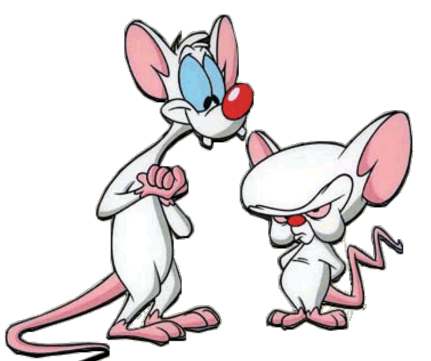
LING 1010

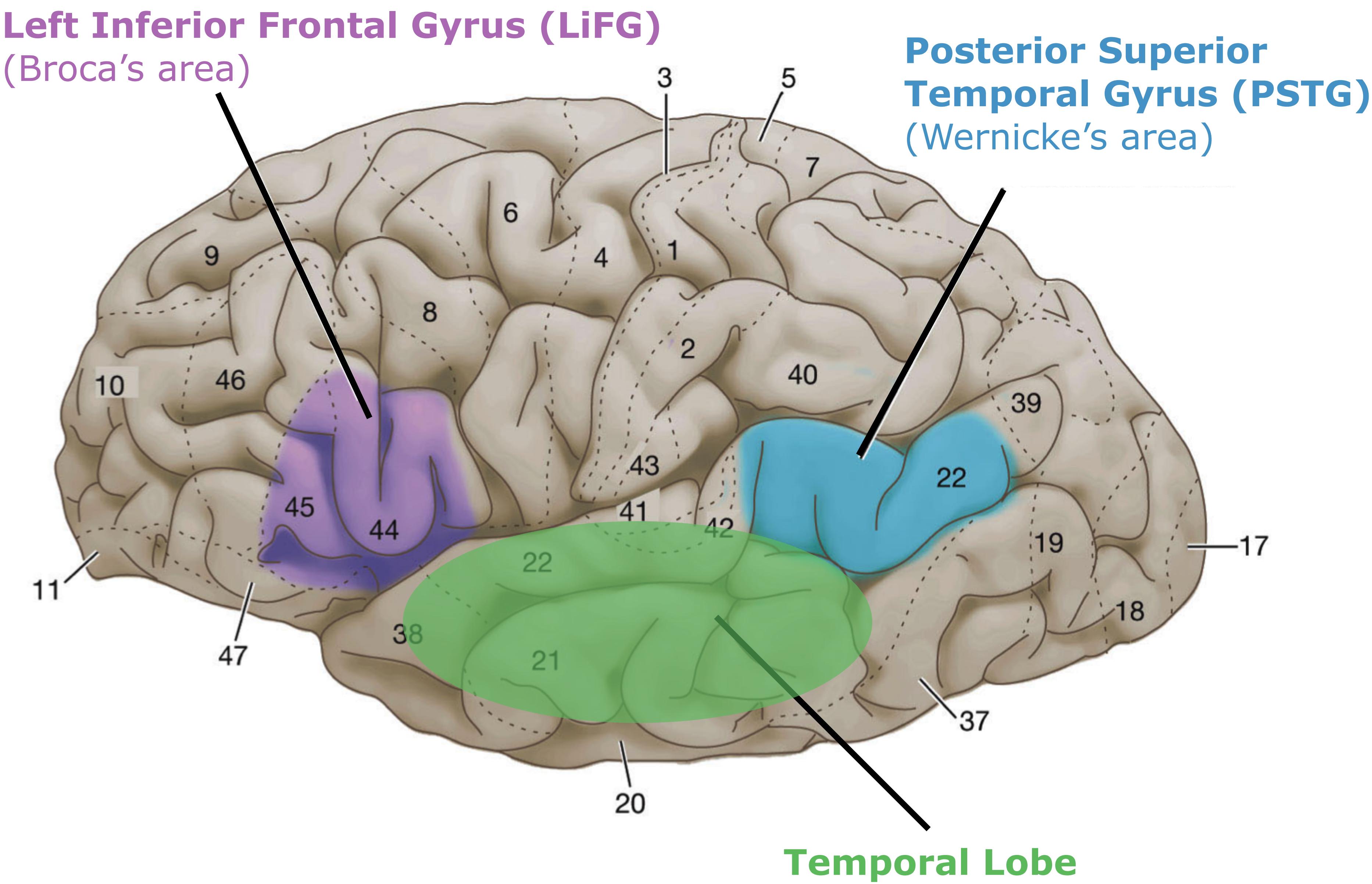
Language and Mind

Prof. Jon Sprouse

04.07.21: Language and the Brain



There is no single “language cortex”



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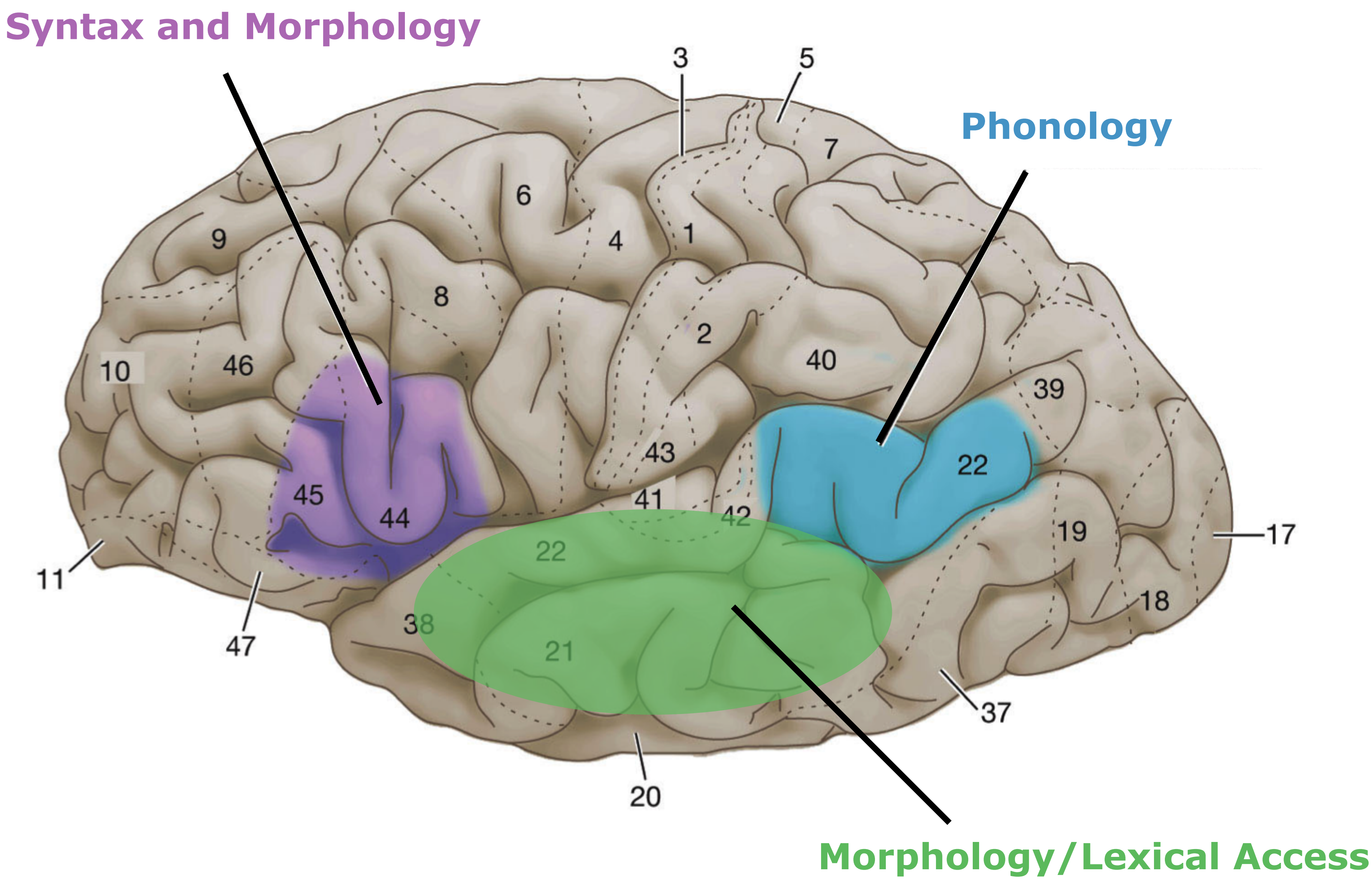


