Intro to Behavioral Neuroscience (B)
Lecture 9: Communication / Language

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https://youtu.be/9Rt6BzagjbE

Lecture video at above link.

Today: Communication

1) Animal Communication

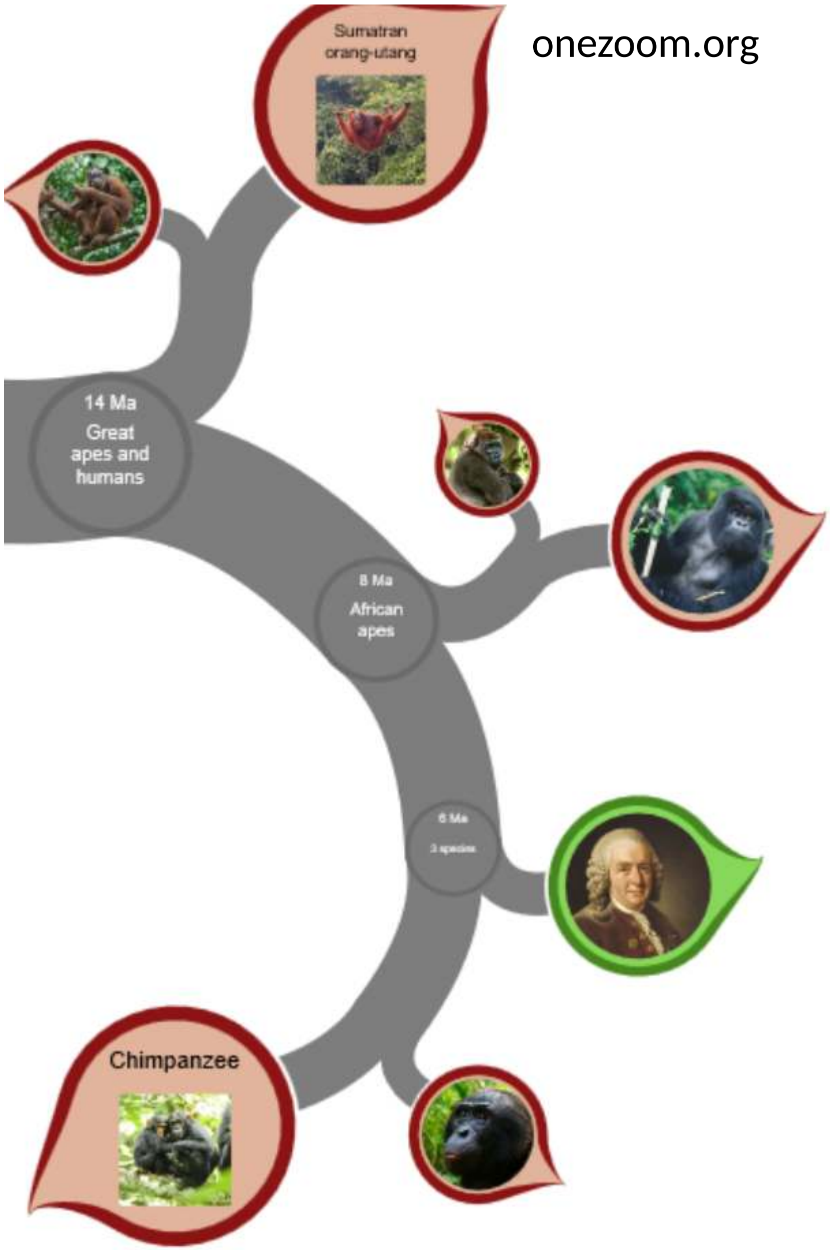
Semantics and Syntax

2) Aphasia (speech disorders)

3) Model of normal language processing

4) Genetics of speech deficits

Human uniqueness?



onezoom.org

What makes humans human?

Is there a gap between humans and other animals (apes, mammals, vertebrates)?

Language is one cognitive faculty in which humans stand out.

Animal communication

Social insects like bees or ants exhibit a complex communication system:

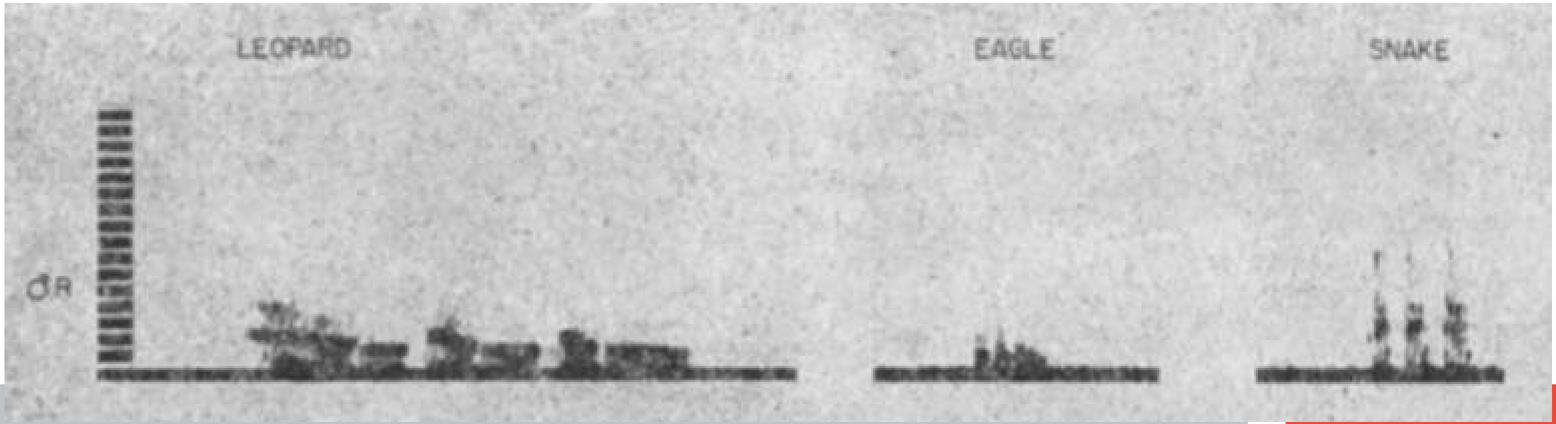
Pharao's ants have a pheromone (chemical for odor-based communication) for short-term attractive trails, that guides foragers to a food source and lasts only 20 minutes. In addition, they have a longer-lived pheromone for long-term trails and a negative 'stop' pheromone. The image shows the pheromone trails on glass surface.

Aphaenogaster albisetosus foragers recruit more workers when they cannot carry the prey alone: they use a pheromone and make some noise ('stridulate'). This makes other ants to release the pheromone and to come to help along the trail.

Animal communication

Vervet monkeys are old-world monkeys in Southern and Eastern Africa.
They live in social groups of 10-70 individuals.

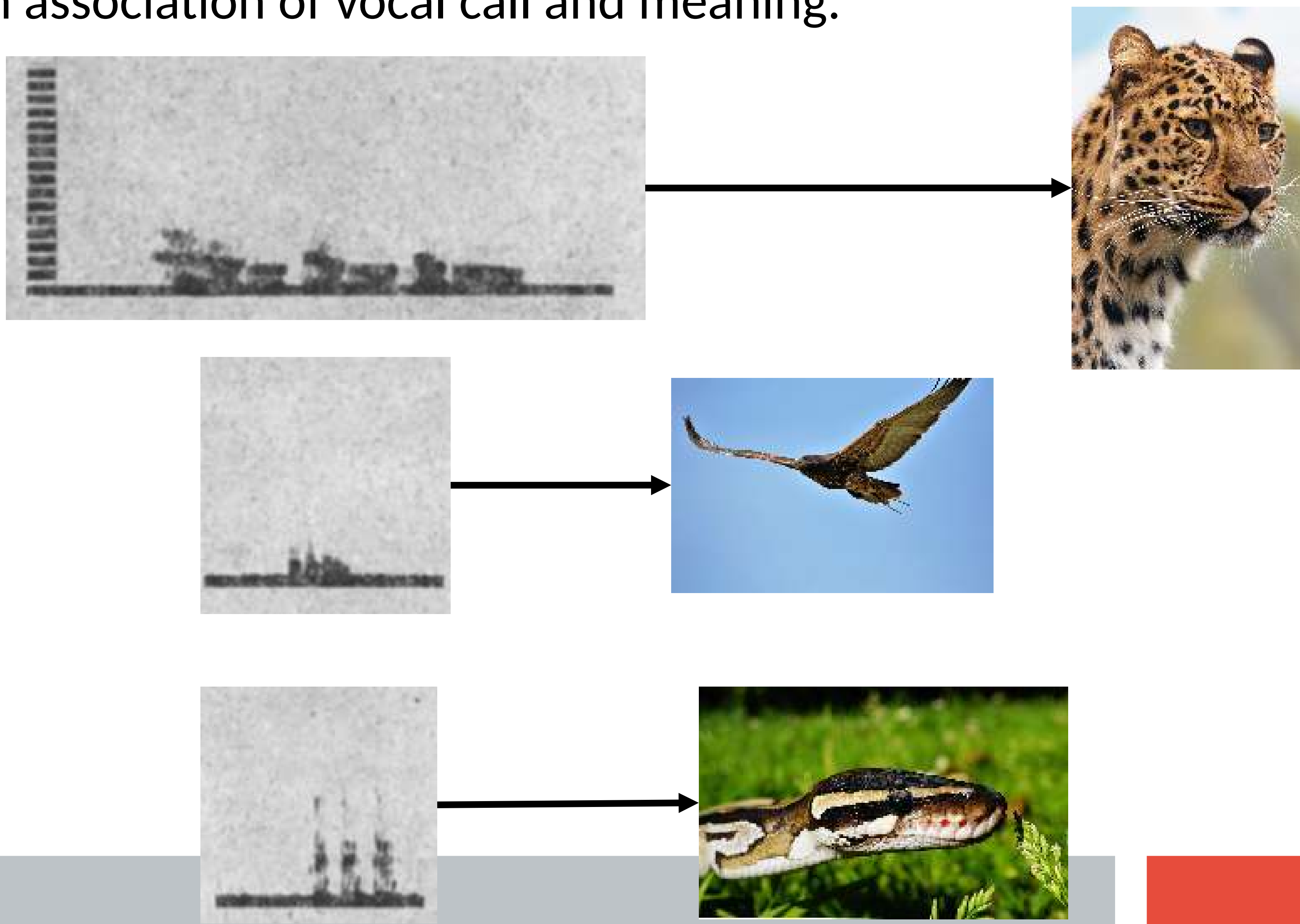
They signal to each other different dangers with different alarm calls and respond to these calls with appropriate behavior:
Leopard call -> run into tree
Eagle call -> run into cover, look up
Snake call -> look down, approach



Seyfarth et al., Anim. Behav., 1980

Animal communication

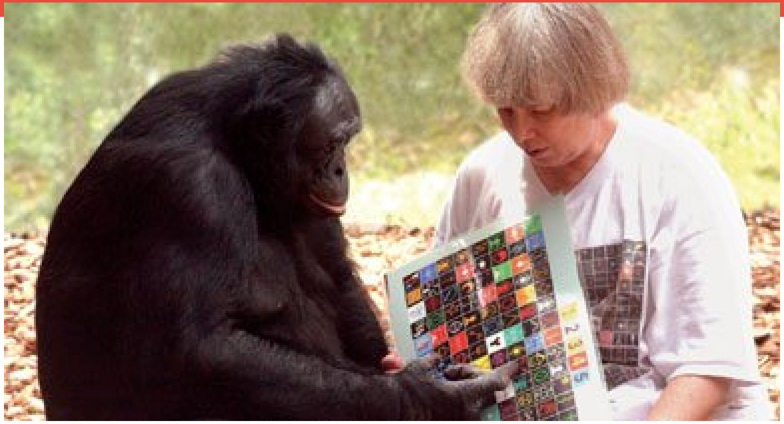
Thus, vervet monkeys show a basic form of semantics: an association of vocal call and meaning.



