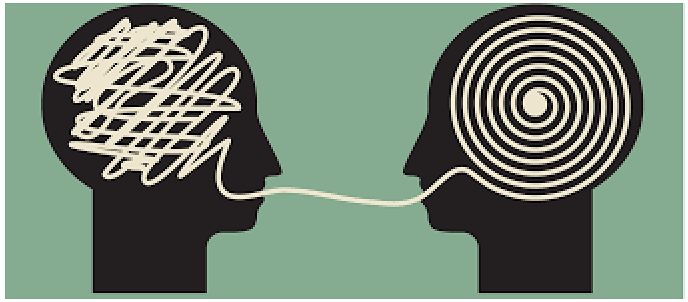
Speech and language

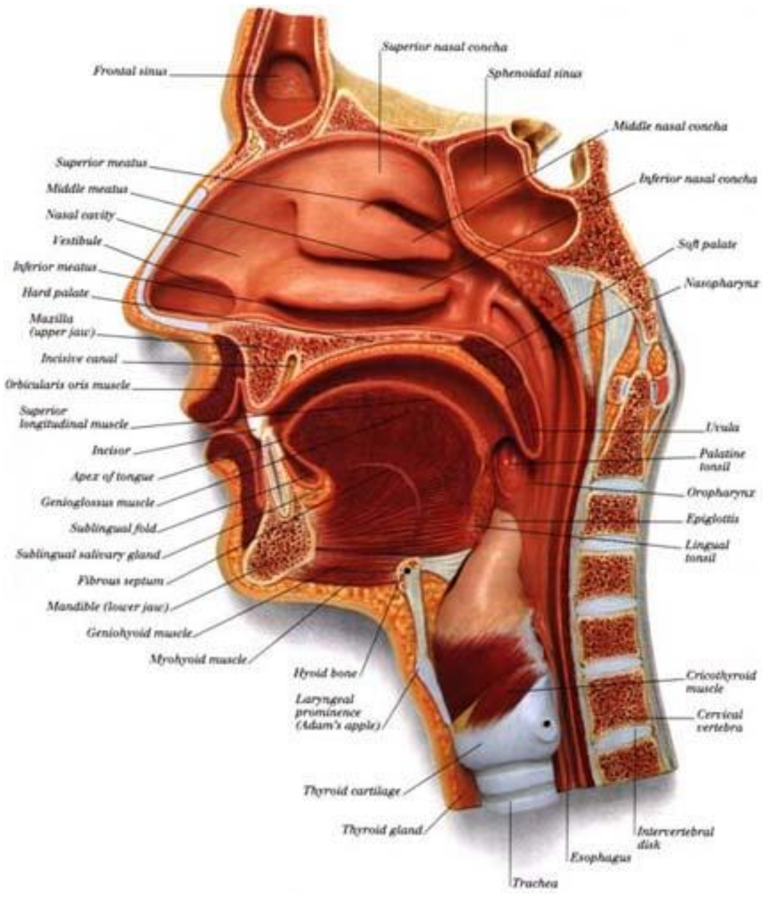
Neuropsychological approach and main findings



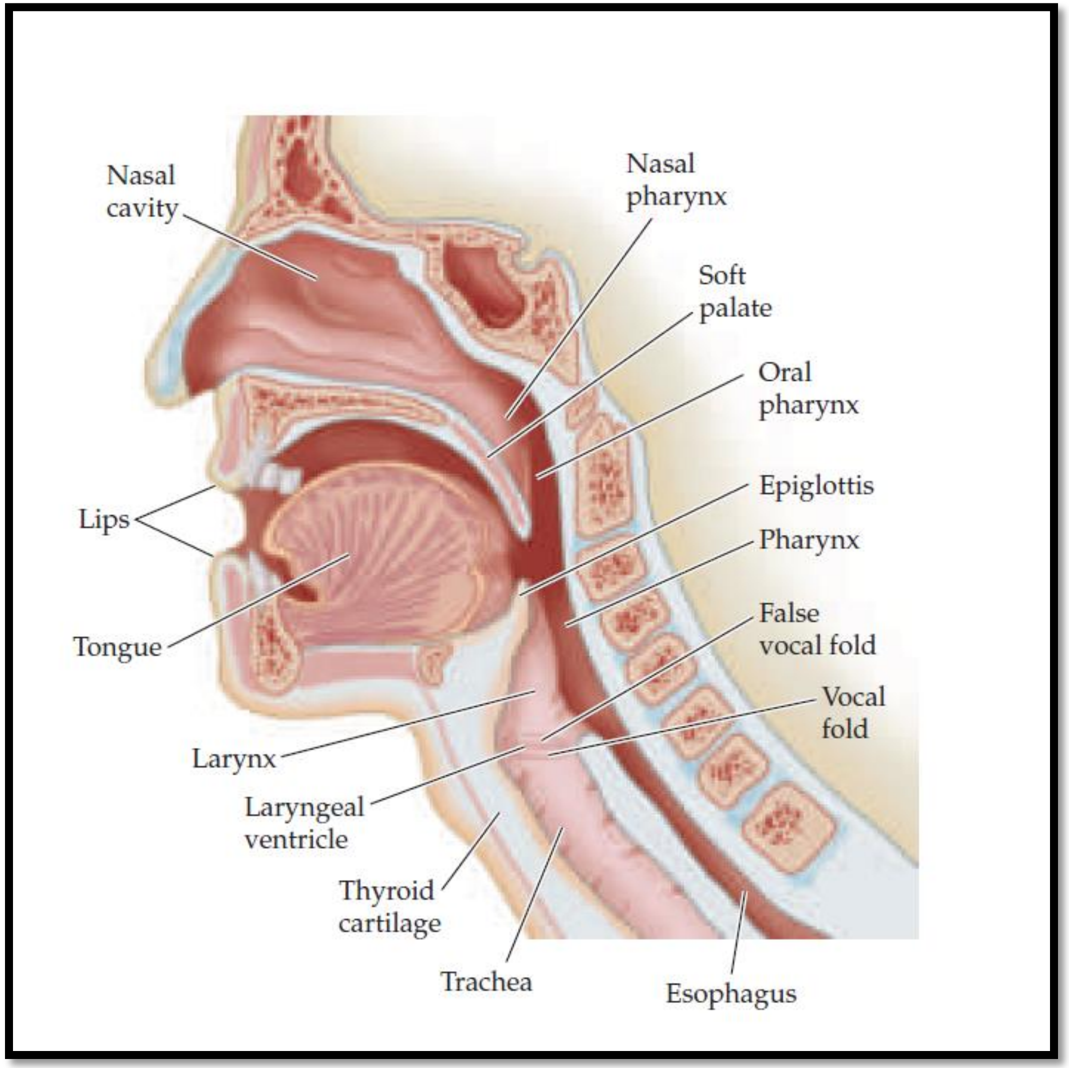
Topics

I. **Basics of language and speech production**
II. **Neurological and developmental foundations of speech acquisition**
III. **Language production models**
IV. **Aphasias, alexia and agraphia**
V. **Language lateralisation**
VI. **Anatomical Differences between the Right and Left Hemispheres**
VII. **Methods in the study of fibre pathways for language and mapping language functions**

