Broca's area is 'motor-like'
Important for grammar / syntax

Wernicke's area is 'sensory-like'
Important for meaning

Broca's Aphasia

"I asked Mr. Ford about his work before he entered the hospital.

I'm a sig. . . no. . . man. . . uh, well,. . . again." These words were emitted slowly, and with great effort. The sounds were not clearly articulated; each syllable was uttered harshly, explosively, in a throaty voice. With practice, it was possible to understand him, but at first I encountered considerable difficulty in this.

"Let me help you," I interjected. "You were a signal. . . ."

"A signal man. . . right," Ford completed my phrase triumphantly.

"Were you in the Coast Guard?"

"No, er, yes, yes. . . ship. . . Massachu. . . chusetts. . . Coastguard. . .years." He raised his hands twice, indicating the number "nineteen."

"Could you tell me, Mr. Ford, what you've been doing in the hospital?"

"Yes, sure. Me go, er, uh, P.T. nine o'cot, speech. . . two times. . . read. . . wr. . . ripe, er, rike, er, write. . . practice. . . get-ting better."

"And have you been going home on weekends?"

"Why, yes. . . Thursday, er, er, er, no, er, Friday. . . Bar-ba-ra. . . wife. . . and, oh, car. . . drive. . . purnpike. . . you know. . . rest and. . . tee-vee."

"Are you able to understand everything on television?"

"Oh, yes, yes. . . well. . . almost." Ford grinned a bit. (Gardner, 1974, pp. 60–61)

Broca's Aphasia

Motor association cortex of frontal lobe

Good comprehension of meaning, good production of meaningful words

Non-fluent, agrammatical speech – syntax is affected


FALMOUTH JAMAICA

Wernicke's Aphasia

"What brings you to the hospital?" I asked the 72-year-old retired butcher 4 weeks after his admission to the hospital.

"Boy, I'm sweating, I'm awful nervous, you know, once in a while I get caught up, I can't mention the tarripoi, a month ago, quite a little, I've done a lot well, I impose a lot, while, on the other hand, you know what I mean, I have to run around, look it over, trebbin and all that sort of stuff."

I attempted several times to break in, but was unable to do so against this relentlessly steady and rapid outflow. Finally, I put up my hand, rested it on Gorgan's shoulder, and was able to gain a moment's reprieve.

"Thank you, Mr. Gorgan. I want to ask you a few—"

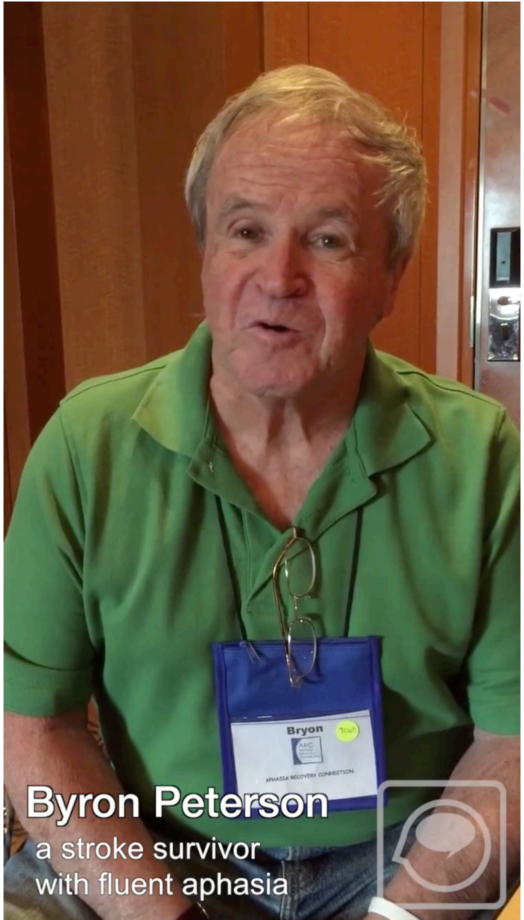
"Oh sure, go ahead, any old think you want. If I could I would. Oh, I'm taking the word the wrong way to say, all of the barbers here whenever they stop you it's going around and around, if you know what I mean, that is tying and tying for repucer, repuceration, well, we were trying the best that we could while another time it was with the beds over there the same thing. . . ." (Gardner, 1974, pp. 67–68)

Wernicke’s Aphasia

Posterior temporal lobe – near auditory cortex

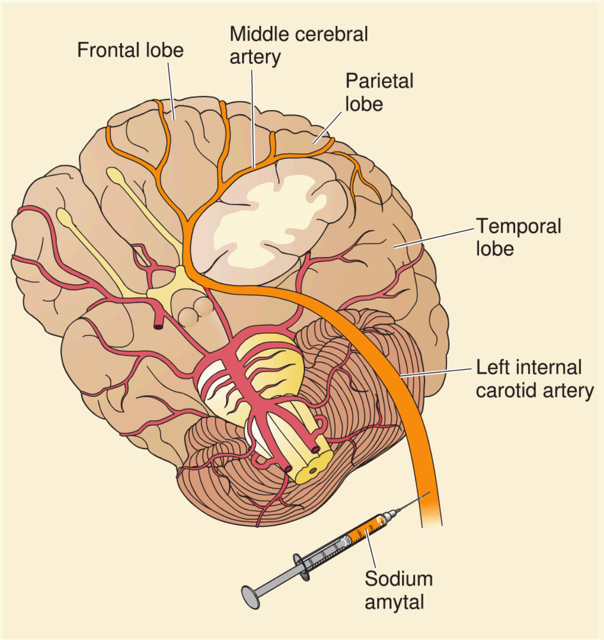
Poor comprehension

Fluent, grammatical, meaningless speech


Bryon
APHASIA RECOVERY CONNECTION
Byron Peterson
a stroke survivor
with fluent aphasia