Animal communication

www.koko.org

Gorilla Koko has been taught to use sign language.



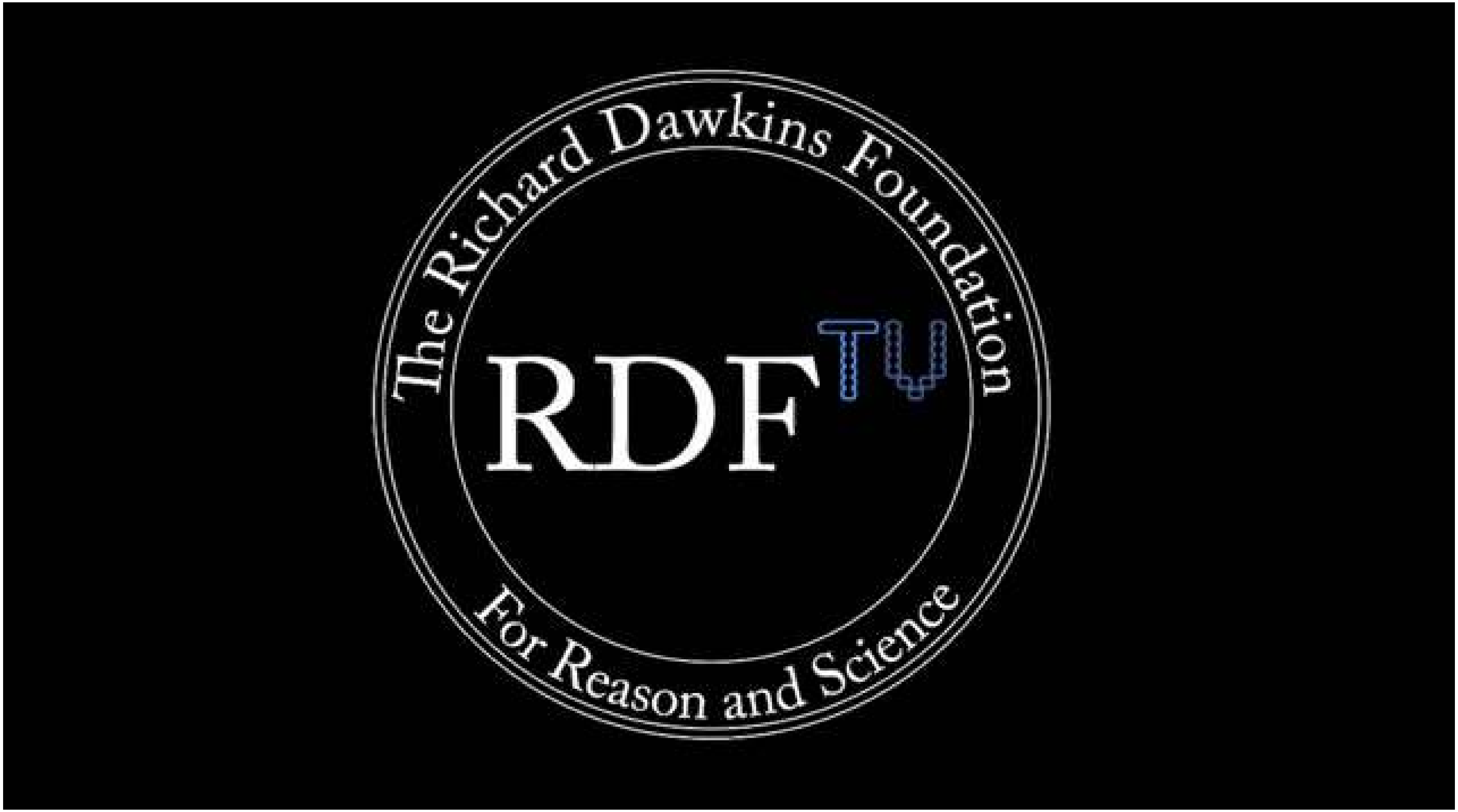
Bonobo Kanzi has been taught to use pictorial symbols to refer to concepts.

www.smithsonianmag.com

www.economist.com

Alex the parrot was taught to use human-like vocalizations to refer to concepts.

Monkeys…

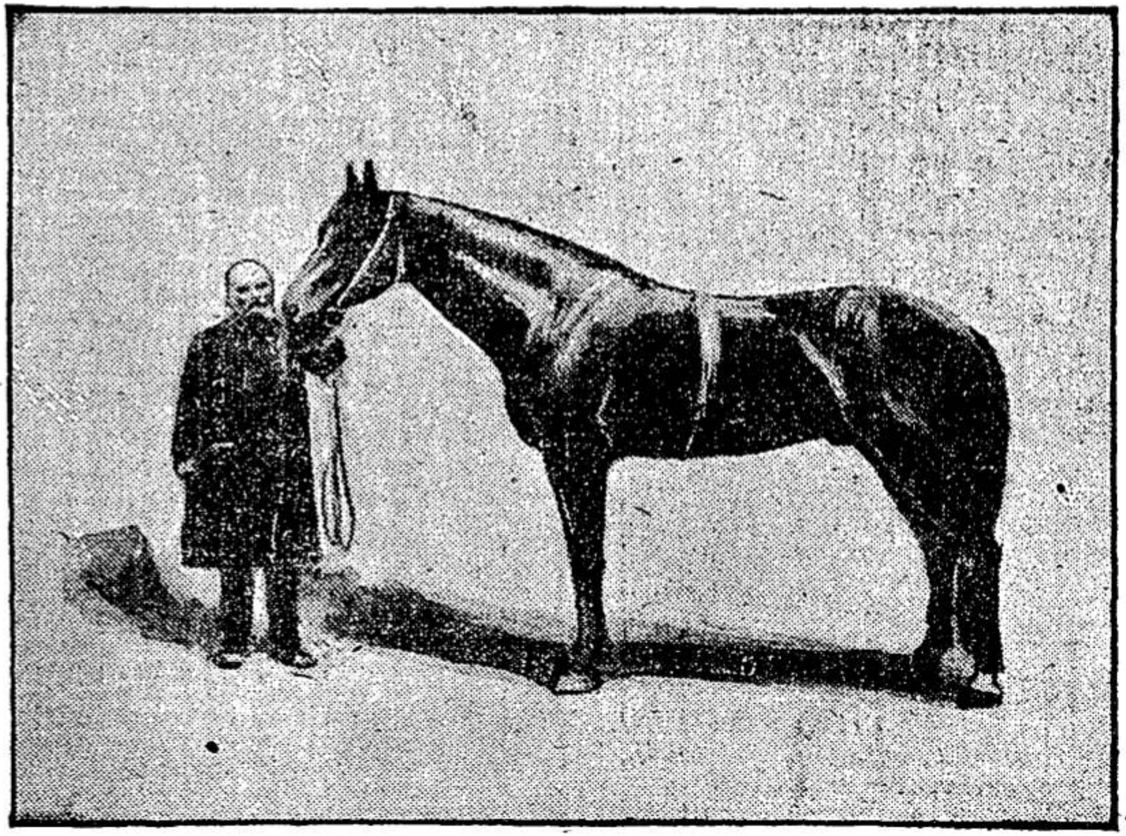

The Richard Dawkins Foundation
RDF TV
For Reason and Science

Birds… (Pepperberg lab)

Methodological concerns

"Clever Hans" was a German horse that was reported (around 1904) to be able to understand human language and to do arithmetic by tapping with the foot (e.g.: What is 2+3?->5 foot taps).

New York Times



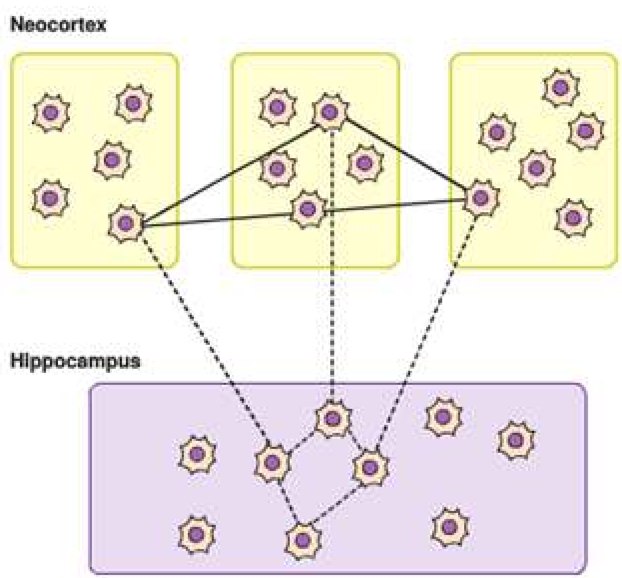
HANS AND HIS OWNER, HERR VON OSTEN.

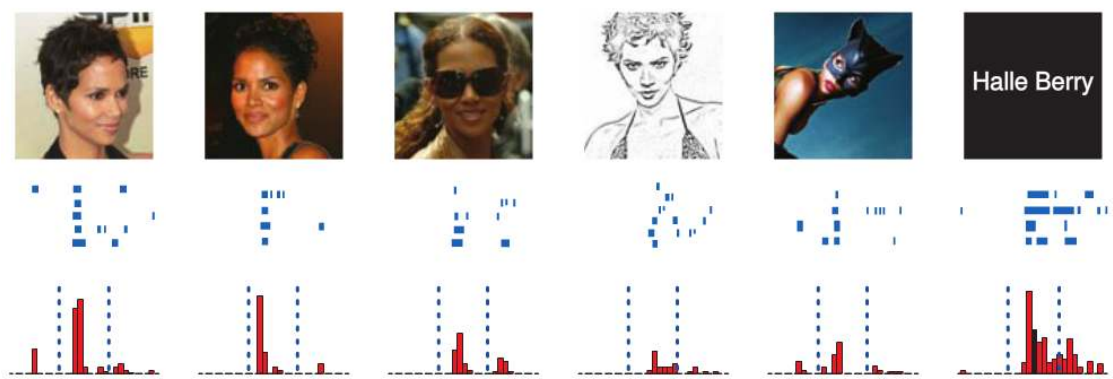
Careful experiments showed that Hans depended on involuntary cues from the animal keeper or others.

This has been taken as a warning to over-interpret animal behavior and thus the need to test trained animals in isolation.