I. Basics of language and speech production



The production of speech



- air expelled from the lungs accelerates as it passes through a constricted opening between the **vocal folds** ("vocal cords") - the glottis
  - decreasing the pressure in the air stream
  - as a result, the vocal folds come together until the pressure buildup in the lungs forces them open again
  - the ongoing repetition of this process results in an oscillation of sound wave pressure, the frequency of which is determined primarily by the muscles that control the tension on the vocal cords

- the frequencies of these range from about 100 to about 400 Hz (depending on the gender, size, and age of the speaker)
- the larynx is important in the production of all vocal sounds
  - additional speech sounds - *glottal stop*

Cortical representation of language

- distinct from the circuitry concerned with the motor control of the larynx, pharynx, mouth, and tongue— the structures that produce speech sounds
- distinct from the circuits underlying the auditory perception of spoken words and the visual perception of written words in the primary auditory and visual cortices, respectively

- the neural substrates for language as such depend on these essential motor and sensory functions
- the regions of the brain that are specifically devoted to language transcend more basic elements

Symbolic communication

The main concern of the areas of cortex that represent language - **using of a system of symbols for communication**

- spoken and heard, written and read, or, in the case of sign language, gestured and seen
- the essential function of the cortical language areas, and of language, is **symbolic representation**

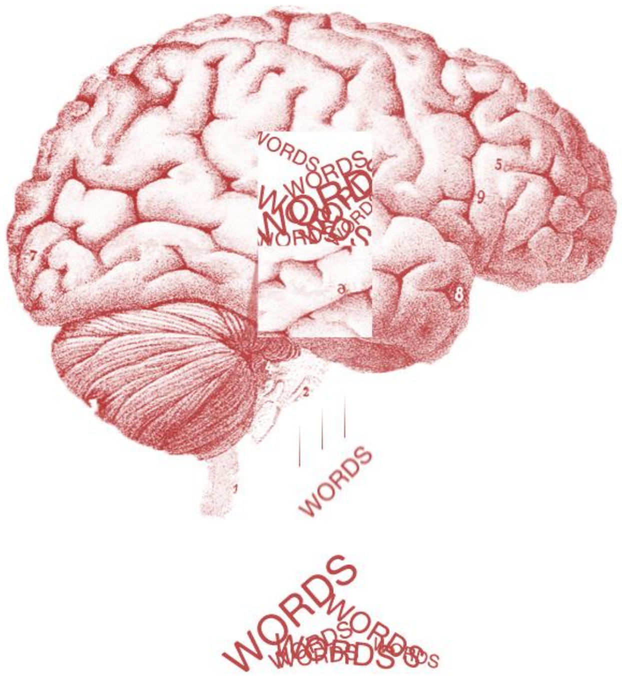
Including:

A. Obedience to a set of rules for using these symbols (**grammar**)

B. Ordering them to generate useful meanings (**syntax**)

C. Providing the appropriate emotional valence by varying rhythm, intensity and pitch (**prosody**)

II. Neurological and developmental foundations of speech acquisition



NEUROLOGY

- **Myelination** of the brain begins near six months in utero, achieves it peak growth between birth and the end of the first year, and continues to grow until adulthood.
- **Wernicke's area**: Peak in number of cell connections during the first half of the first year and mature number of connections during the second half of the first year.
- **Broca's area**: Density of cell connections does not peak until 15 months, and does not reach a mature number of connections until 6 to 8 years old.
- **Hippocampus** develops after the child is born, especially during second year of life.
- **Prefrontal cortex**: Cell connections in the prefrontal lobes develop slowly throughout childhood and do not reach maturity until after adolescence

ORAL MECHANISM

- Infant cf. adults
  - Oral space is smaller. Lower jaw smaller and retracted. Sucking pads are present, teeth emerge. Tongue large compared to size of oral cavity and therefore has more restricted movement. (Moves with jaw) Nose breather. Epiglottis and soft palate are in approximation as a protective mechanism. Newborns breathe/swallow at same time. Larynx is higher in newborn. Eustachian tube lies in horizontal position. (More vertical in adults)

PERCEPTION

- By at least 2 days of age, the neonate has an ability to discriminate language specific acoustic distinctions.
- The 12 month old human has developed the capacity to categorise only those phonemes which are in its native language.

VOCALISATION

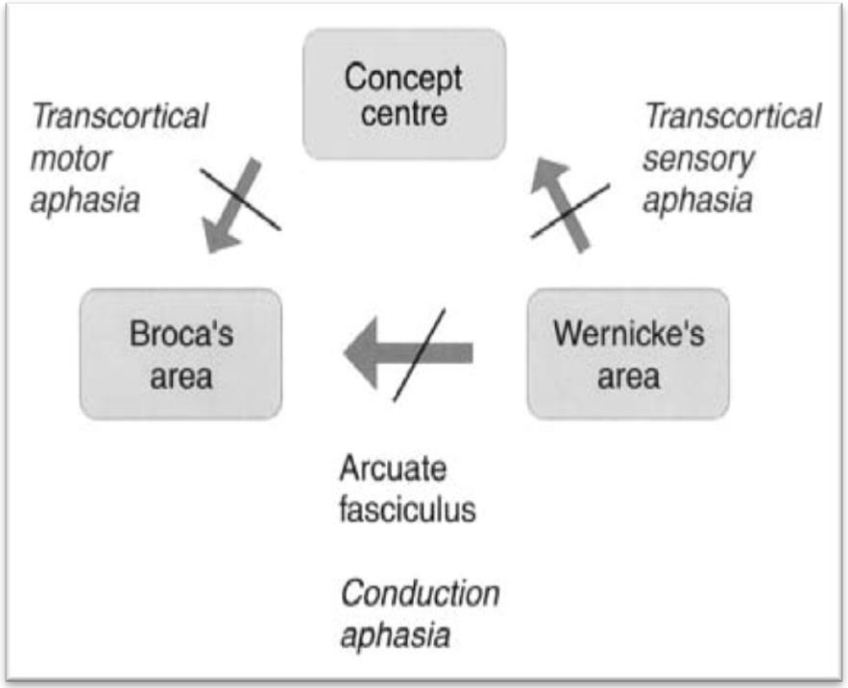
- 0-6 weeks = reflexive vocalisations: cry, fuss
- 6-16 weeks = coo and laughter: vowel-like
- 16-30 weeks = syllable-like vocalisations
- 0-0;2 = phonation, quasivowels & glottals
- 0;2-0;3 = primitive articulation stage: gooing
- 0;4-0;5= expansion stage: full vowels, raspberries, marginal babbling
- BABBLING "Late onset of canonical babbling may be a predictor of disorders… [ie.] smaller production vocabularies at 18, 24 & 36 mths"

III. Language production models

Lichtheim’s model of connectivity serving language functions

- Wernicke’s area processed the sound image of words - fed forward via the arcuate fasciculus to Broca’s area - responsible for the generation of speech output

- A second route between Wernicke’s and Broca’s areas is via the concept centre (the part of the brain where meanings were stored).