Asymmetrical language processing in the two cerebral hemispheres

Wada procedure



Sodium amytal (fast-acting barbiturate) is injected into the carotid artery on one side of the neck

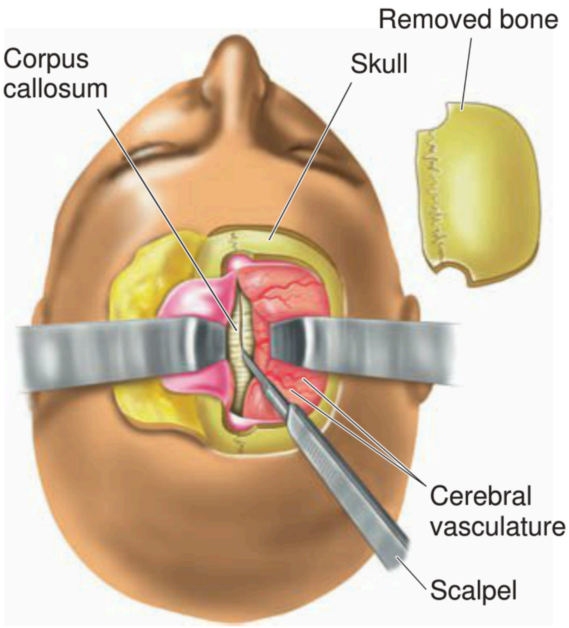
Anesthetizes ipsilateral hemisphere

In seconds, the limbs on the side of the body contralateral to the injection become paralyzed, and somatic sensation is lost.

Can now ask patient questions and assess hemispheric contributions to function – can they still speak?

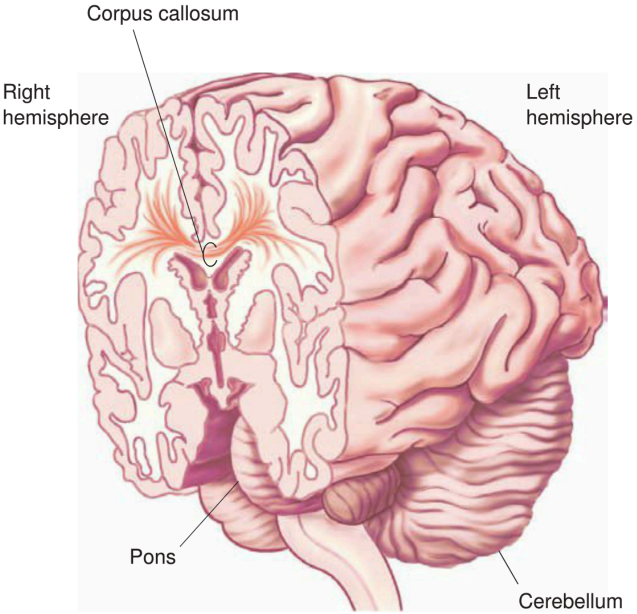
Left hemisphere is dominant for language in most people, even left-handed people