Semantic networks

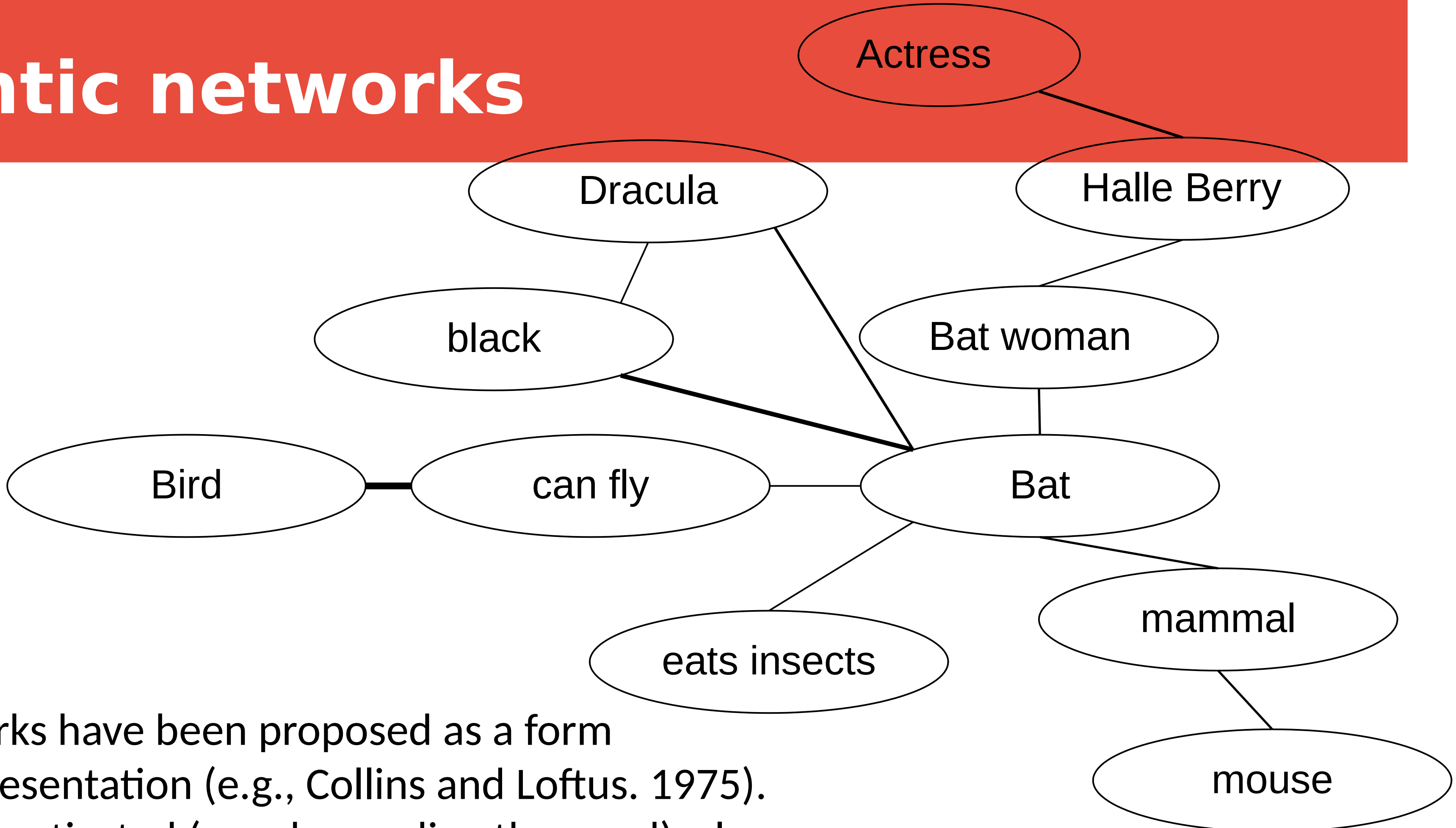
Bear, Neuroscience





Remember the class about memory (class 4): abstract concepts (such as “Halle Berry”) can be stored in wide-spread networks and these networks can be activated by different pictures or even modalities (visual, written, auditory).

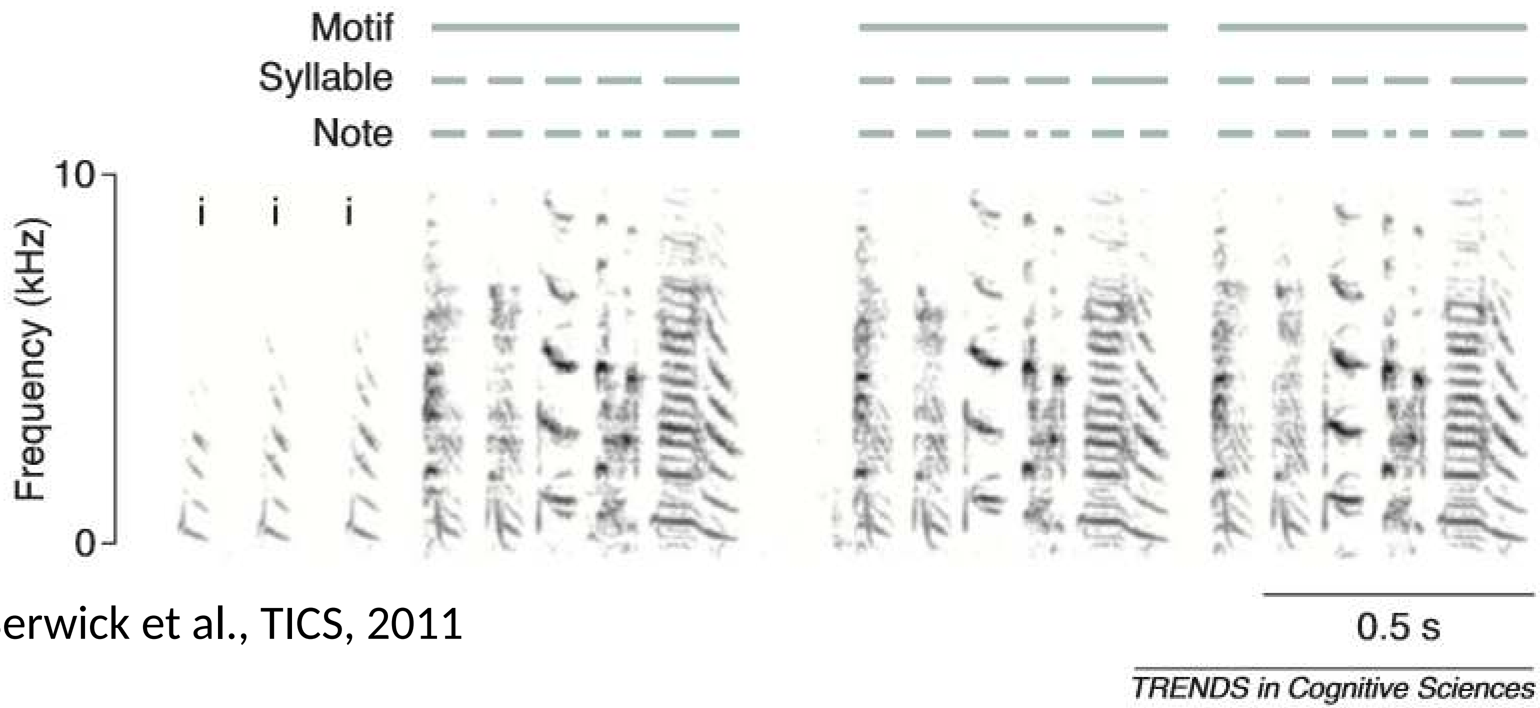
Semantic networks



Semantic networks have been proposed as a form of semantic representation (e.g., Collins and Loftus. 1975). If one concept is activated (e.g., by reading the word), close neighbors can be activated by spreading activation.

Semantic priming is facilitation (increased speed) of word processing by preceding presentation of a semantically related word (e.g., bat→Dracula) and can be explained by spreading activation.

Bird song syntax

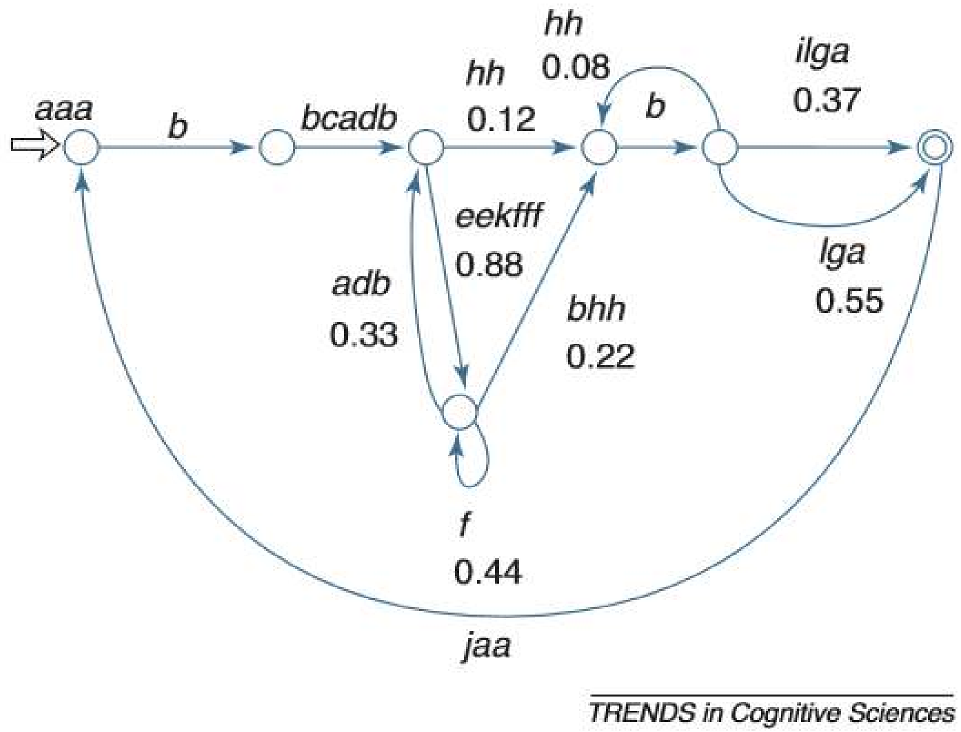


Berwick et al., TICS, 2011

Bird songs (here: zebra finch) can have complex rules how vocalizations are structured. In zebra finches, single notes are grouped into syllables, and these in turn are grouped in motifs.
A sequence of motifs is called song bout.

Bird songs syntax

Berwick et al., TICS, 2011

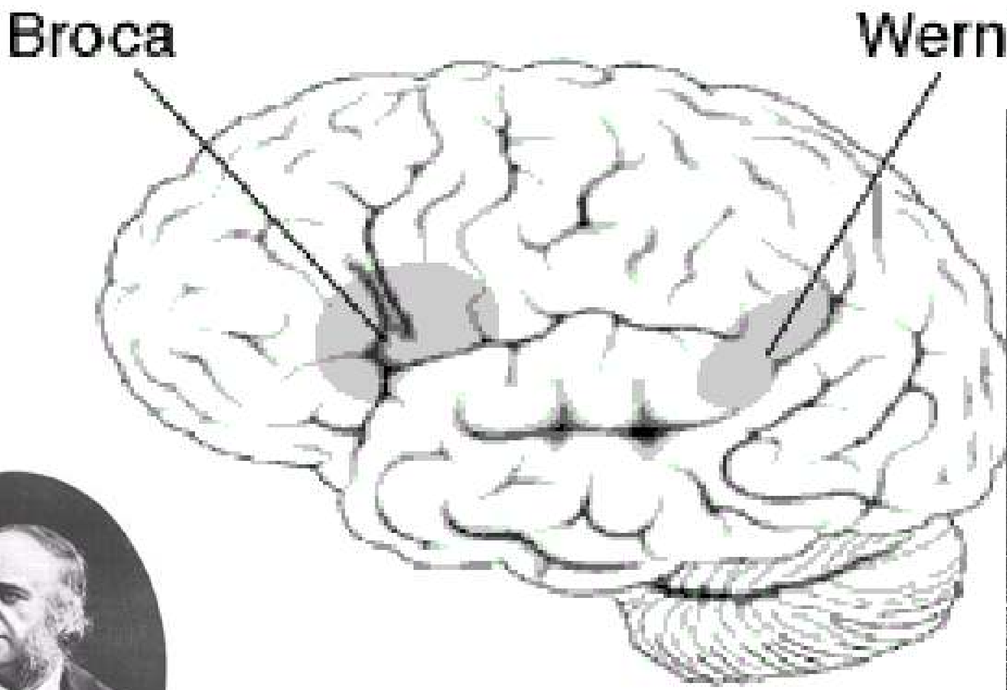


The image shows the transition rules and probabilities for a Bengalese finch song.