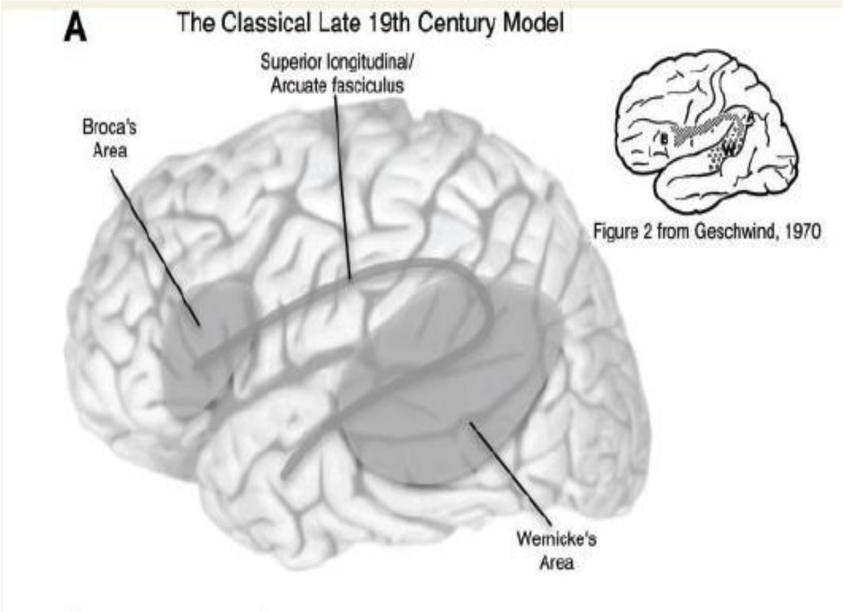


The exact location of the concept centre

- in Lichtheim’s model – unclear
  - Concept centers - actually distributed widely throughout the cortex
- More recent interpretations (Geschwind, 1967) localised it to the left inferior parietal lobe - the angular gyrus and the region just anterior to this - supramarginal gyrus.
  - this area is connected to (but separate from) Wernicke’s area
  - patients with damage to this region certainly have ‘receptive’ language problems

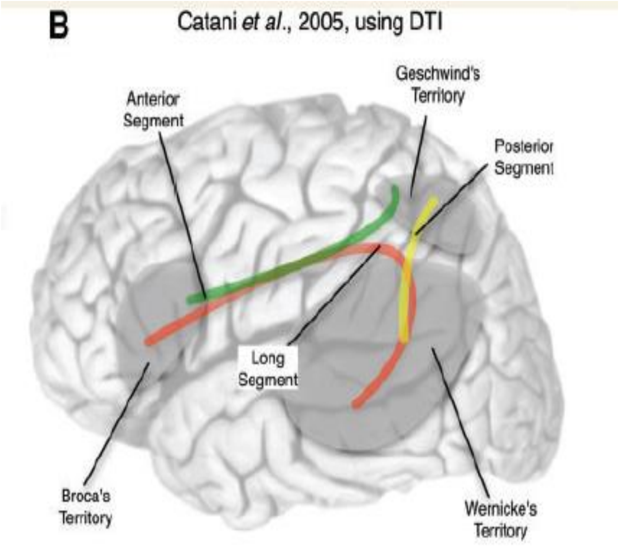
Contemporary - conflicting notions of SLF/AF connectivity

- the idea of a central role for the SLF/AF pathway to language became prominent in the latter part of the 19th century



Contemporary - conflicting notions of SLF/AF connectivity

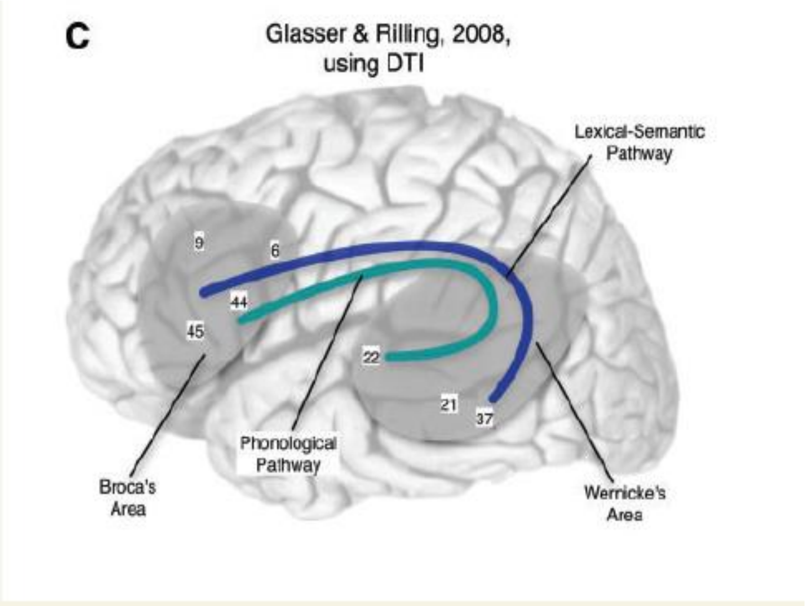
- Since Geschwind, a number of divergent and sometimes conflicting descriptions of the SLF/AF fibre pathway have emerged.
- Catani and colleagues (2005) and Thiebaut de Schotten et al. (2011b) used DTI to delineate the SLF/AF into three segments.
    A. a long 'direct temporo-frontal segment' - essentially the classical SLF/AF pathway
    B. two lateral segments that comprise an indirect temporal–parietal– frontal pathway
- modifies, to some degree, the classical understanding by suggesting additional connectivity through the parietal lobe



Contemporary - conflicting notions of SLF/AF connectivity

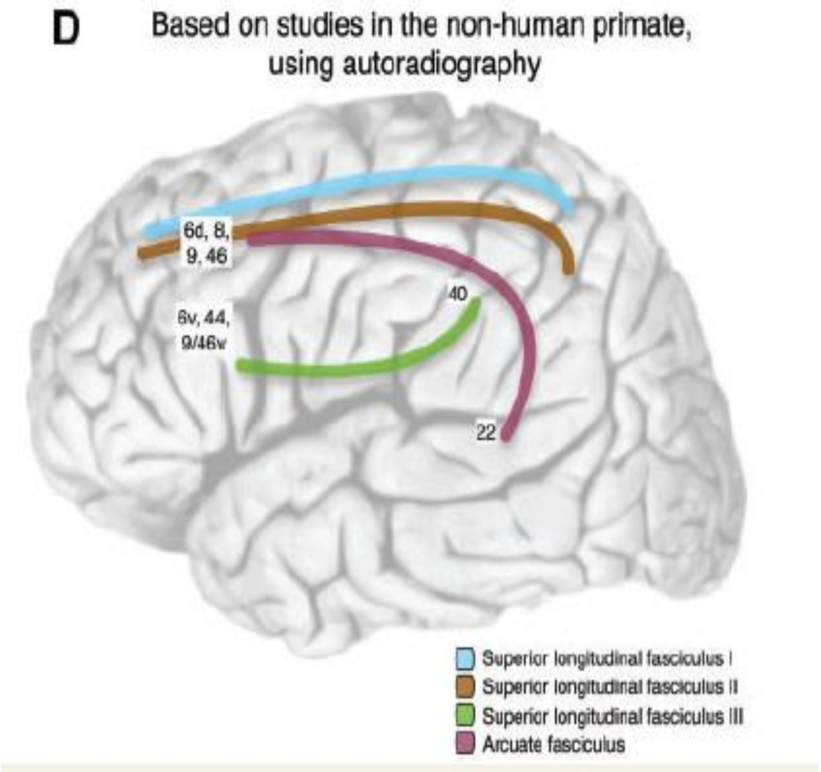
- an alternative characterization

- Using DTI, Glasser and Rilling (2008) propose a division of the SLF/AF into
  1) a middle temporal-inferior frontal ‘lexico-semantic’ segment
  2) a superior temporal inferior frontal ‘phonological stream’ segment