How do we study the brain?

Option 1: Neuroimaging

Magnetic Resonance Imaging

MRI is a brain imaging technique that allows us to measure the the location and density of a given element in the body.

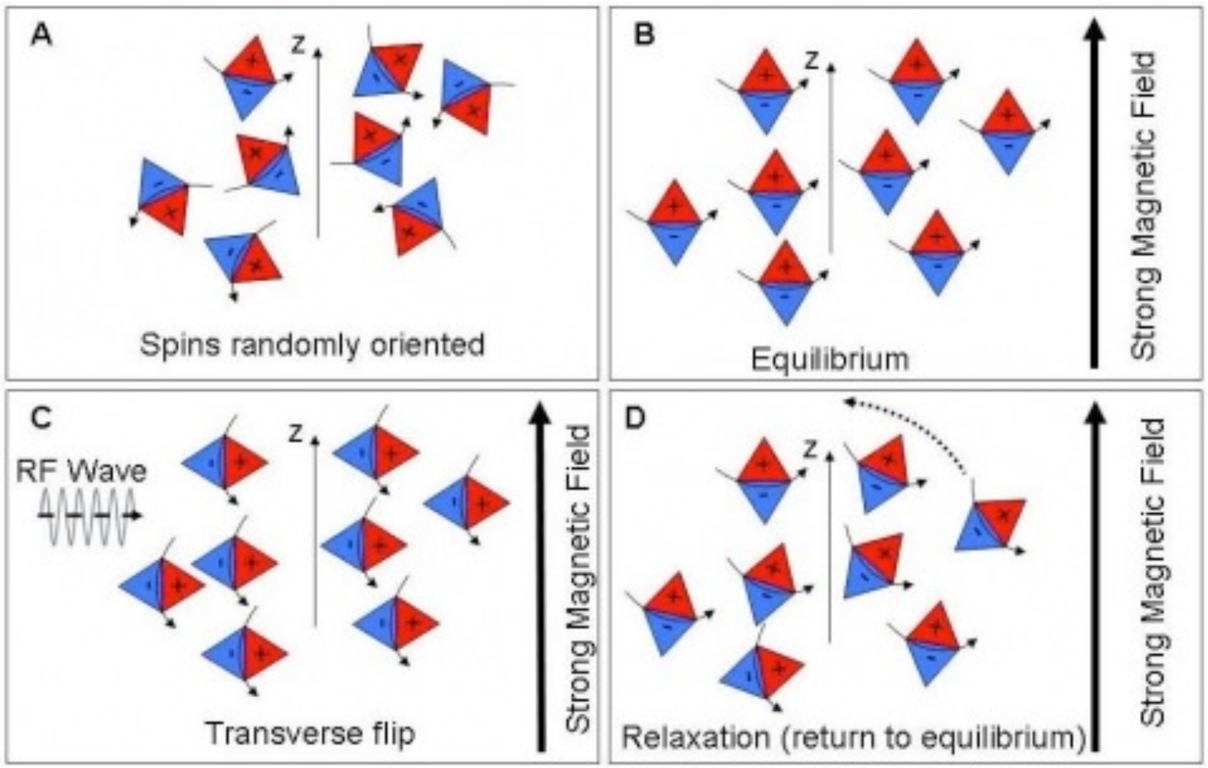
Typically, we use MRI to measure the location and density of hydrogen atoms. This is because hydrogen atoms are abundant in the body (in both water and fat). But in principle, we can look for any number of elements.

Different tissues in the body will have different amounts of hydrogen. These differences in density allow us to create detailed images of tissues inside of the body.

Magnetic Resonance Imaging

1. Hydrogen atoms are like little magnets with N-S poles. Their poles are naturally aligned randomly.

2. A strong magnetic field can be used to artificially align the poles of all of the hydrogen atoms.



3. A strong RF field can be used to alter that alignment while the magnetic field is still present.

4. Removing that RF field causes the atoms to re-align with the magnetic field, emitting their own RF pulse. Sensors in the MRI detect these RF pulses.