A song example:
aaa b bcadb eekfff b lga

In contrast to humans, syntax in songbirds has no semantic role (only attraction of mates, deterring rivals, and defending territory). In humans, e.g., putting an ‘s’ to ‘apple’ or changing word order can change the meaning of a sentence.
Human sentences can be indefinite and can have recursively nested dependencies (‘Mary thought that Pat ate the apple that Lucy thought....’) which seems not to be the case for songbirds.

How the brain processes language: Evidence from brain damage



Carl Wernicke (1848-1905)

Paul Broca (1824-1880)

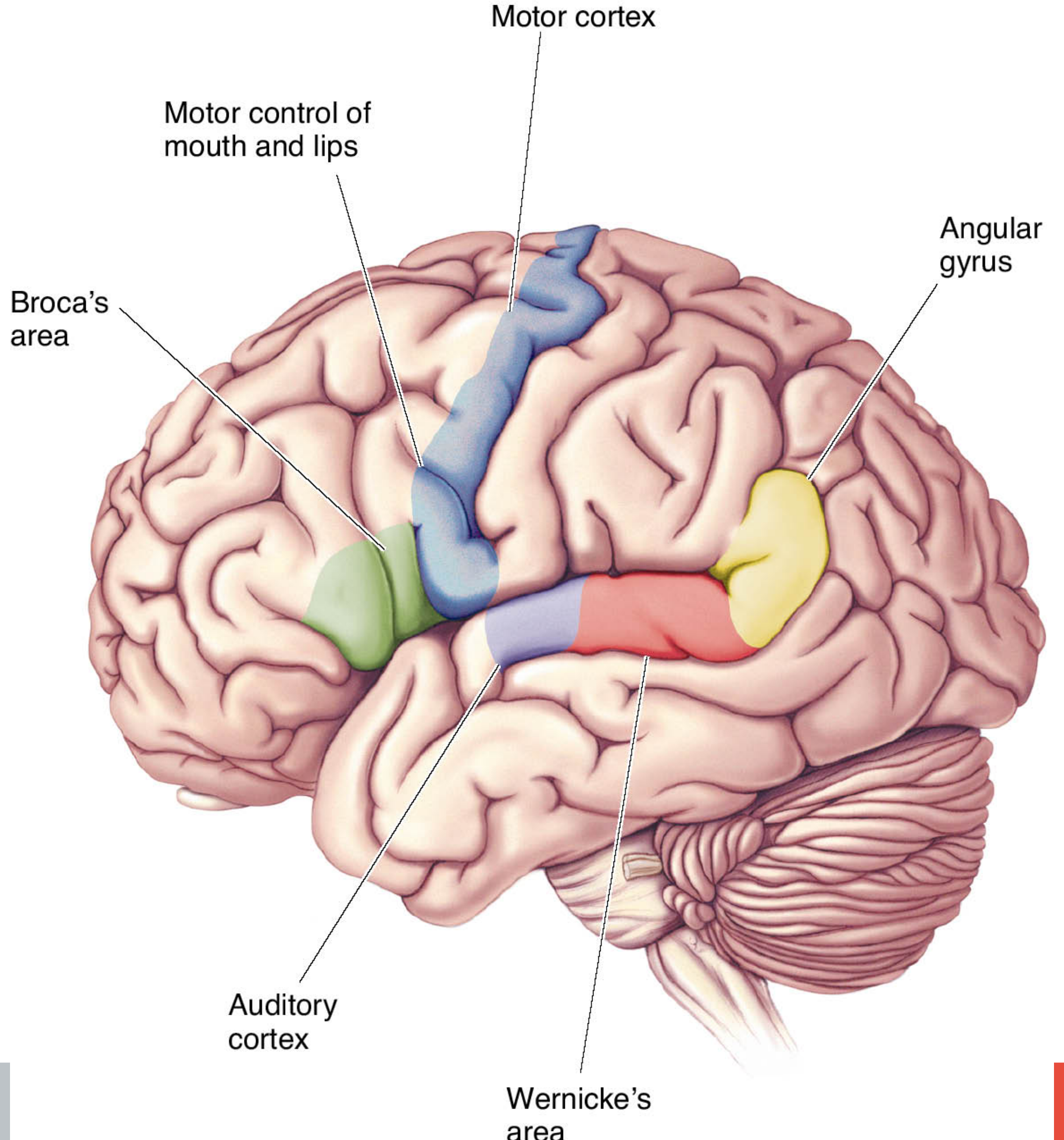
The study of language disorder (aphasia) after brain damage has two influential founding fathers: the neurologists Paul Broca and Carl Wernicke.

Broca’s Aphasia

In 1861, Paul Broca saw a patient who was almost entirely unable to speak, only “Tan”. Therefore this person was called “Monsieur Tan”.

A lesion was found in left frontal cortex (as in eight other similar cases), an area that is now called Broca’s area.

(Video Example: https://auditoryneuroscience.com/brocas_aphasia)



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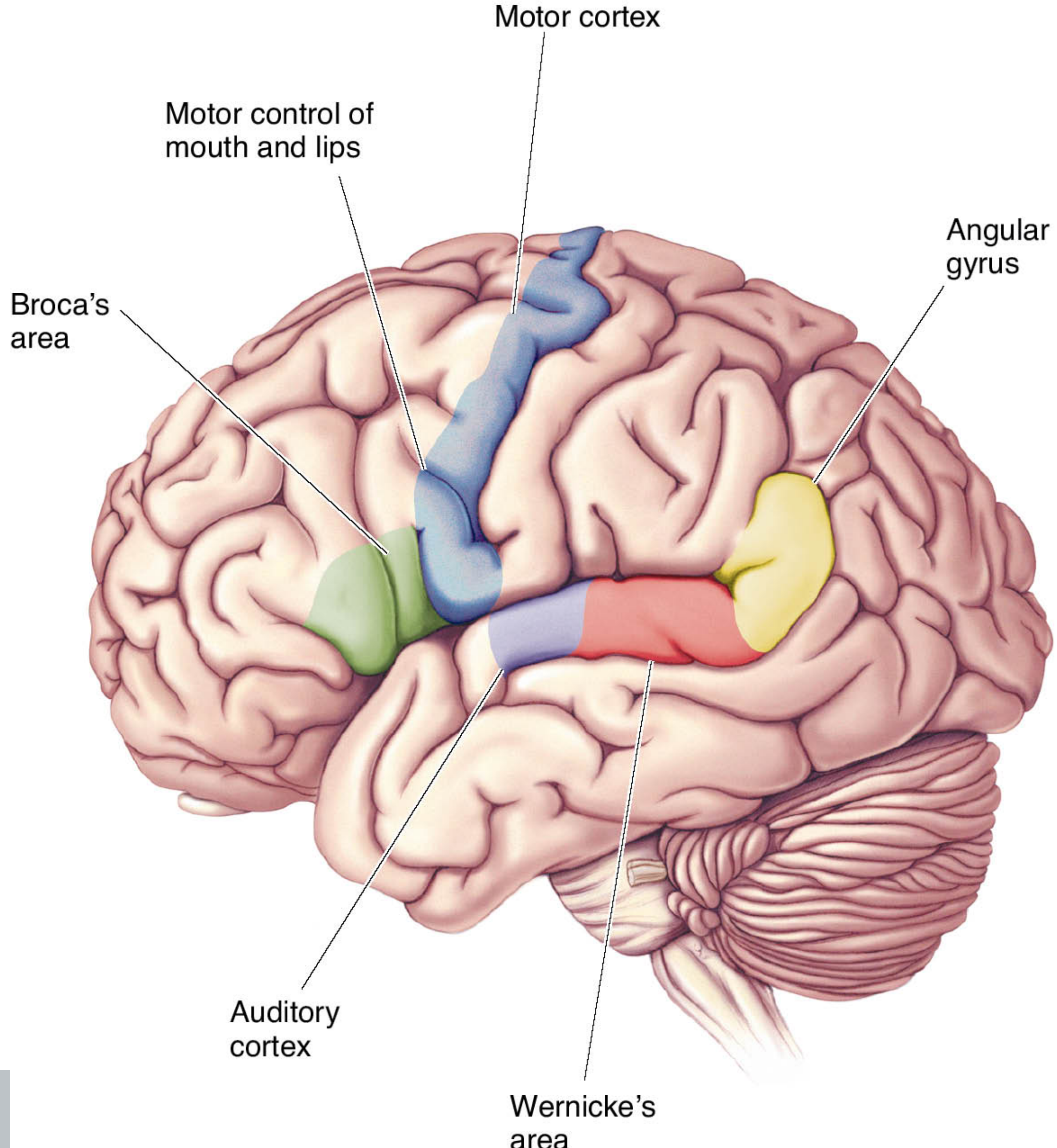
Broca’s Aphasia

Broca’s Aphasia

Deficits in Broca’s aphasia:

Broca’s aphasia is a non-fluent aphasia characterized by a **difficulty to speak**, articulate and find words (anomia). Function words are often left out and patients have problems constructing a grammatically correct sentence.

Comprehension of language is often preserved.