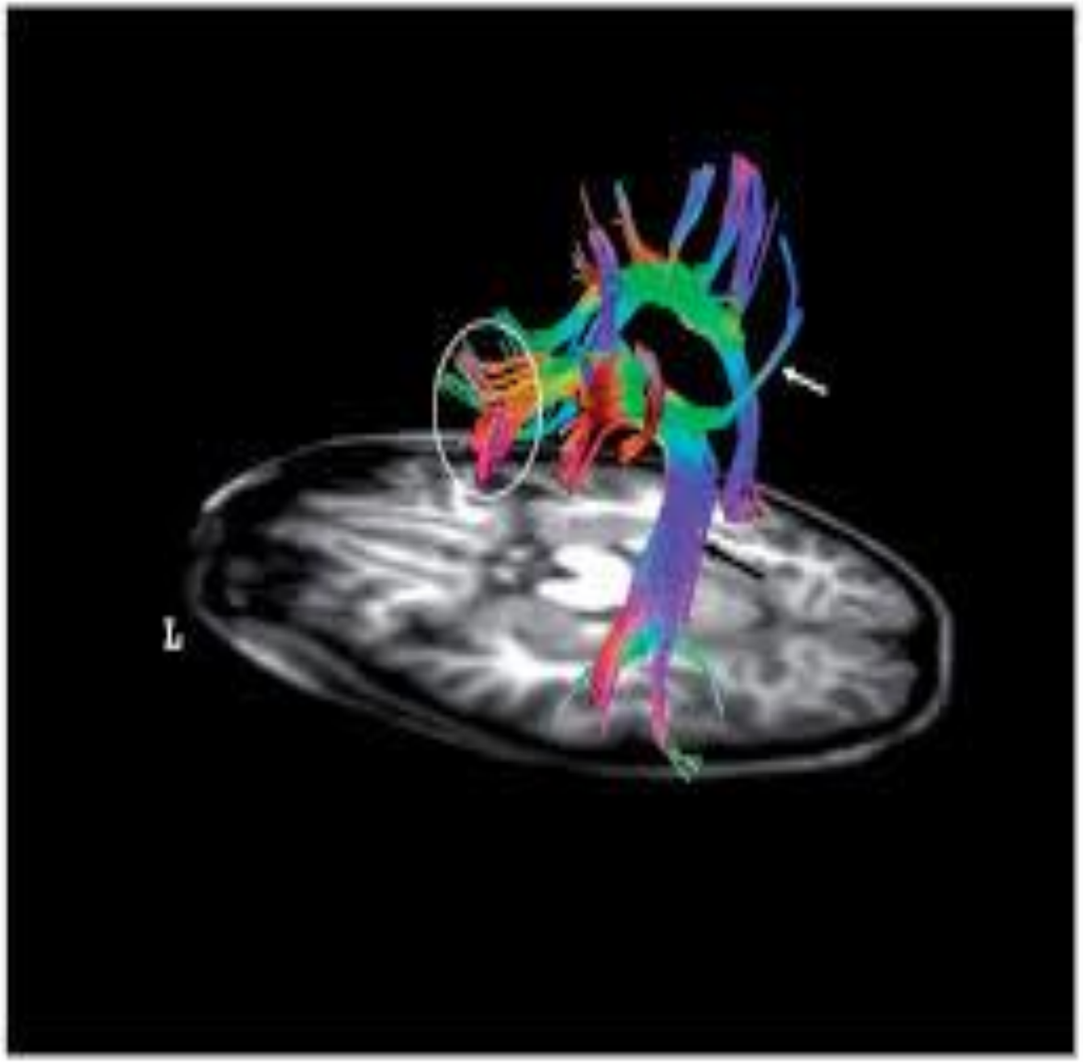


Contemporary - conflicting notions of SLF/AF connectivity

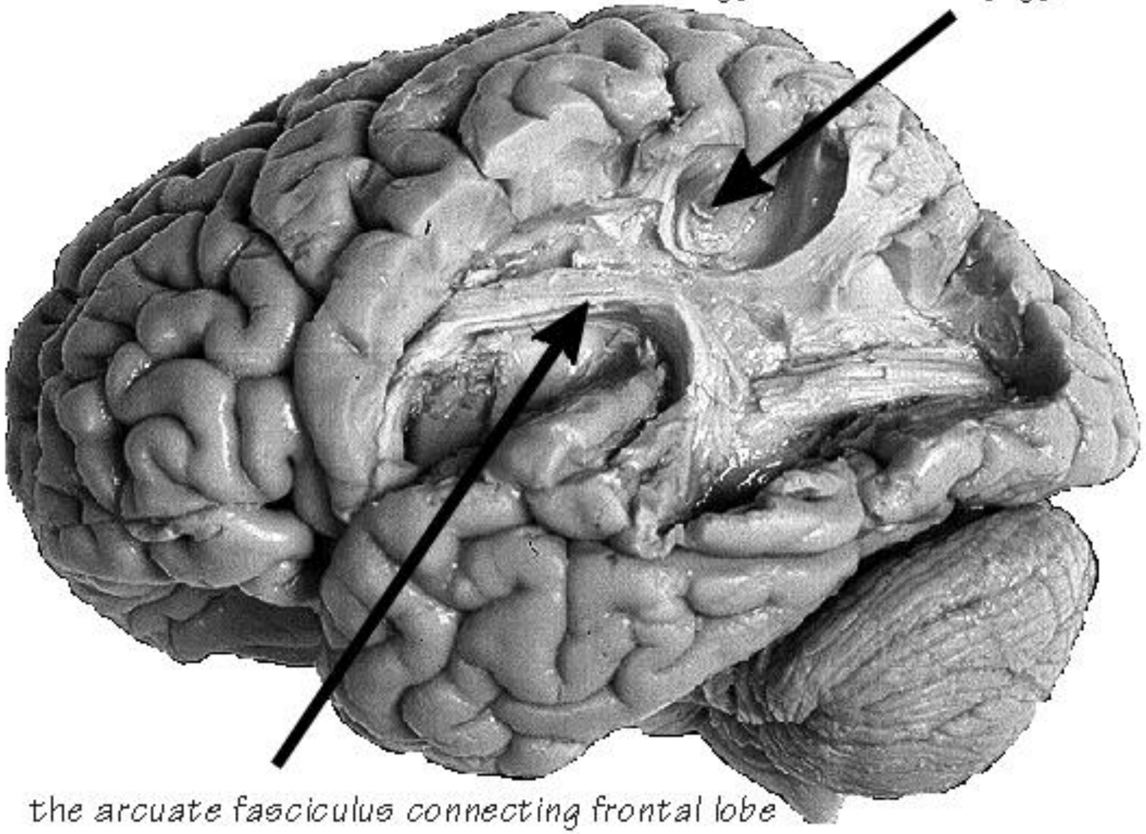
- data from non-human primates - new insights into temporal–parietal–frontal connectivity
- challenged the classical notion of the SLF/AF by suggesting separation into four subcomponents