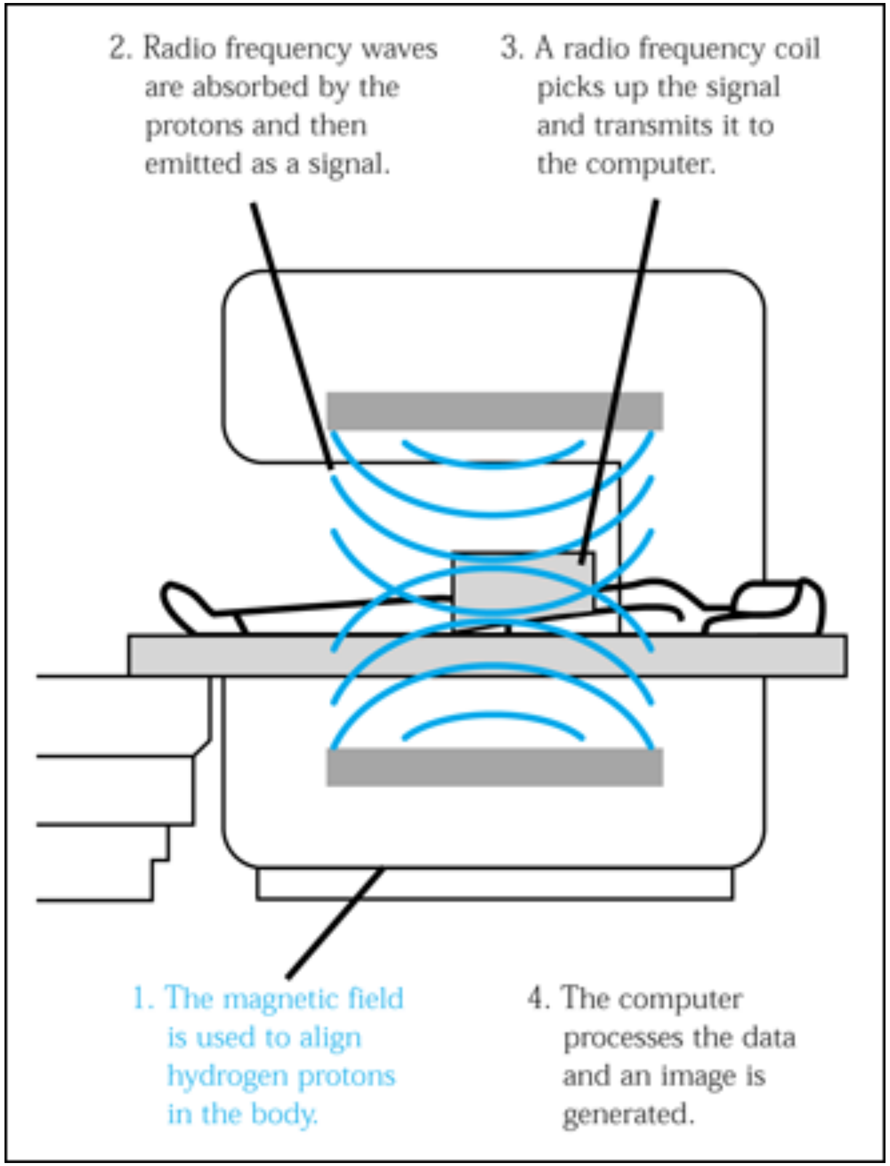
Magnetic Resonance Imaging

The MRI performs all of these functions:

1. It applies a constant strong magnetic field

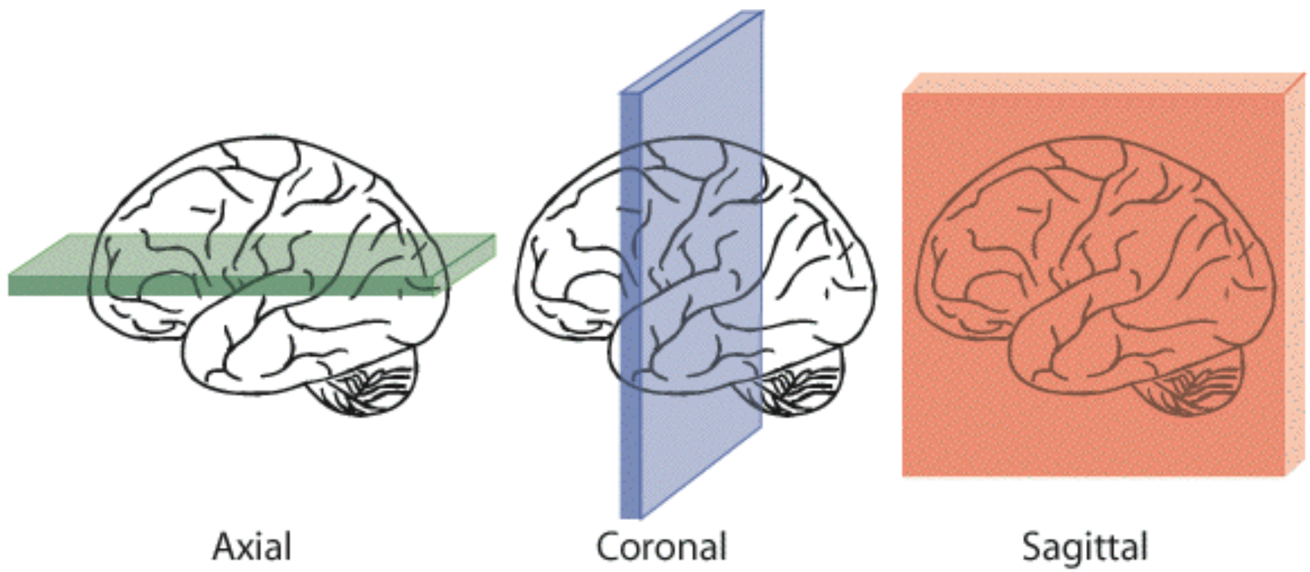
2. It fires pulses of RF to mis-align the hydrogen atoms

3. It detects the emission of RF pulses by the re-aligning hydrogen atoms



Structural MRIs
(looking at anatomy)

A **structural MRI** measures the location and density of hydrogen to create an image of the anatomical structures inside the body. You can use it for almost any part of the body, including the brain. Structural MRI reveals very fine grained details:

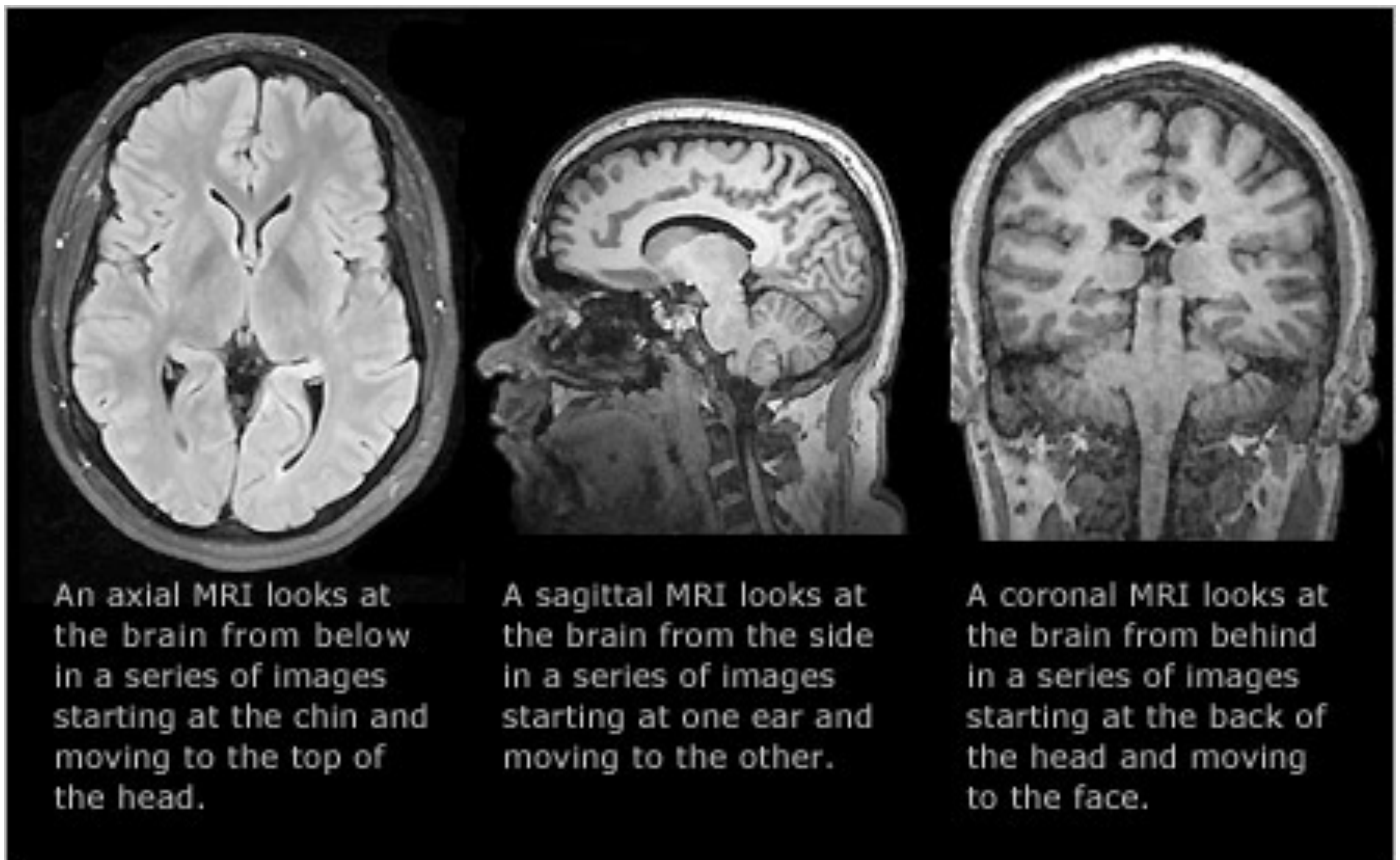


One thing to keep in mind is that the brain (and the rest of your body) is three dimensional. So in order to look at a 2D picture of it, you have to look at a “slice”.

Because there are three dimensions, there are three ways that you can slice the brain (or the body in general). To make things easier, they are called axial, coronal, and sagittal.

Structural MRIs
(looking at anatomy)

Here is an example of three slices from a structural MRI of a human brain. Note that the different types of matter in the brain (grey matter, white matter, bone, cerebral spinal fluid, etc) show up in different shades of gray. This is because they have different hydrogen densities.



functional Magnetic Resonance Imaging (fMRI) (looking at brain function)

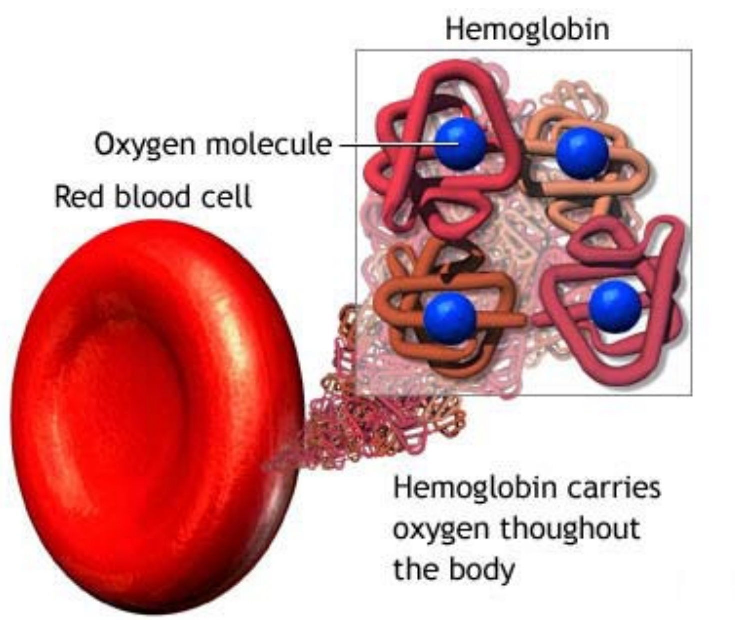
fMRI is a special technique that allows us to look for (de)oxygenated hemoglobin instead of hydrogen.

The reason we want to look for oxygenated hemoglobin is that we think it can show us which areas of the brain are active.

The idea behind this is that brain areas that are recruited for a cognitive task will require more oxygen, therefore the circulatory system will send more oxygenated blood those areas.

So by looking for (de)oxygenated hemoglobin, we can see which areas are active!

functional Magnetic Resonance Imaging (fMRI) (looking at brain function)

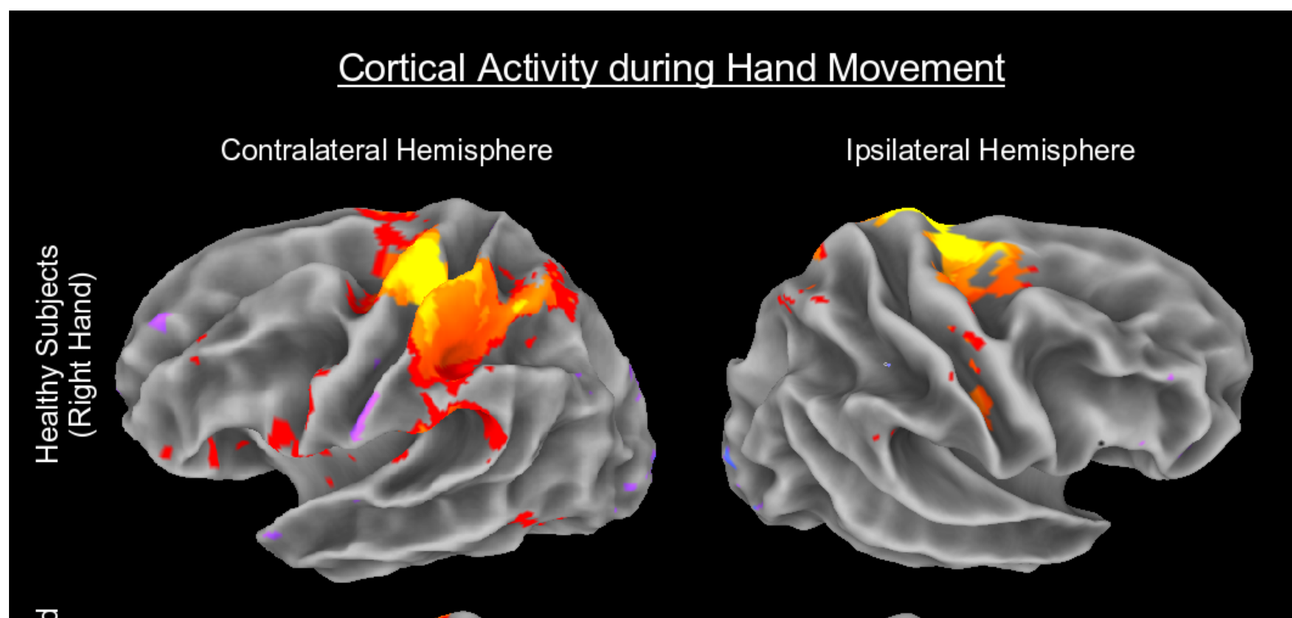


This is just a picture of a hemoglobin molecule so that you can see how it can carry oxygen.

fMRI can detect magnetic differences between deoxyhemoglobin and oxyhemoglobin, and therefore tell us how much oxygen is in a chunk of cortex at a given time.