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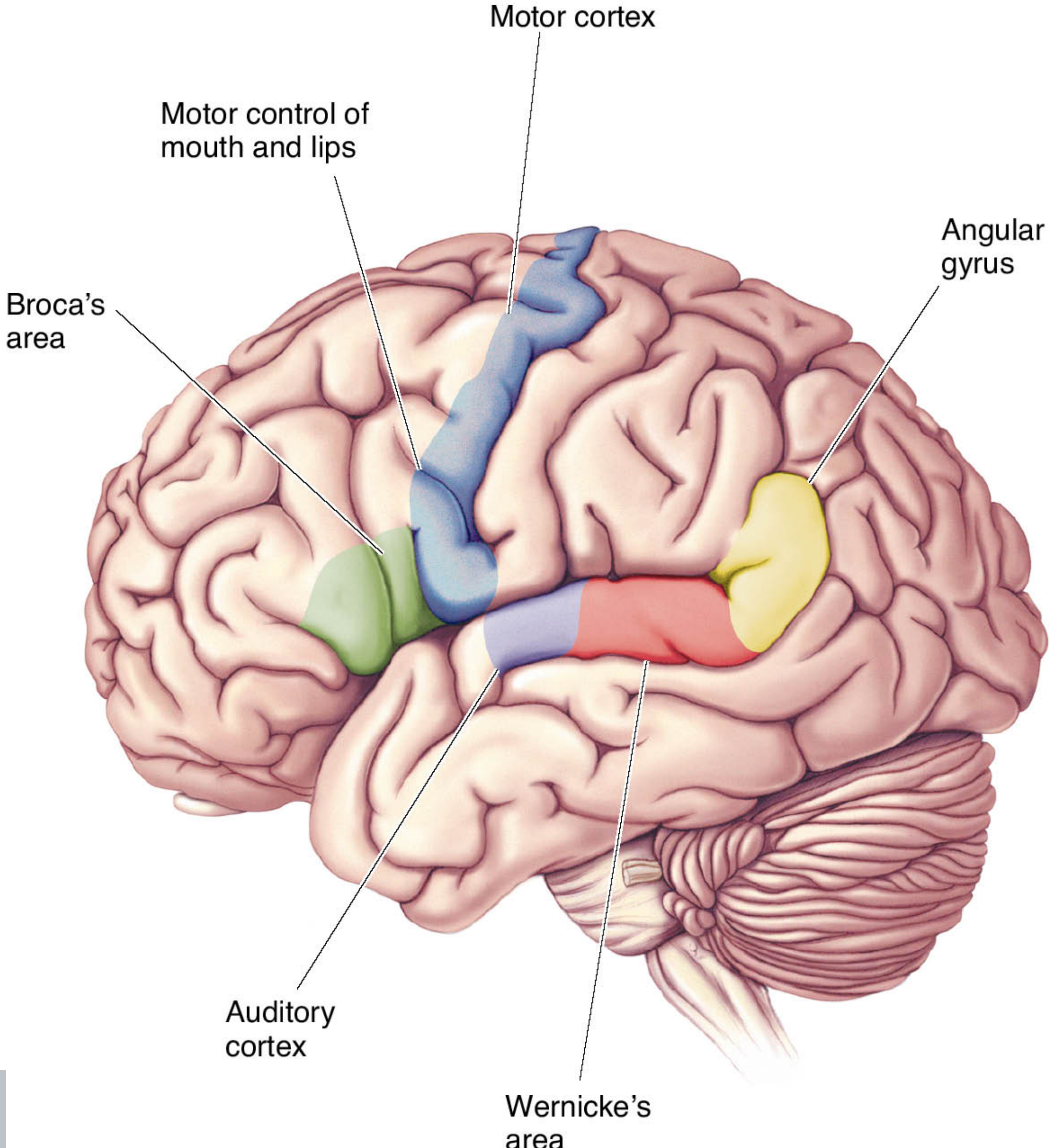
Wernicke's Aphasia

In 1874, Carl Wernicke found an area different from Broca's area in which a lesion can lead to language deficits:

The left posterior superior temporal lobe (now Wernicke's area), situated close to auditory cortex.

(Video Example: https://auditoryneuroscience.com/wernicke_aphasia)



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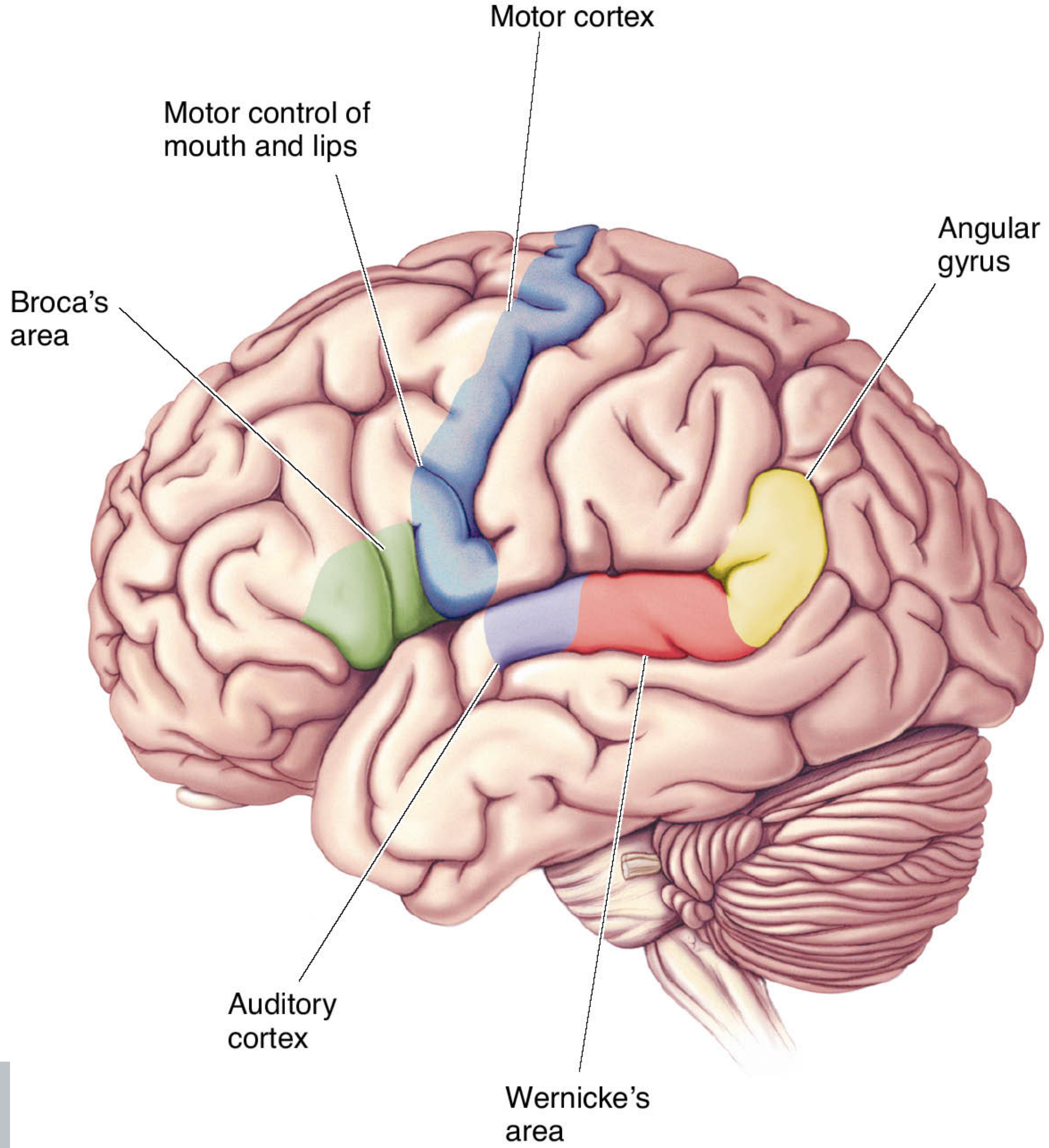
Wernike's Aphasia

Wernicke’s Aphasia

Wernicke’s aphasia is characterized by fluent speech, but an **inability to comprehend** speech.

To test speech comprehension only, the patient is asked to respond nonverbally, for example “put object A on object B”.

Produced speech is often meaningless – a “word salad”.



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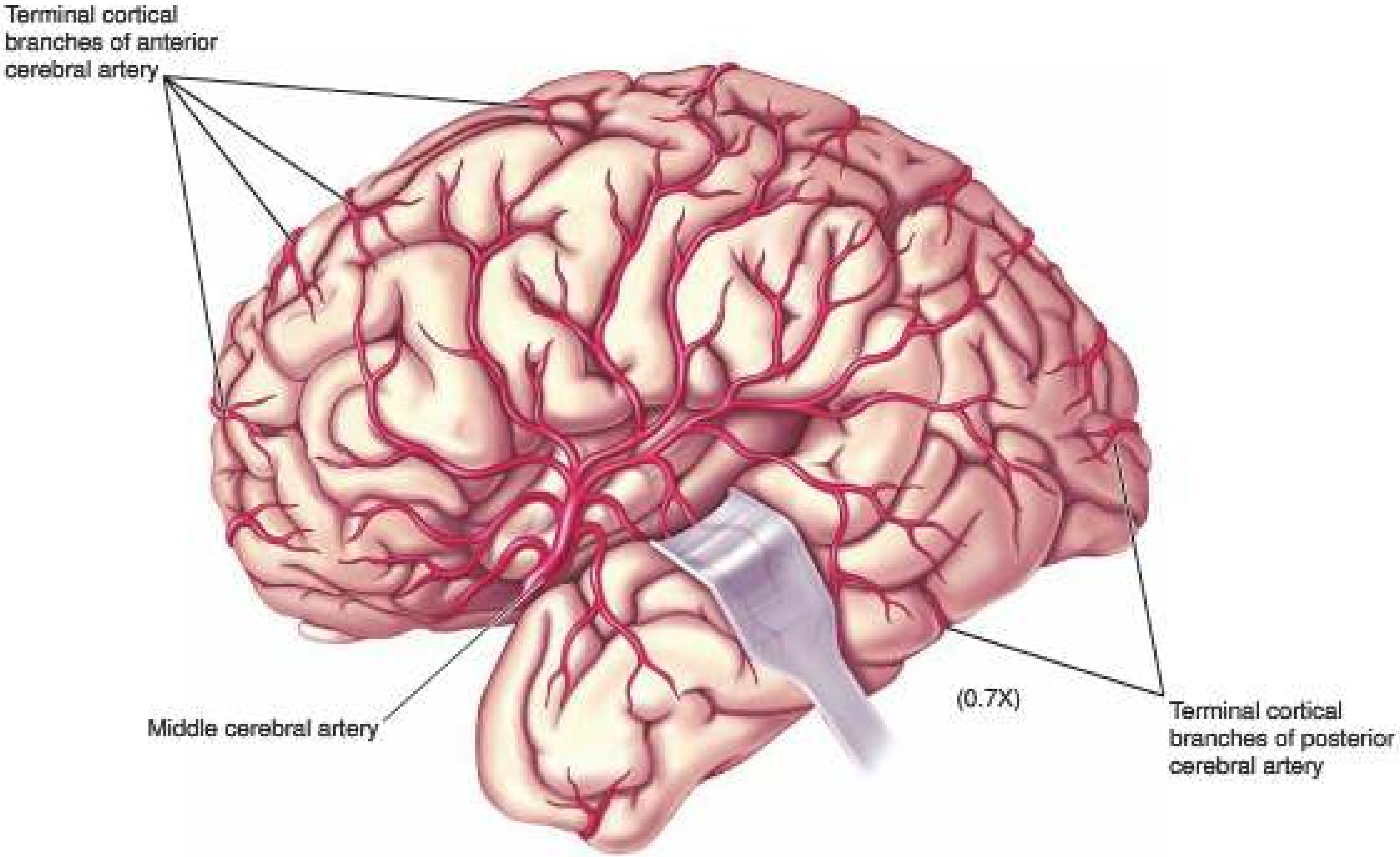
Aphasia

Aphasia very often occurs as a result of a stroke involving the left middle cerebral artery. It supplies both frontal and temporal language areas.