Split-brain surgery for epilepsy

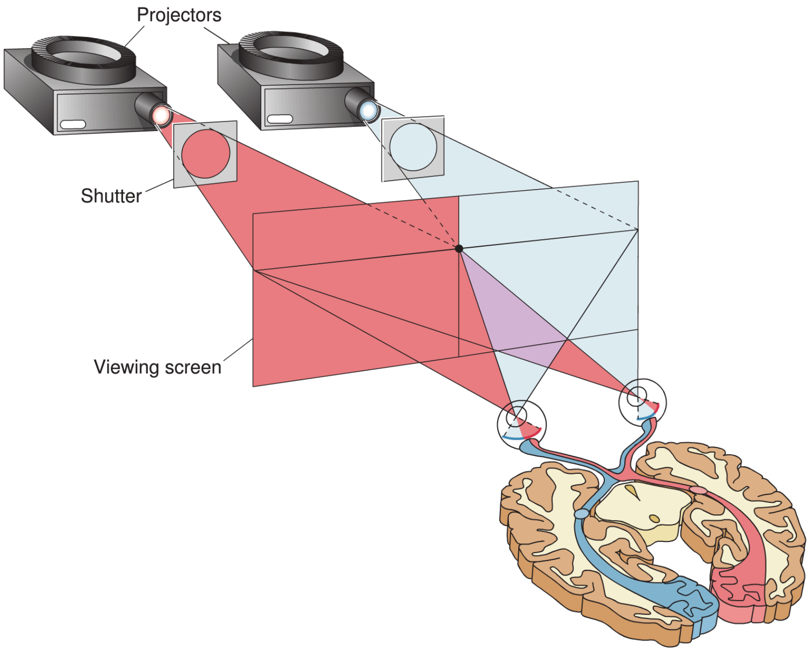


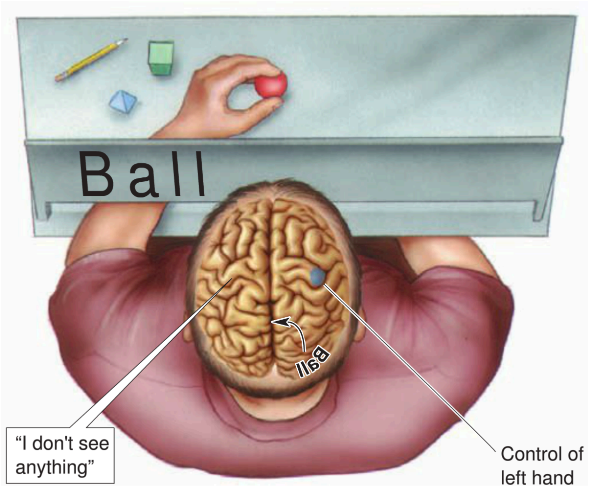
Michael Gazzaniga

Corpus Callosum



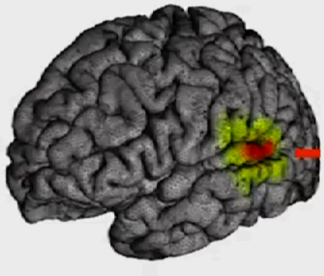
Visual stimulation of only one hemisphere in humans





Language comprehension, but not production, in the right hemisphere

Neurophysiology of language



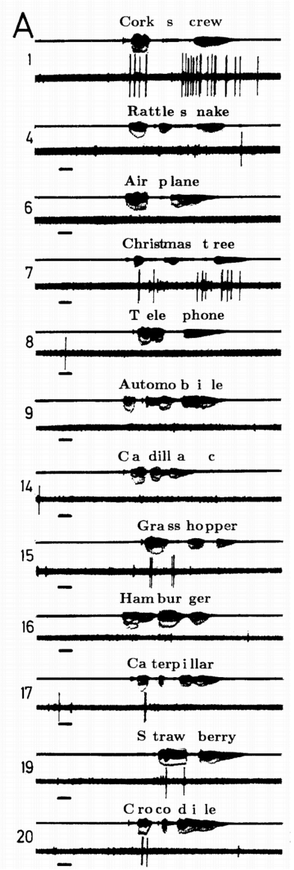
Superior Temporal Gyrus

Wernicke's area

Non-primary auditory cortex of the superior temporal gyrus

<u>Non-human primates:</u>
Single neurons respond more to broadband, complex sounds than to simple tones
(Rauschecker 1995)

<u>Human fMRI:</u>
Greater response to speech than to non-speech sounds
(Binder 2004)



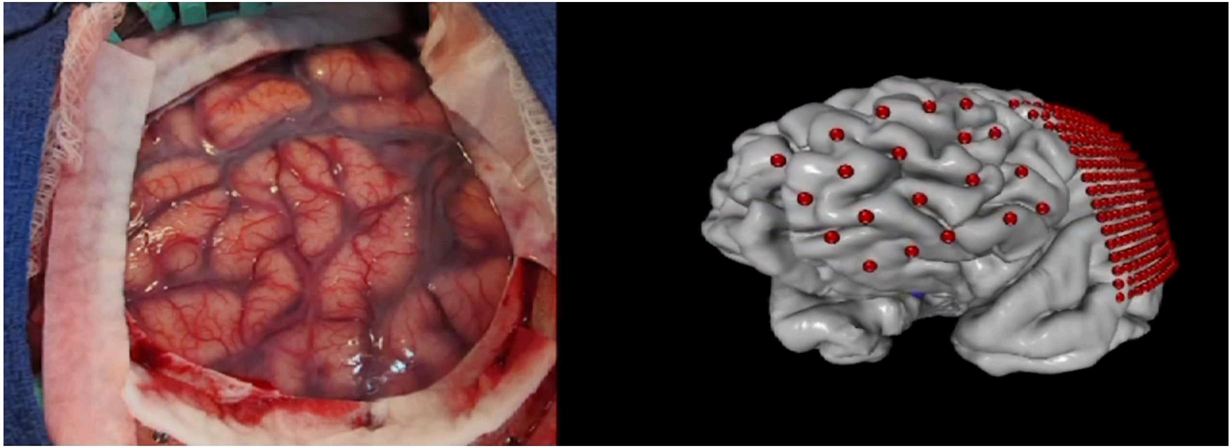
Superior temporal gyrus

Single neuron recordings in human patients:

“This pattern was thought to reflect responses to specific phoneme categories”

Phoneme = perceptually distinct unit of sound

Electrocorticography (ECoG)



Dr. Edward Chang, UCSF

ECoG Electrode Array