This is an example of what an fMRI image looks like. Notice that we don't have detailed structural information anymore.

Instead, we use coloring to indicate an increase in oxygenated hemoglobin in a given area. (hot colors typically mean more oxygen, cold colors typically mean less oxygen)



Two examples of Neuroimaging and Language

fMRI and morphological structure-building

Lehtonen et al. 2006 wanted to see if they could find brain regions that appear to support morphological structure-building. So they compared mono-morphemic words (which require no structure-building) to multi-morphemic words, which require structure-building rules.

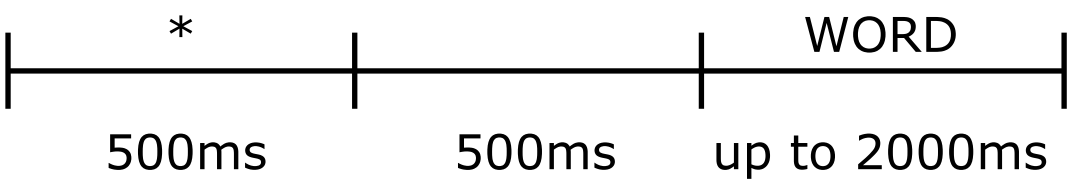
The experiment was conducted in Finnish (because the research team was from Finland). It was a simple lexical-decision task like we saw in unit I.

mono-morphemic: paketti

package

multi-morphemic: uunissa

in the oven

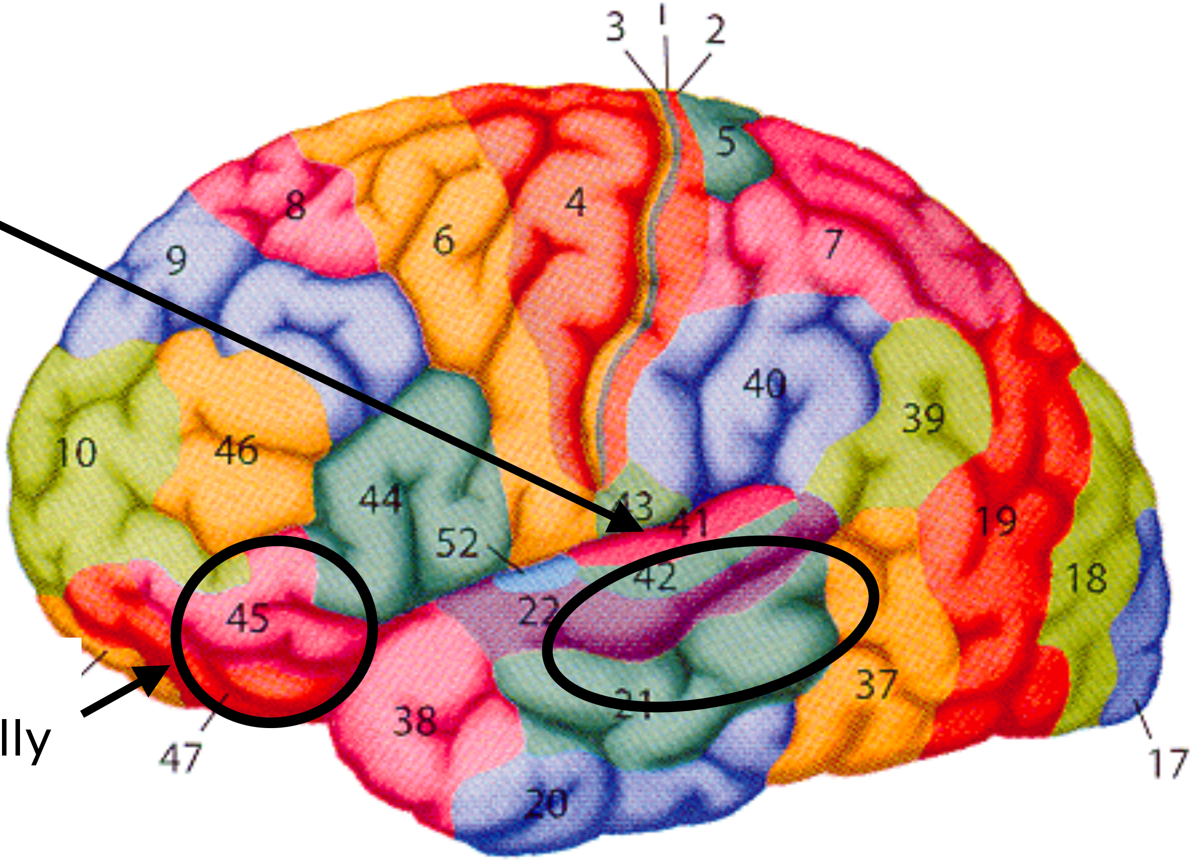


fMRI and morphological structure-building

They found two areas that were more active for multi-morphemic words (than mono-morphemic words):

1. An area of the temporal lobe. We will see this again when we look at aphasias (specifically anomia).

2. Two regions of left inferior frontal gyrus (LIFG), specifically BA 47 and BA 45



These results suggest that LIFG may be one of the brain areas that support morphological structure-building (under the assumption that the temporal lobe is responsible for lexical access, which we will see soon).

fMRI and syntactic transformations

Many studies have tried to isolate activation for transformations. The general idea is to compare two sentences that differ in the size of the movement that is required:

Relative Clauses (Just et al. 1996):

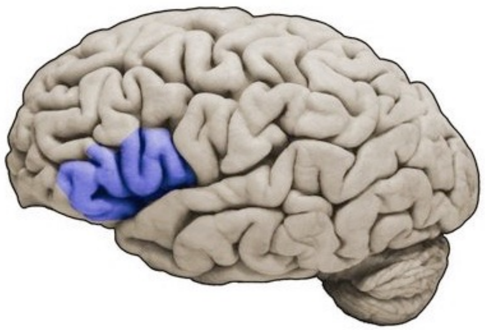
The reporter that the senator attacked ___ admitted the error.

The senator that ___ attacked the reporter admitted the error.

Cleft sentences (Caplan et al. 1999):

It was the juice that the child enjoyed ___.

It was the child that ___ enjoyed the juice.



The longer transformations activate Left inferior Frontal Gyrus (Broca's area).