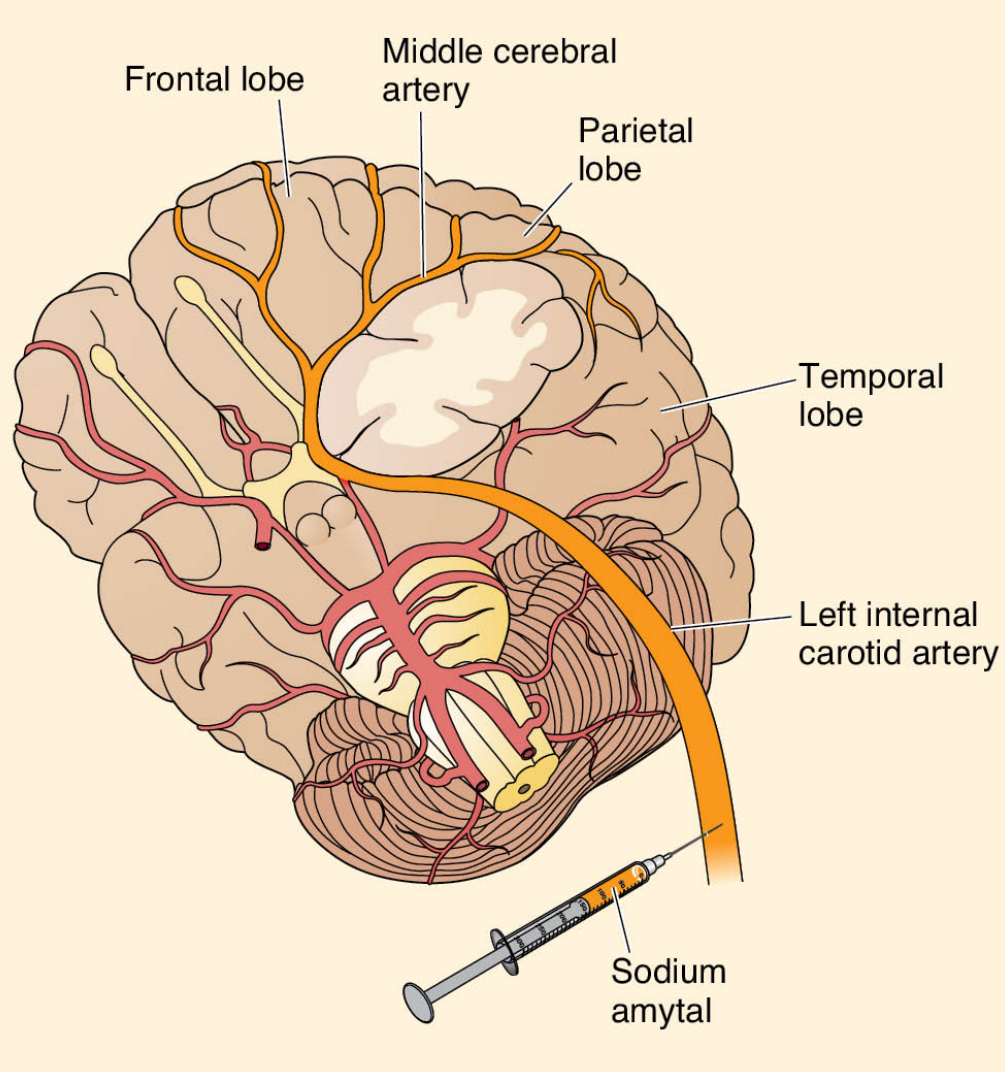
Hemispheric Lateralization

Language functions are left-dominant in most humans:

Language-dominance can be tested by injecting sodium amytal into one hemisphere (a barbiturate that will inhibit brain function). If the language-dominant side is inhibited, patients are unable to speak and to respond to questions.

<u>**Right-handers**</u>: ~96% have a left-hemisphere language dominance, 4% right.

<u>**Left-handers**</u>: ~70% have a left-hemisphere language dominance, 15% right, and 15% bilateral.



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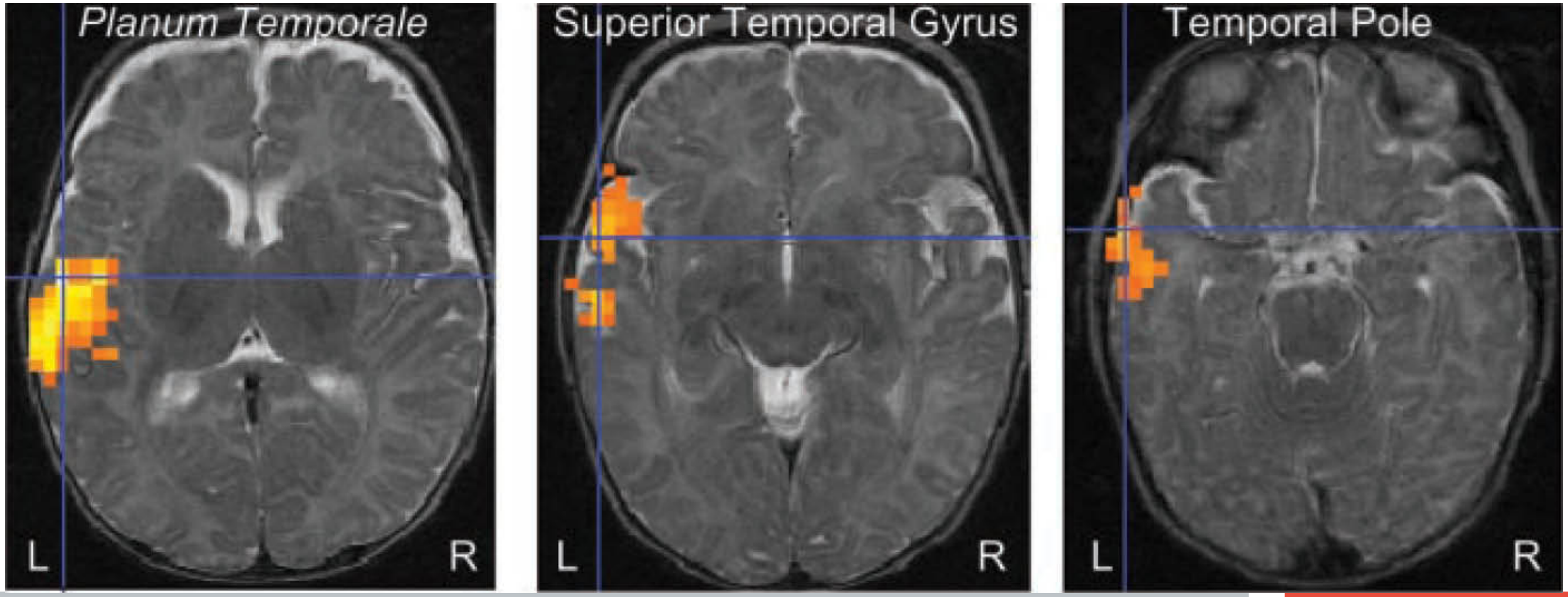
Hemispheric Lateralization

Functional magnetic resonance imaging (fMRI) studies show that already in early infancy (at 3 months of age), listening to speech activates brain areas in the temporal lobe, with a dominance of the left hemisphere (Dehaene-Lambertz et al., 2002).

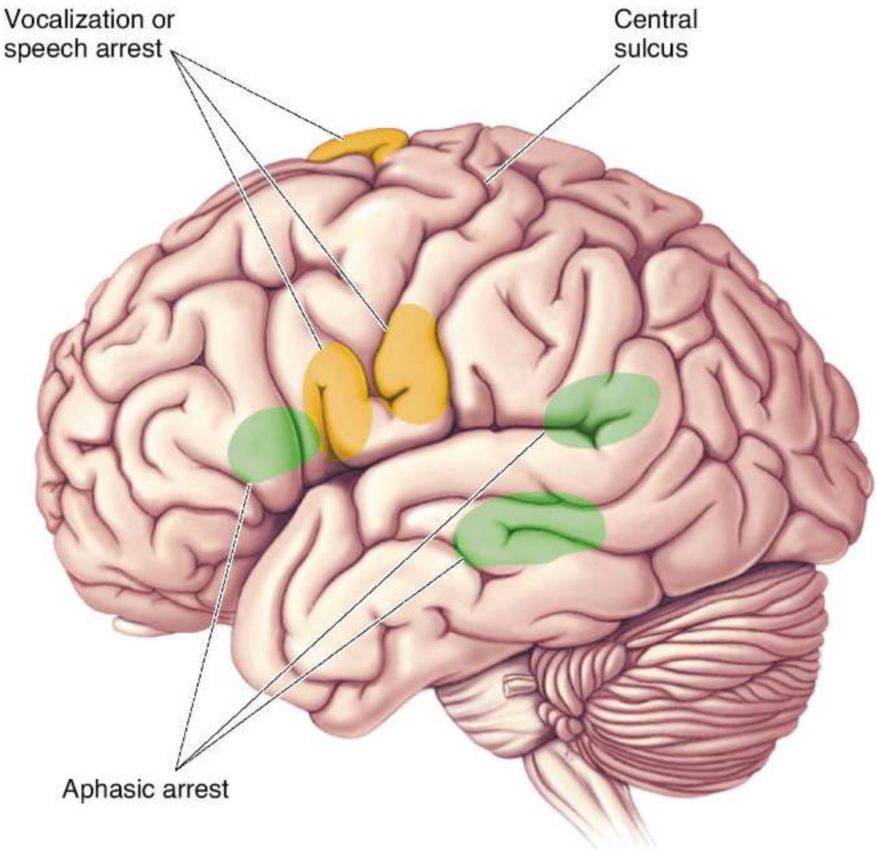


Electrical stimulation of motor/speech areas

Electrical stimulation in patients before surgery (Penfield and Rasmussen, 1950) can lead to speech impairments.

Speech arrest (stop of vocalization) or sudden vocalization occurs after stimulation of motor cortex on both hemispheres (brown).

Aphasic arrest, i.e., speech problems (slurred speech, stop of articulation, inability to name things, etc.) occurs after stimulation of language areas (Broca, Wernicke areas, temporal lobe) on the left hemisphere.



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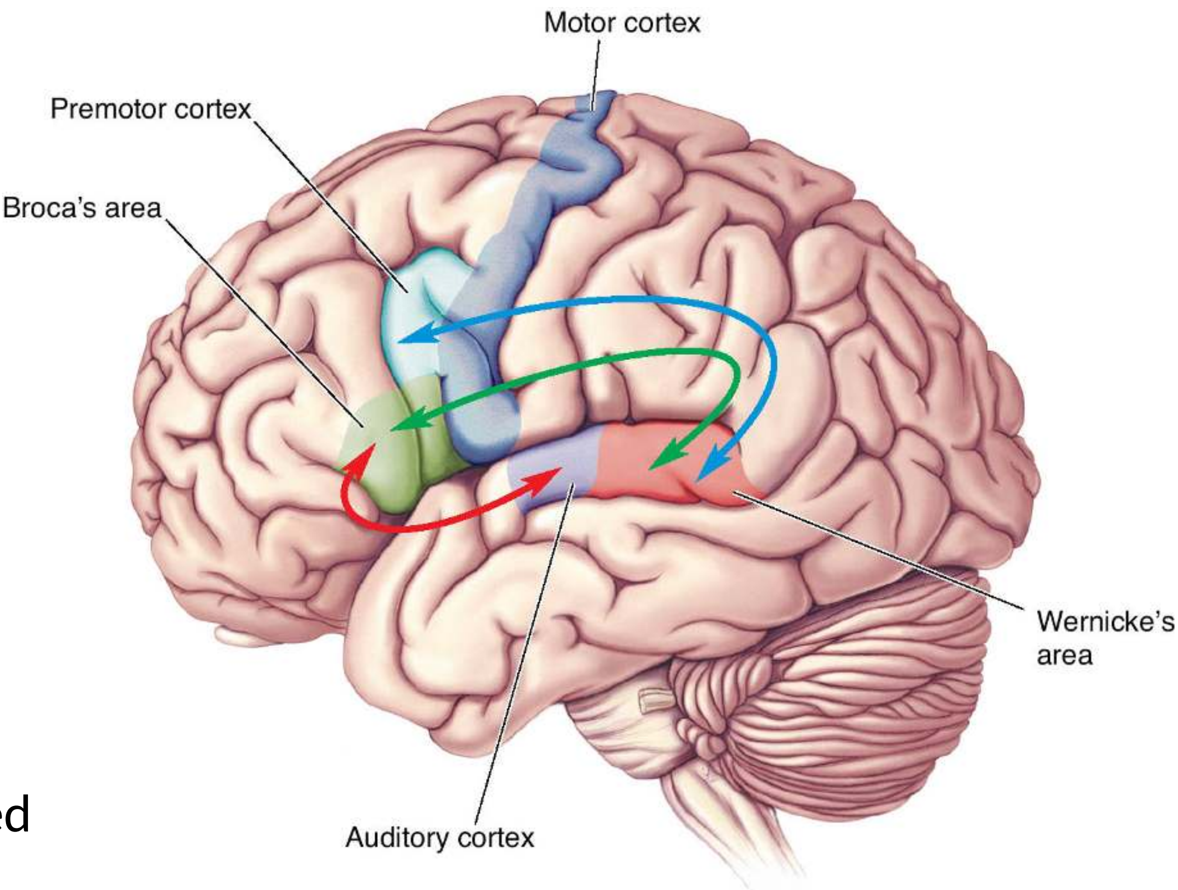
Models of speech processing

Current models of language processing in the brain not only take into account the isolated Broca's and Wernicke's area but also the connections between them.