- The superior longitudinal fasciculus III and arcuate fasciculus - the most attention for **language**.
- The superior longitudinal fasciculus III connects the anterior inferior parietal lobule with the ventral premotor and posterior inferior frontal gyrus.
  - fibres originating from the inferior parietal lobule terminate in areas of the macaque brain that match the cytocarchitectonic profile of Brodmann areas 44 and 45 in the human brain
  - this connectivity profile suggests the superior longitudinal fasciculus III is a candidate language pathway



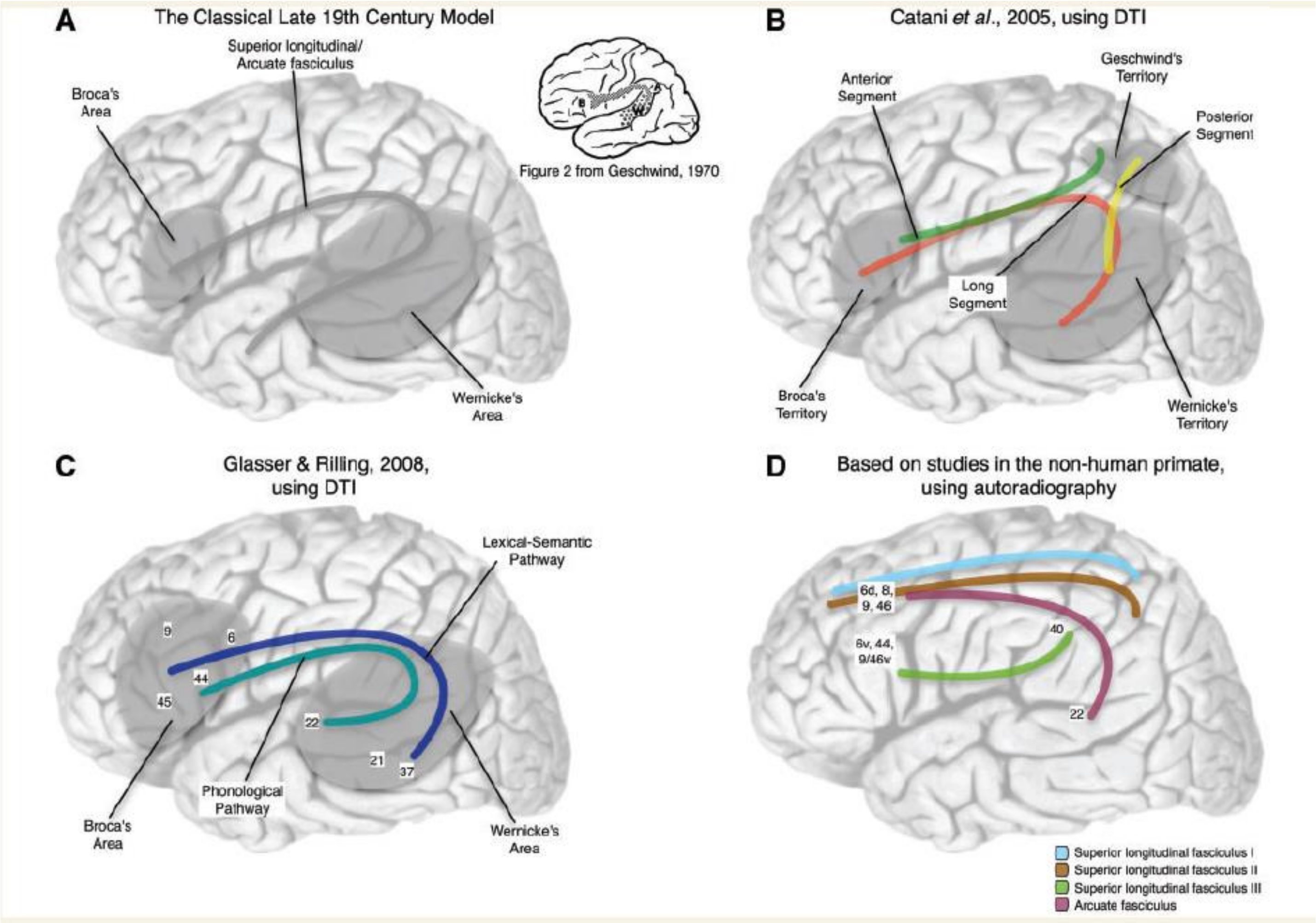
shorter U-fibers are the corticocortical axons that travel from one gyrus to nearby gyri.



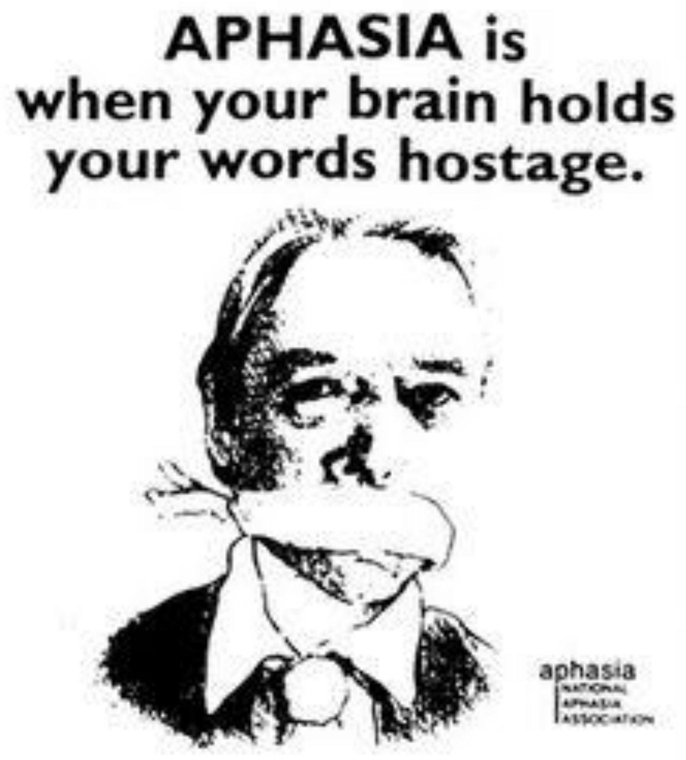
the arcuate fasciculus connecting frontal lobe to temporal and parietal lobes

from *The Digital Anatomist*
http://www1.biostr.washington.edu/DigitalAnatomist.html