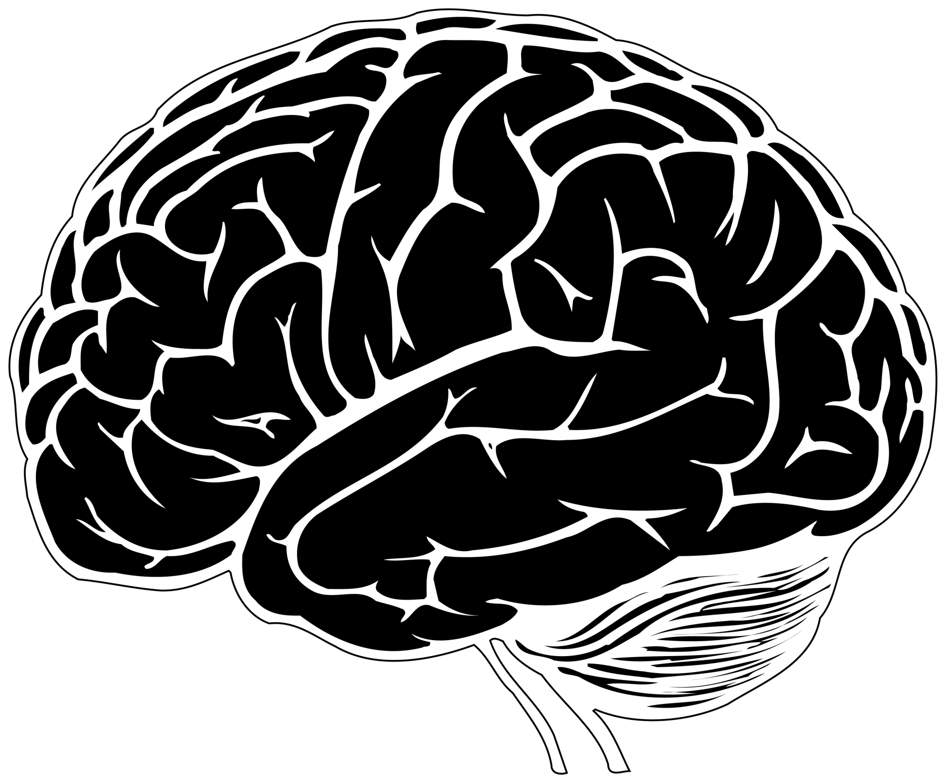
Option 2: Language Disorders

Language disorders caused by brain injury

Dysarthria is muscle weakness of the vocal tract. It is caused by damage to the nervous system (including the motor cortex) from stroke, Parkinson’s, ALS, etc.

Apraxia is paralysis or other malfunction of the vocal tract. It is caused by damage to the motor cortex that disrupts the motor signals to the vocal tract (typically stroke).

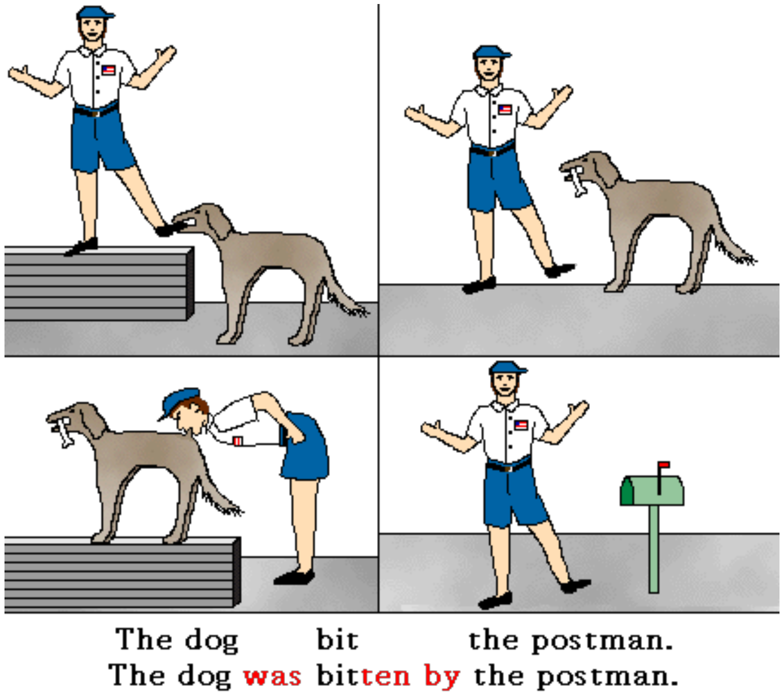
Dementia is a general term for impairments in mental ability. Dementias can affect language ability if they affect the motor cortex (speech), or memory centers relevant to words/concepts.



Aphasia is a language impairment that arises from damage to an area of the brain that is relevant for language processing beyond the motor cortex or memory systems (typically stroke). As such, aphasias are the most relevant disorder for the study of language in the brain (we won’t look at dysarthria, apraxia, or dementia in this class).

Investigating Aphasias

The first step is to asses the deficit caused by the aphasia. This means giving the patient a battery of tests designed to test different aspects of language ability: production, comprehension, phonology, morphology, syntax, etc.



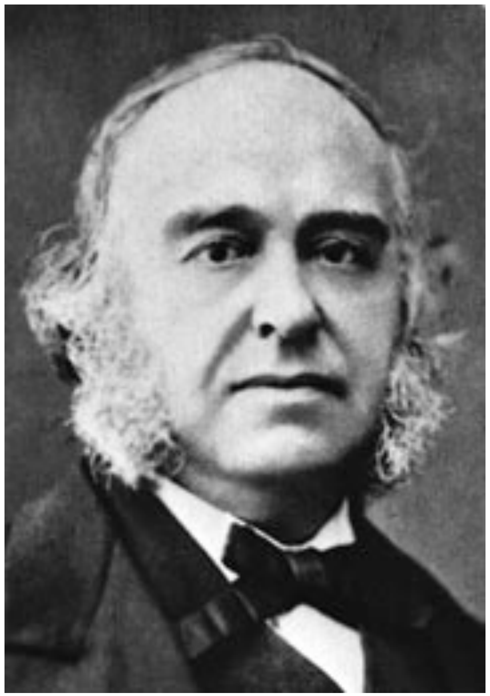
For example, you can test syntactic knowledge by asking patients to match a sentence to a picture, while varying the syntactic complexity of the sentence.

The second step is to use (structural) MRI to localize the damaged portion of the brain for each patient.

We can then look for patterns between the damaged locations and the language deficits. If everybody with a specific deficit shows damage in the same part of the brain, that would suggest that that part of the brain is (at least partially) responsible for the processes and/or knowledge underlying that specific language ability.