Ventral pathway (red):
Extraction of meaning;
speech sound information enters auditory cortex and is processed along the anterior temporal lobe and transmitted via fibers to Broca's area.

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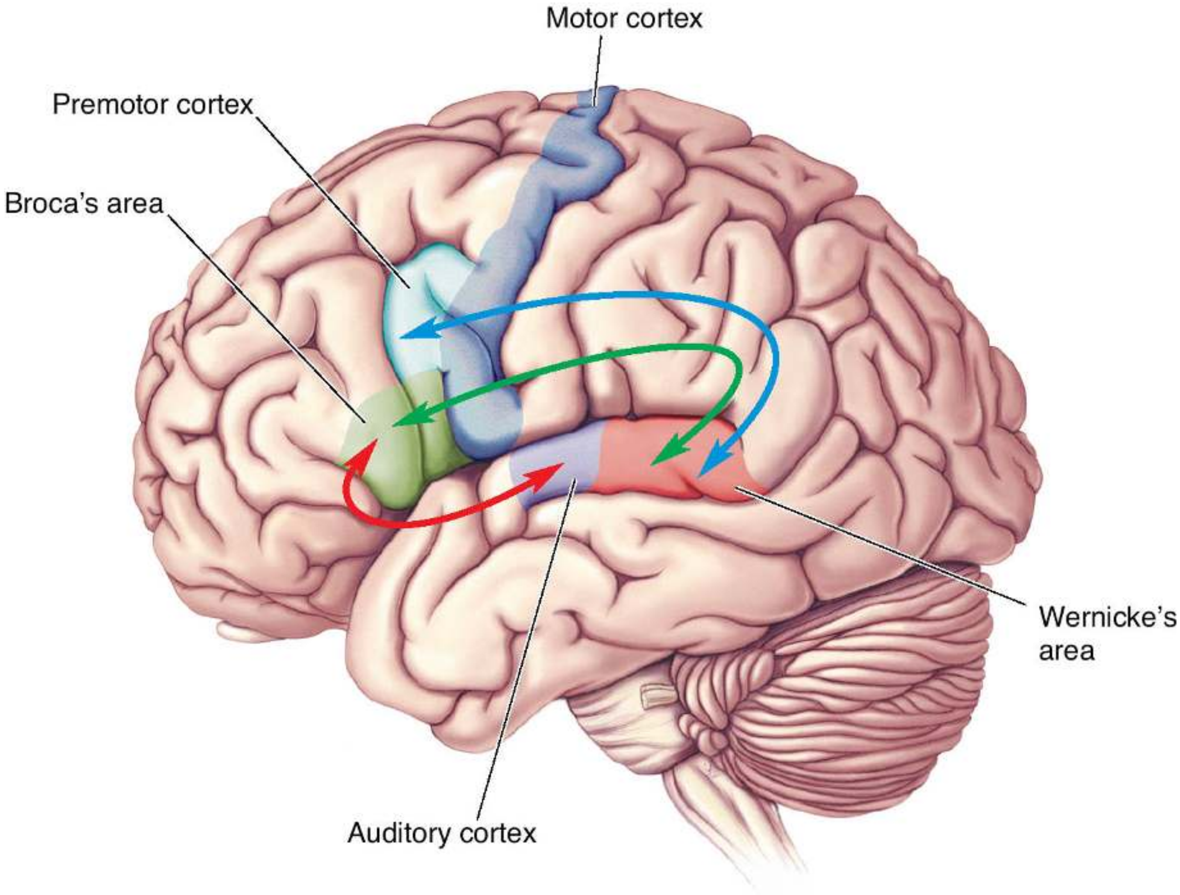
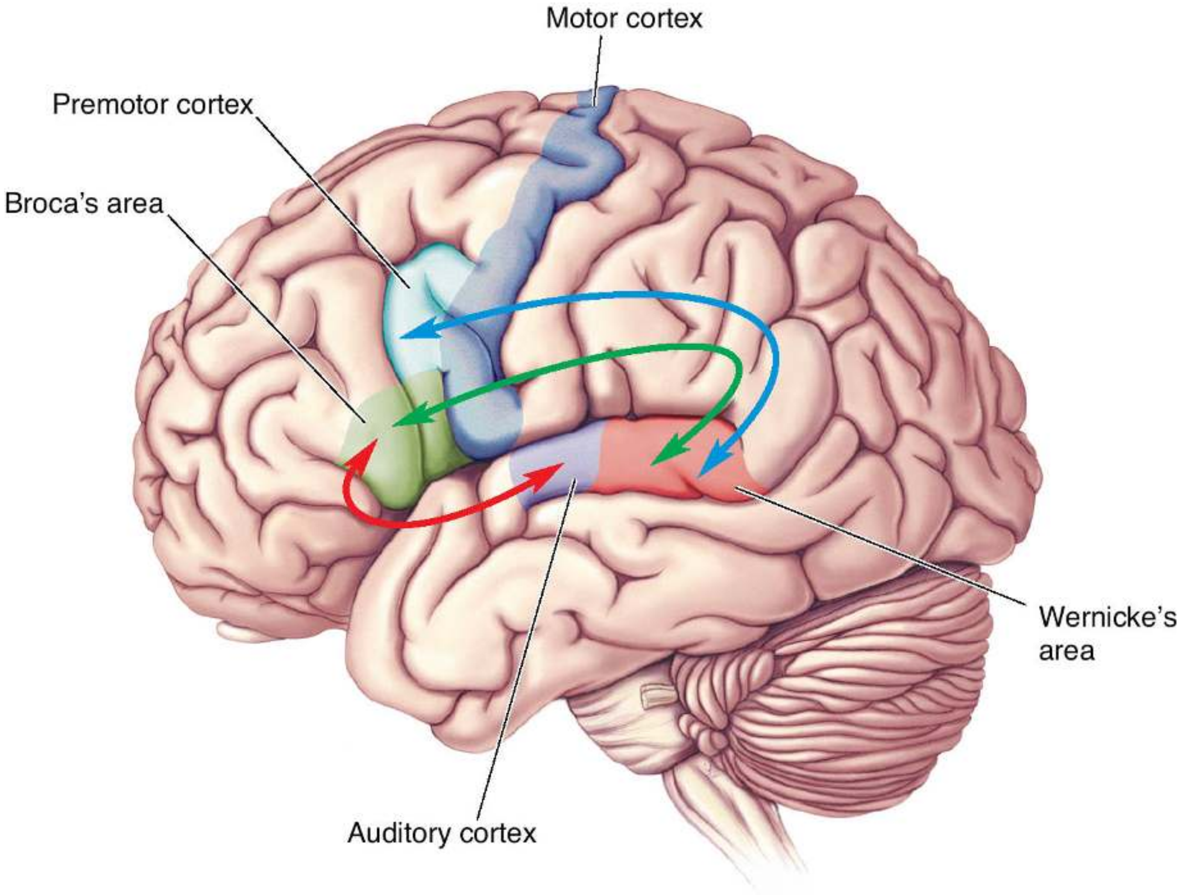
Models of speech processing

Lower dorsal pathway (green): Processing of complex syntactic structure; speech sound information enters auditory cortex and is processed along the posterior temporal lobe and transmitted via fibers to Broca's area.



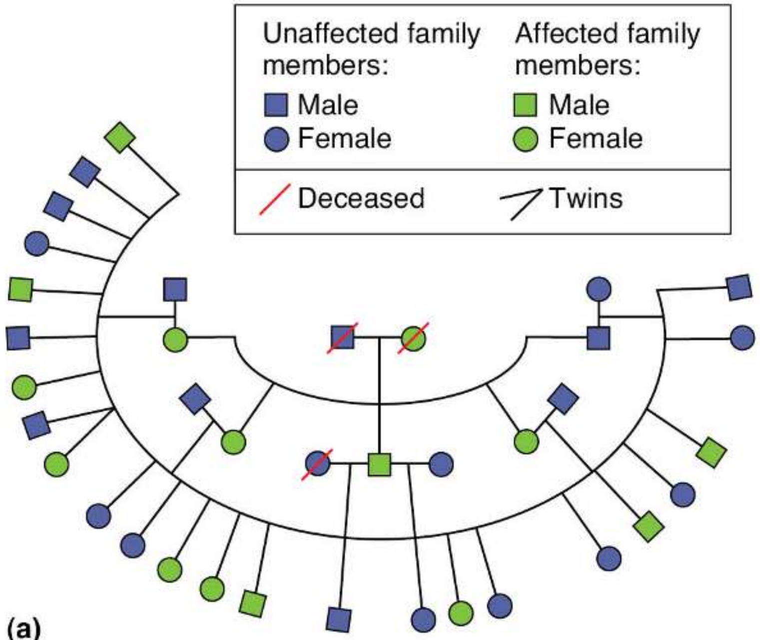
Models of speech processing

Upper dorsal pathway (blue): Pathway for speech production and repetition of heard words; speech sound information enters auditory cortex and is processed along the posterior temporal lobe and transmitted via fibers to premotor cortex.