Contemporary - conflicting notions of SLF/AF connectivity



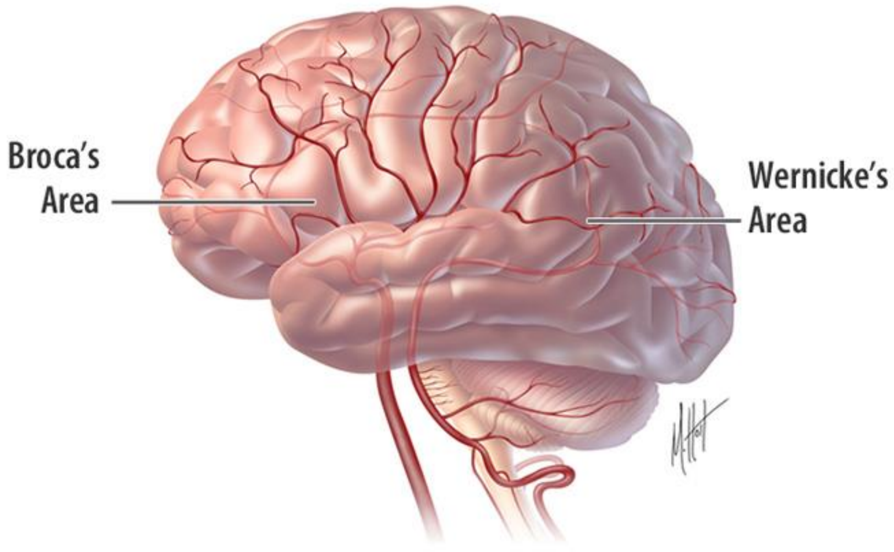
IV. Aphasias, alexia nad agraphia



Aphasias

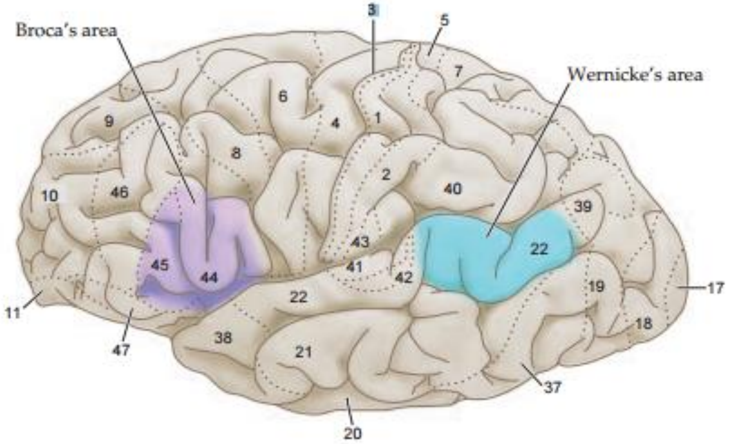
These syndromes – **aphasias** - diminish or abolish the ability to comprehend and/or to produce *language*

- sparing the ability to perceive the relevant stimuli
- missing in these patients is the capacity to recognize or employ the **symbolic value of words**
  - depriving such individuals of the linguistic understanding, grammatical and syntactical organization, and appropriate intonation that distinguishes language from nonsense



Aphasias

- the distinction between language and the related sensory and motor capacities on which it depends - first apparent in patients with damage to specific brain regions
- the ability to move the muscles of the larynx, pharynx, mouth, and tongue
  - compromised without abolishing the ability to use spoken language to communicate (even though a motor deficit may make communication difficult)
- damage to the auditory pathways
  - can impede the ability to hear without interfering with language functions per se (as is obvious in individuals who have become partially or wholly deaf later in life)
- damage to specific brain regions
  - compromise essential language functions while leaving the sensory and motor infrastructure of verbal communication intact



The Boston classification

1. Broca's (motor, nonfluent) aphasia

2. Wernicke's (sensory) aphasia

3. Conduction (central) aphasia

4. Anomic (amnesic) aphasia

5. Transcortical motor aphasia

6. Transcortical sensory aphasia (isolation syndrome)

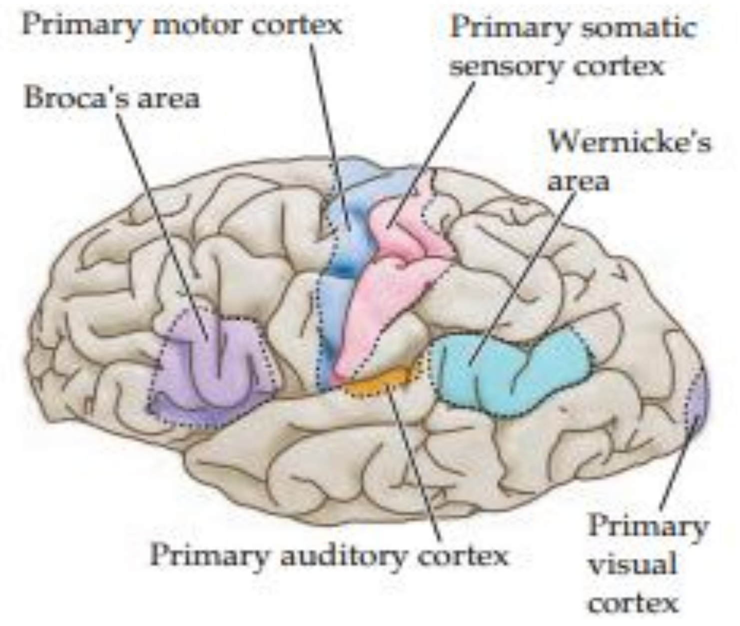
- *global* aphasia
  - massive and severe disturbance of language functions across a number of these categories
- *Alexia* and *agraphia*
  - specific disorders of reading and writing respectively - included within the classification by some
- there are other, more peripheral forms of speech pathology, which affect articulation

Broca’s aphasia

- suggested that language abilities were localized in the **ventroposterior region of the frontal lobe**
- the loss of the ability to produce meaningful language—as opposed to the ability to move the mouth and produce words—was usually associated with damage to the left hemisphere

Broca's aphasia

- the core feature is a marked difficulty in producing coherent speech
  - 'expressive' or 'non-fluent' aphasia



Most Broca's aphasics:

- can speak a little
- seem to have problems in finding the words they want to use
- problems with prepositions, conjunctions and other relational words (words like 'in', 'and', 'but', 'about', 'above' and so on) - often omitted
- speech is slow, effortful and deliberate, and may have only a very simple grammatical structure

Broca’s aphasia

- errors in the actual production of words – **Paraphasias** - relatively common
  - the phonemic variety where the target word is usually identifiable
- some error in the selection or production of sound elements
- it is generally possible to tell what the patient is intending to say
- difficulty with repetition and with naming
  - although prompting by sounds or context can be of significant help with the latter
  - secondary to the problems with speech output, limiting the performance that might otherwise be attained

Written output:

- affected in the same way as speech
  - certain common output mechanisms
  - difficulty lies in **language production generally rather than specifically with speech**

Broca’s aphasia

‘**telegraphic speech**’

‘ *. . . in car . . . off to the . . . the match . . . City play . . . good watch . . . like City . . .*’

Perserved functions:

1. well-practised expressions without obvious difficulty
   ‘*It never rains but it pours!*’

2.they may also be able to sing a well-known song faultlessly

Not related to ‘the mechanics’ of moving the muscles that are concerned with speech!

- Example
  - Video 1,2,3

Wernicke's aphasia

- **The fluent but nonsensical speech**
- all the harder to understand because of two further characteristic features:
  - patient's use of **non-words or made-up** words (known as 'neologisms')
  - use of '**paraphasias'** – words that are semantically related to the desired word, but nevertheless inappropriate (binoculars instead of glasses)

- Most Wernicke's aphasics also have little or **no 'insight' into their condition**.

- Wernicke thought that the underlying deficit in this condition was in linking sound images to stored representations (memories) of words. More recent evidence suggests, once again, that this analysis may be somewhat simplistic, and that other areas of the cortex, in addition to Wernicke's area, may be important in understanding spoken language.

Wernicke's aphasia

- “Fluent - the most striking feature of patients suffering from this type of aphasia is their verbal behavior
- sometimes excessive amounts of speech - generally quite unintelligible

- Neologisms - resulting in *jargon aphasia*.
  - This jargon is usually meaningless, as for example in this response of a patient asked what a pen was used for: “This is a tape of brouse to make buke deproed in the auria”.
  - The form and often the intonation makes such speech sound like sensible English, even though it is nonsense.
  - Short phrases, particularly if relatively “automatic” or well used, may be preserved.