Broca’s aphasia
(probably syntax)

Aphasia and Syntax: Broca’s aphasia



Pierre Paul Broca

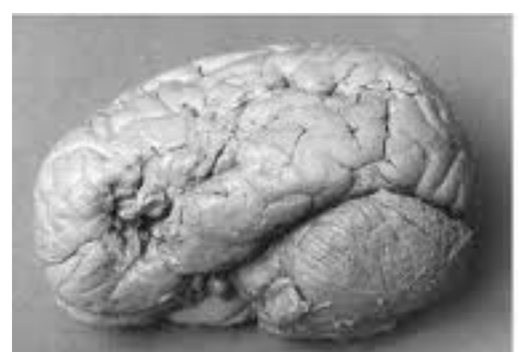
Pierre Paul Broca was a french physician in the 19th century who found himself embroiled in early debates about whether brain function is localized or not.

He encountered two patients that led him to believe that brain function is localized.

The first, Leborgne, was a patient who could only produce one word “Tan” (you will often find him referred to as “Tan” in the literature.)

The second, Lelong, could only produce five words: yes, no, three, always, and ‘Lelo’ (in French).

At autopsy, Broca found that both patients had lesions in approximately the same location of LiFG. An area we now call **Broca’s area**.



Leborgne’s brain

Lelong’s brain

Aphasia and Syntax: Broca's aphasia

Damage to Broca's area is classically associated with a disorder known as **Broca's Aphasia**.

Broca's aphasia has two major consequences:

1. Patients with Broca's aphasia have difficulty producing fluent speech. Their speech also often lacks grammatical function words like auxiliary verbs and prepositions.

2. Patients with Broca's aphasia have difficulty comprehending sentences with complex syntax, especially when the order is not subject-verb-object:

   relative clauses: The reporter that the senator called __ wrote the story.

An older patient: https://kaltura.uconn.edu/media/Broca%27s+Aphasia.mp4/1_ae4ncw3d

A younger patient: https://kaltura.uconn.edu/media/Expressive+Aphasia+-+Sarah+Scott+-+Teenage+Stroke+Survivor.mp4/1_bl1h9y0a

3 years later: https://kaltura.uconn.edu/media/Sarah+Scott+-+Update+3+years+after+her+stroke+-+Broca%27s+Aphasia..mp4/1_emr8mg2p

stroke symptoms: www.youtube.com/watch?v=q5XHH1XfAbM

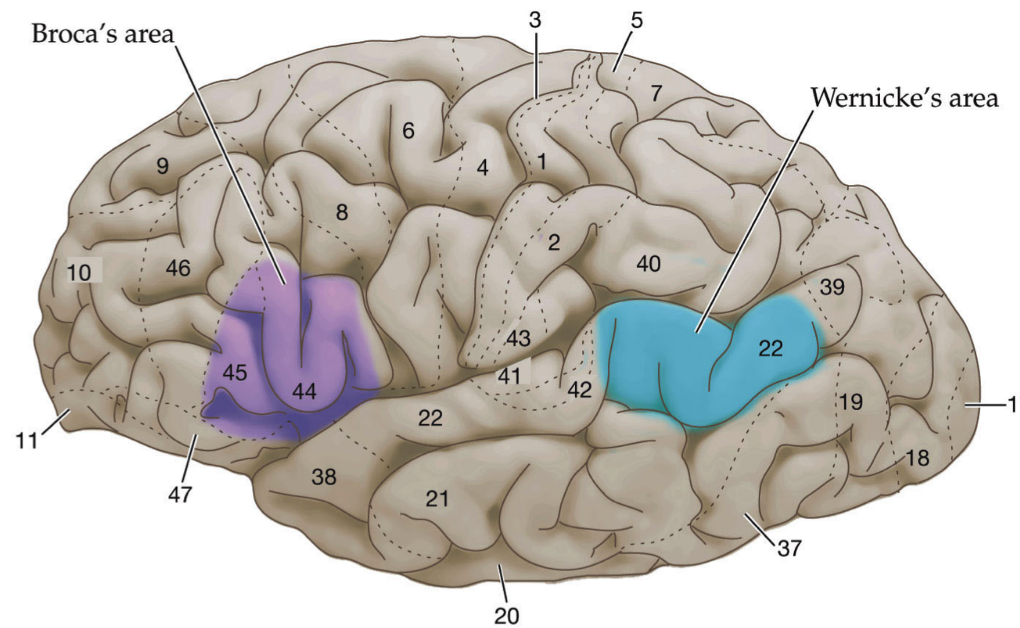
Wernicke's aphasia
(probably speech processing)

Aphasia and Phonology: Wernicke's aphasia

Carl Wernicke was a german physician in the 19th century.

He was keenly interested in Broca's work on aphasia, and set out to perform his own studies on patients suffering from language disorders.

He found that not every language disorder resulted from a lesion to Broca's area. In particular, he found several patients with damage to the **posterior superior temporal gyrus**. This region is now known as **Wernicke's area**.



Aphasia and Phonology: Wernicke's aphasia

Wernicke's aphasia was first identified by Carl Wernicke in the late 1800s (~1874):

https://kaltura.uconn.edu/media/Fluent+Aphasia+%28Wernicke%27s+Aphasia%29.mp4/1_91i91q1c

Wernicke's aphasia is sometimes called **fluent aphasia** because patients appear to produce fully grammatical sentences. However, the productions tend not to be composed of real words (gibberish). Even when real words are used, they tend not to form sentences that make any sense (suggesting that they aren't the words that are intended).

It is also sometimes called **receptive aphasia** because patients suffer from catastrophic comprehension difficulties. They simply cannot understand what people are saying to them.

This suggests an impairment of speech processing, which would then affect both comprehension and production of speech.

Anomia
(probably lexical access)

Aphasia and Morphology: Anomia

Patients suffering from Anomia succeed at word repetition tasks. They also succeed at auditory comprehension (unlike patients with Wernicke's Aphasia).

The defining characteristic of Anomia is that patients fail at **naming certain objects**.

That is actually what the word anomia means: a = no, nomia = names.

Anomia is fairly common, although I could only find one video of a patient suffering from anomia online:.

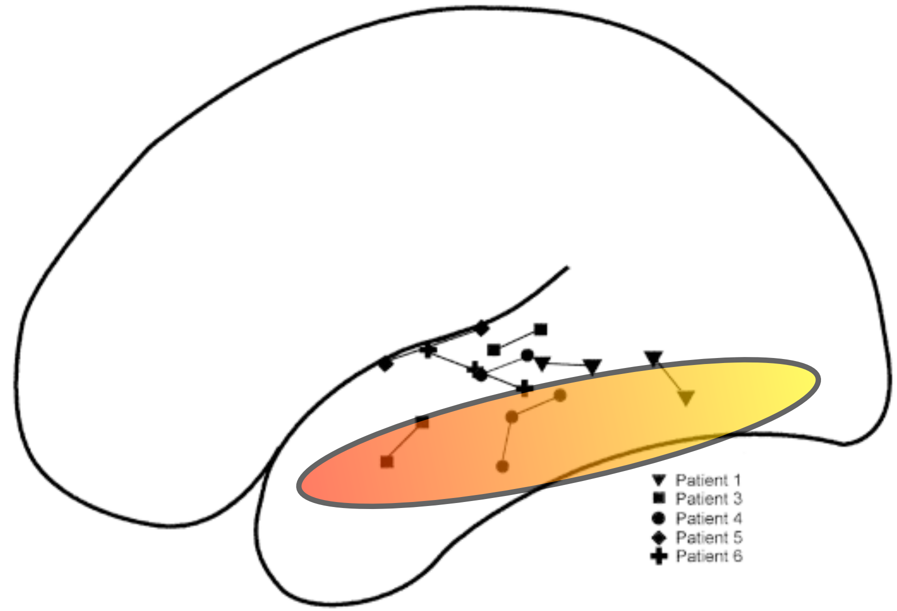
https://kaltura.uconn.edu/media/Anomia+video.mp4/1_uagjs2wt

This is actually a pretty good example of anomic symptoms. Pay particular attention around 1:40 -- the doctor tries to give the patient a hint!