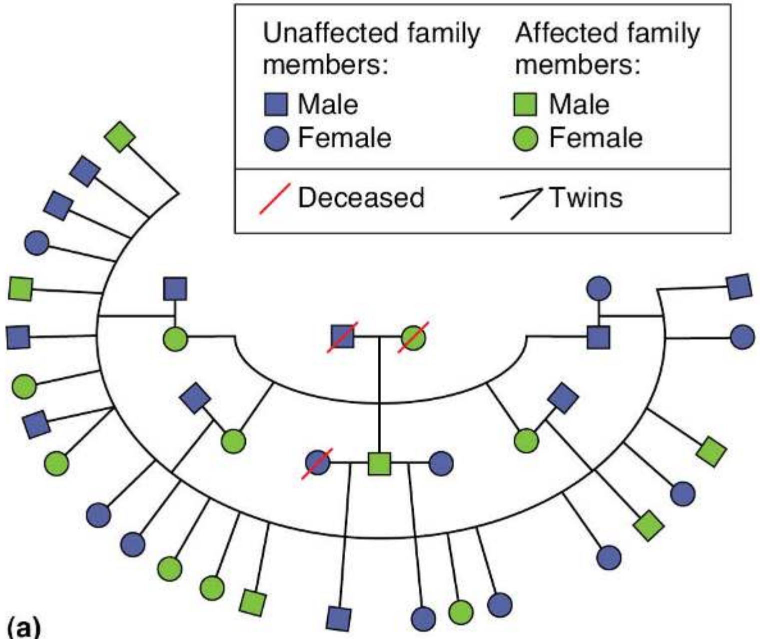
Inherited speech deficits

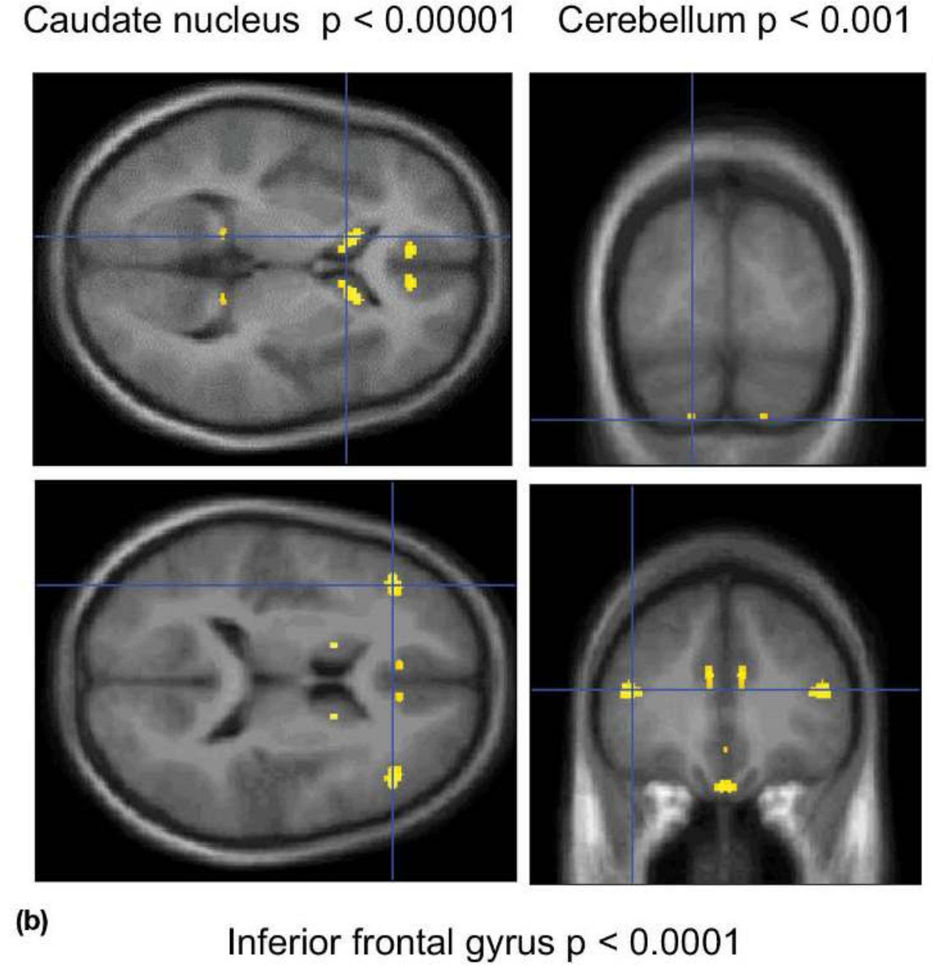
In 1990, a British family, KE, was described in which some affected members exhibited unintelligible speech (they often used hand signs instead). This was often accompanied by grammar and general language deficits and lower intelligence.



Inherited speech deficits

MR imaging showed reduced gray matter in caudate nucleus (basal ganglia), cerebellum, and inferior frontal gyrus. It is caused by a mutation in the FOXP2 gene, a transcription factor that turns other genes on and off.





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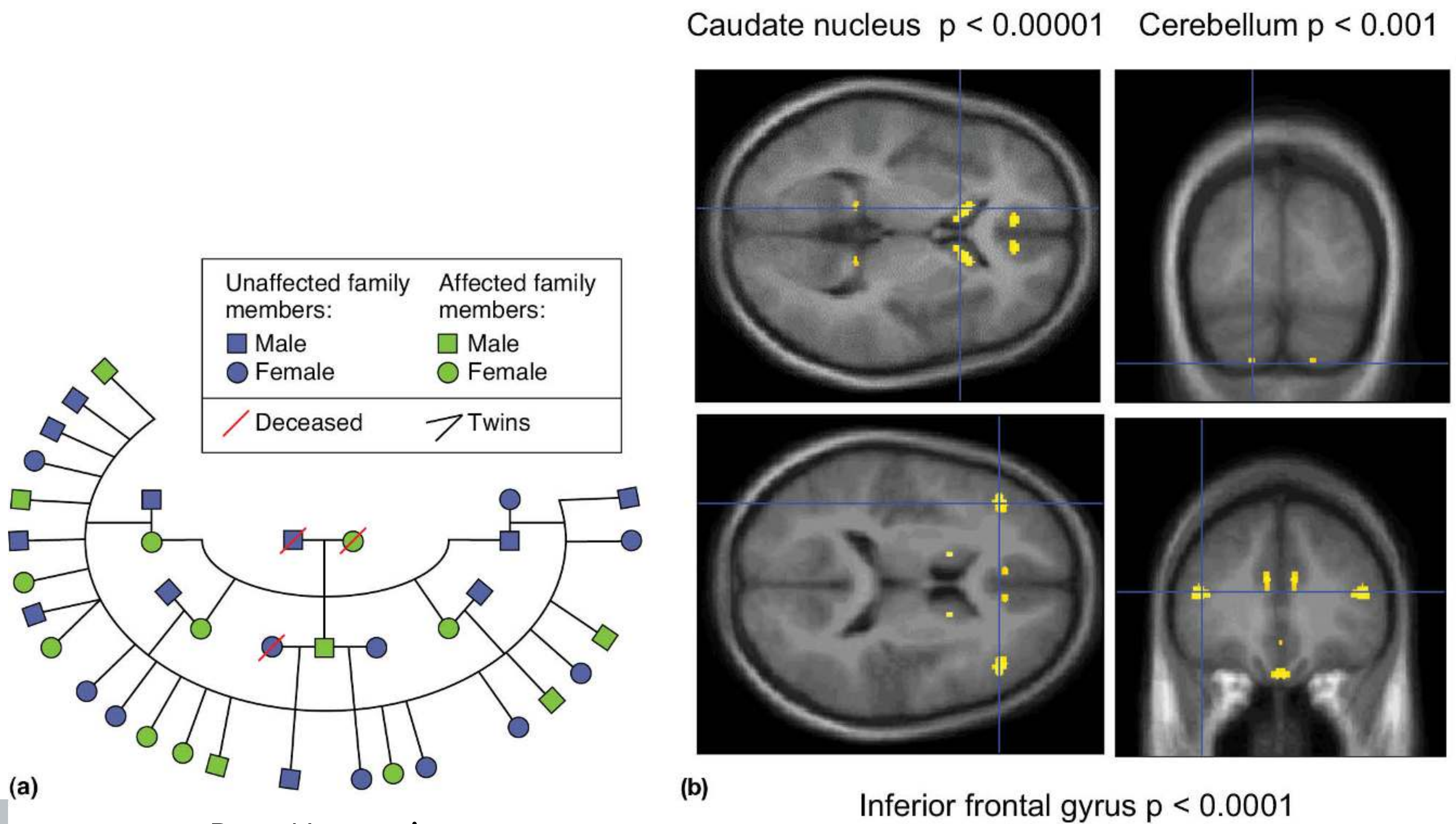
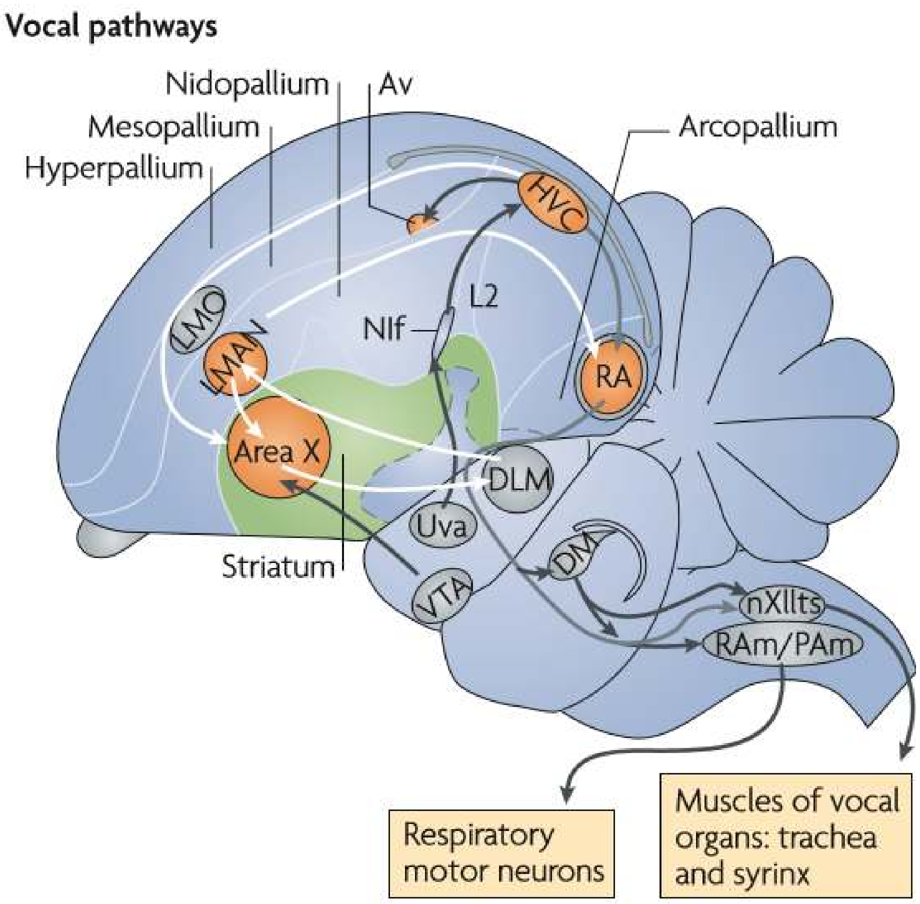
Inherited speech deficits

The FOXP2 transcription factor is probably involved in the development of motor-related brain areas important for fine control of the lower face muscles.



FOXP2 in songbirds

FOXP2 is highly conserved in mammals and can be found in other animals, in particular birds.



In songbirds, FOXP2 plays a role in pathways important for song production and learning during early development.

In juvenile zebra finches, FOXP2 mRNA expression levels are high in Area X during sensorimotor learning, i.e., learning to produce a newly learnt song.

Area X is part of the bird basal ganglia and of a pathway important sensorimotor learning and adult song plasticity (new neurons are added to this area throughout life-time).

Bolhuis et al., Nature Rev. Neurosci., 2010

Summary: Communication

1) Animal Communication

   proto-semantics in vervet monkey alarm calls
   phonological syntax in songbirds

2) Aphasia (speech disorders)

   inferior frontal lesion → Broca's aphasia (production impairments)
   superior temporal lesion → Wernicke's aphasia (comprehension impairments)

3) Model of normal language processing

   3-pathway model involving auditory cortex, premotor cortex, Broca's and Wernicke's area

4) Genetics of speech deficits

   FOXP2 gene mutations can lead to speech disorder in humans and plays a role in songbird vocal plasticity