Wernicke’s aphasia

- **caused partly by the comprehension deficit**
- the mechanisms for monitoring speech output overlap with those for interpreting incoming language, so that the patient loses control of his language expression by being unable to check on what is being produced

- Example
  - Video 4,5

Global aphasia

- in most cases caused by large ‘peri-Sylvian’ lesions
- massive and severe disturbance of language functions across a number of categories affected by all other aphasias

- Example
  - Video 6

Broca's and Wernicke's conclusions

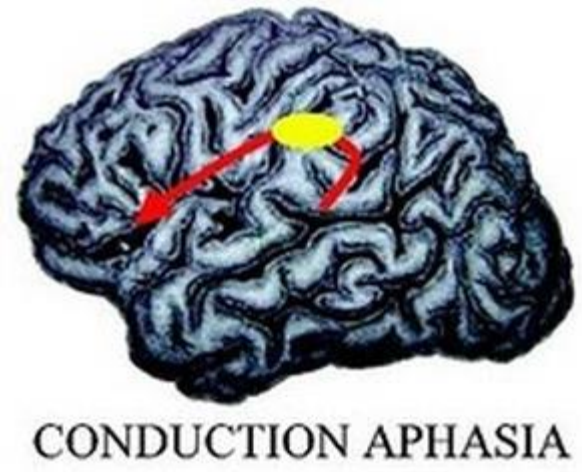
Two rules about the localization of language - taught ever since!

1. Lesions of the left frontal lobe in a region referred to as **Broca's area** affect the ability to *produce* language efficiently - **motor** or **expressive aphasia**, also known as **Broca's aphasia**
    - must be specifically distinguished from *dysarthria* - the inability to move the muscles of the face and tongue that mediate speaking
    - the deficient motor-planning aspects of expressive aphasias accord with the complex motor functions of the posterior frontal lobe and its proximity to the primary motor cortex

2. Damage to the left temporal lobe causes difficulty *understanding* spoken language - **sensory** or **receptive aphasia**, known as **Wernicke's aphasia**
    - deficits of reading and writing—*alexias* and *agraphias*— separate disorders, but most aphasics also have difficulty with these closely linked abilities as well
    - receptive aphasia generally reflects damage to the auditory association cortices in the posterior temporal lobe, a region referred to as **Wernicke's area**

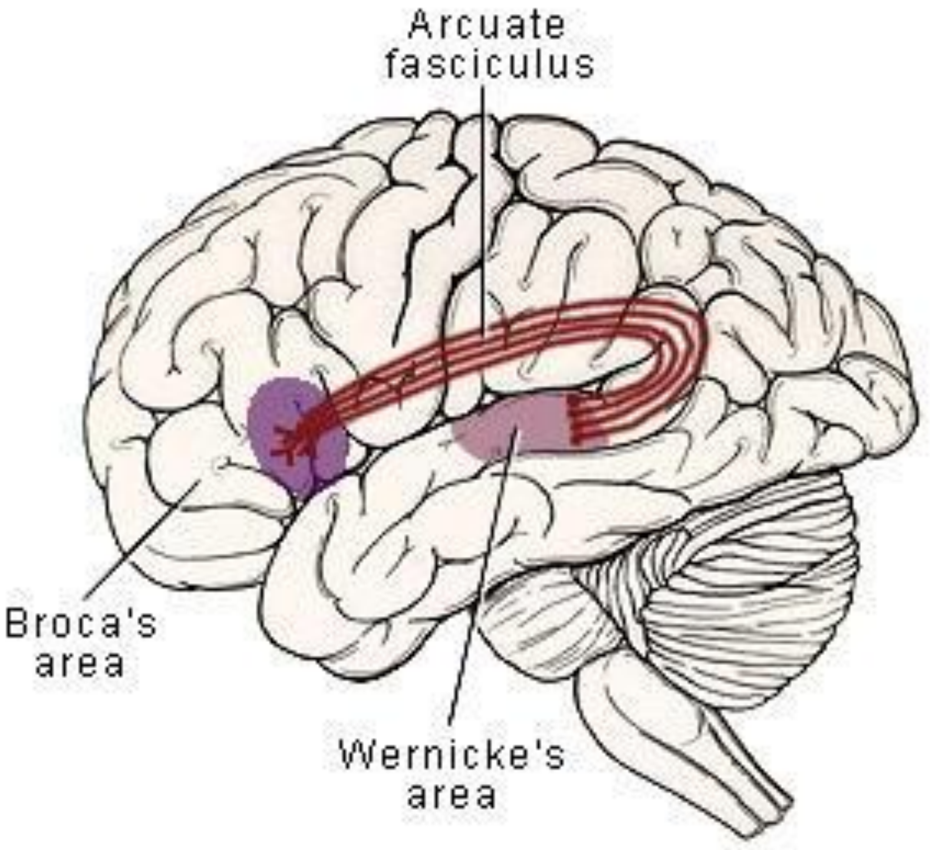
Conduction Aphasia

a) repetition is disordered - the central characteristic
b) comprehend both speech and writing normally
c) produce more or less normal speech; it is at least reasonably fluent, the meaning is clear and appropriate, and the syntax is usually correct
d) occasionally phonemic paraphasias may be introduced, but these are relatively minor
e) the target word is generally clear both from the context and from the form of the actual word produced
f) naming may be mildly affected, but again the impairment tends to be connected with phonemic paraphasias



Conduction Aphasia

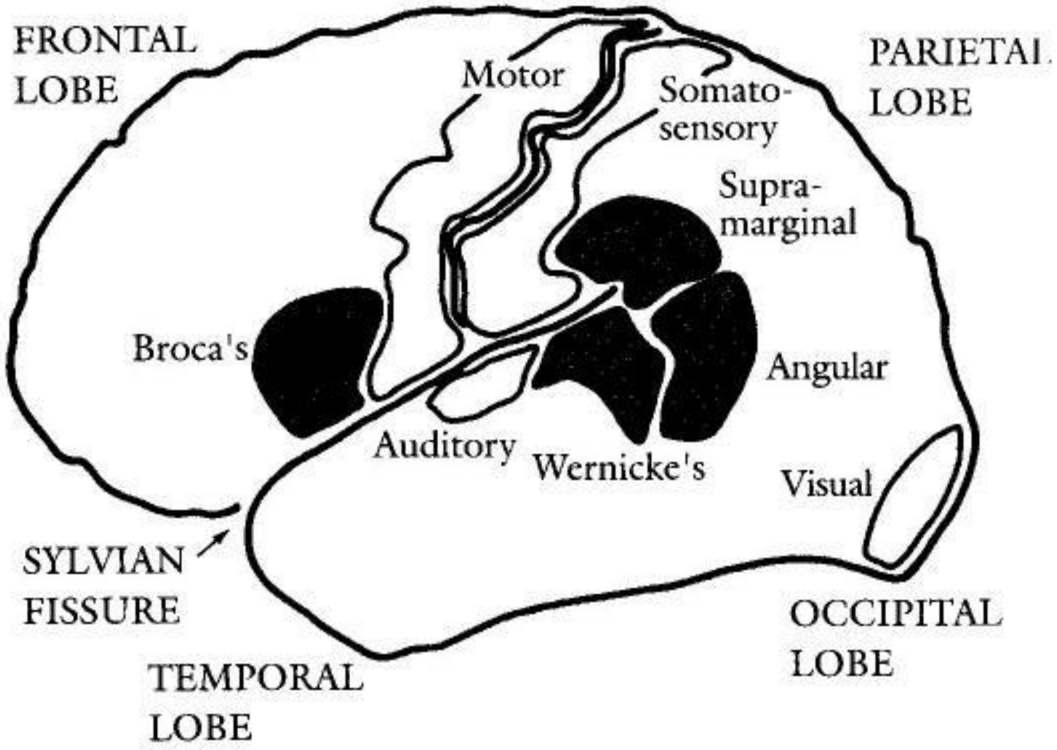
- the critical lesion site producing conduction aphasia - often considered to be in deeper tissue and affecting the **arcuate fasciculus**, which connects anterior and posterior language centers
- a model of how the “conduction” from reception to expression might be interrupted, but it is not universally accepted
- the role of short-term memory dysfunction in association with this aphasia has never been properly clarified