Aphasia and Morphology: Anomia

In general, anomia results from diverse lesion sites across the left temporal lobe.

It is generally more inferior than superior, and more anterior lesions tend to be worse than posterior lesions.



This may make some sense: if we assume that lexical entries are distributed throughout the area, then the connections between meaning and phonological processing may also be distributed be distributed throughout the area.

In a famous study, Boatman et al. (2000) implanted electrodes in six patients brains prior to surgery to cure epilepsy. They then sent electric currents to those electrodes in an attempt to (temporarily) induce aphasia symptoms. The black lines above are the electrodes that induced Anomia.

Category-specific Anomia

It is relatively common for Anomia patients to demonstrate poor performance on certain classes of nouns.

For example, Ferreira et al. 1998 report three patients who show more trouble with animals than tools.

Although rarer, there are also patients who show more trouble with tools than animal (e.g., Cappa et al. 1997).

This **double dissociation** suggests that living entities and inanimate objects may have distinct cortical substrates.

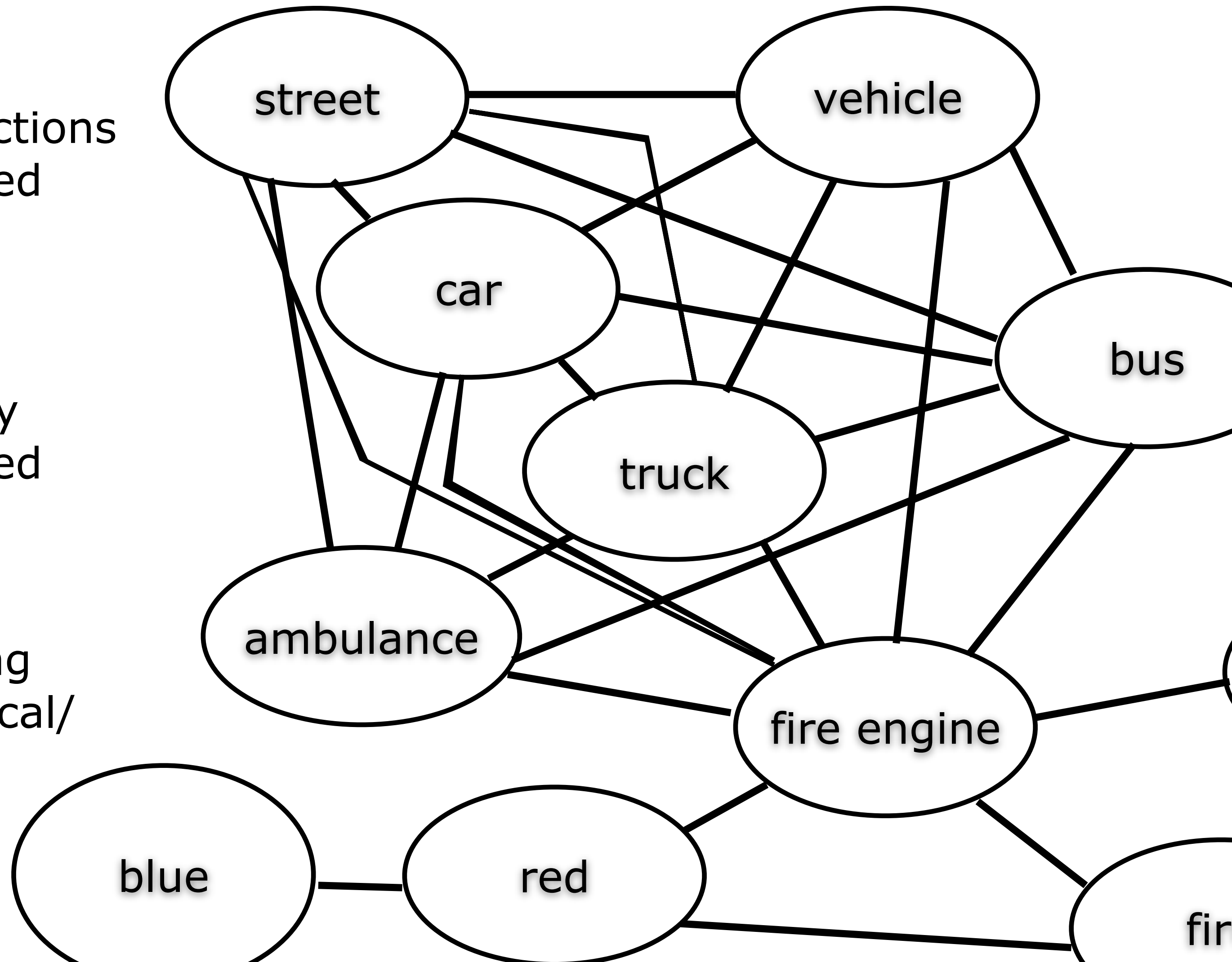
Anomia and Semantic networks

The existence of category-specific Anomia makes some sense given the semantic priming effects that we've already seen.

The spreading activation framework suggests connections between semantically related words.

Category-specific Anomia suggests geographic locality between semantically related words.

This suggests that spreading activation is indeed a physical/ geographic process.



Some conclusions

MRI is a brain imaging technique that allows us to measure the the location and density of a given element in the body.

A **structural MRI** measures the location and density of hydrogen to create an image of the anatomical structures inside the body.

fMRI is a special technique that allows us to look for (de)oxygenated hemoglobin and reveal which brain areas are active during a cognitive process.

Aphasia is a language impairment that arises from damage to an area of the brain that is relevant for language processing beyond the motor cortex or memory systems (typically stroke).

Broca's Aphasia is caused by damage to LiFG, and results in non-fluent speech and problems comprehending complex syntactic constructions.

Wernicke's Aphasia is caused by damage to pSTG, and results in fluent but non-sensical speech and catastrophic problems comprehending speech.

Anomia is caused by damage to the temporal lobe, and results in problems naming objects.