- Example
    - Video 7

Anomic Aphasia

- produced by lesions of the angular gyrus, and of the middle posterior temporal lobe
- the most common of the aphasias
  - poorly understood
- may exist as a residual form following recovery from one of the other types



Anomic Aphasia

both comprehension and expression are essentially intact, and repetition is normal

a specific difficulty, with finding the names for objects

specific deficit in word finding, particularly prominent for nouns – has a limited effect in speech output, although it may not be immediately apparent

some blocking or hesitation in speech as a noun is being searched for, and careful testing often shows that words are substituted to avoid the problems raised by a word that cannot be found

the substitutions are often appropriate and acceptable, it may go undetected in spontaneous speech

in severe cases the speech may be described as “empty” because the content lacks principal noun elements

Anomic Aphasia

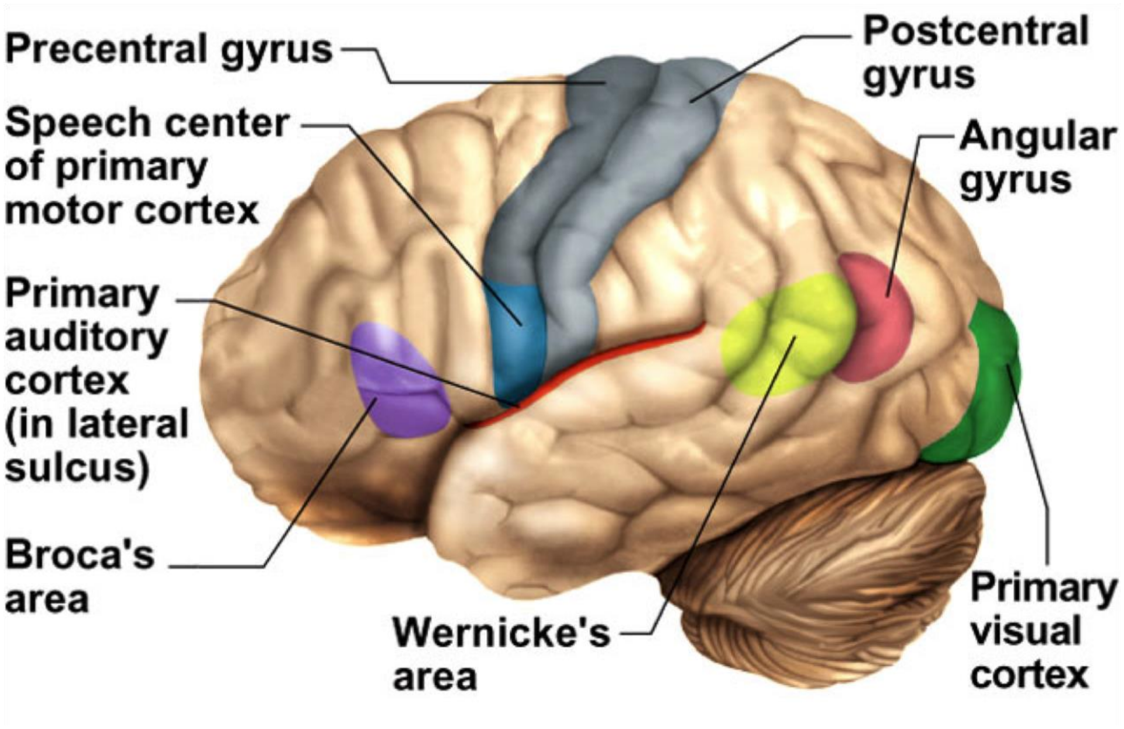
Word finding - a complex process

1. Essential characteristics for naming an object must be abstracted for identification
2. The semantically correct word must be retrieved and translated into a form that can be produced in speech

The following is not of great assistance to the anomic patient:

- Prompting
- Providing the context in which the word occurs
- Providing the initial sound
- Providing a rhyming word

often use a related verb (the same word) to explain how they cannot find the correct noun

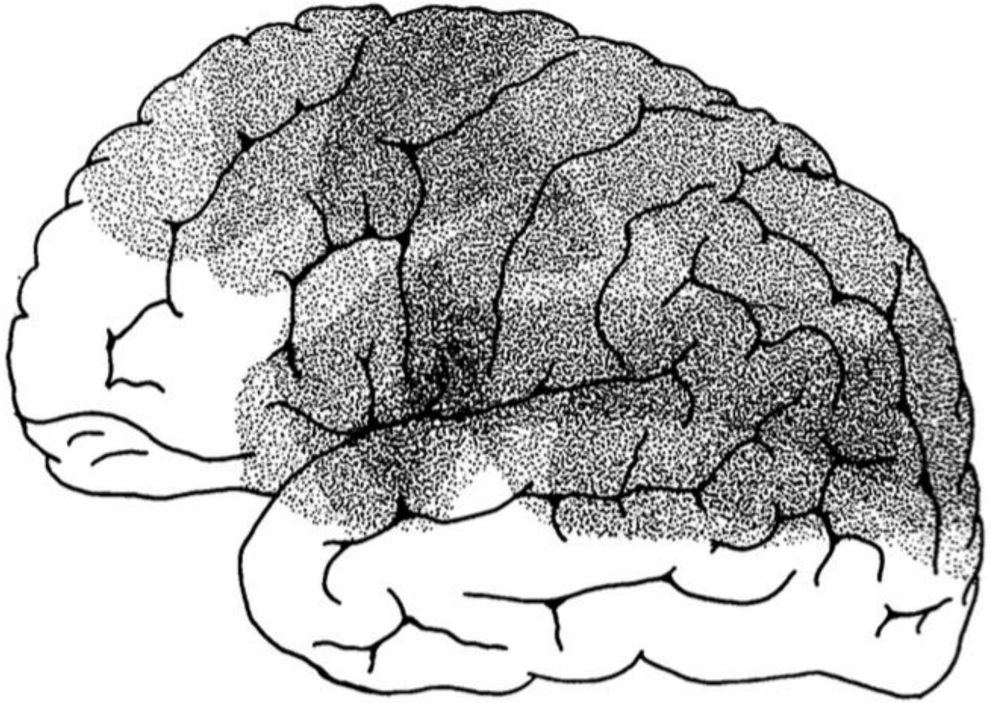


- Example
  - Video 8

Transcortical aphasias

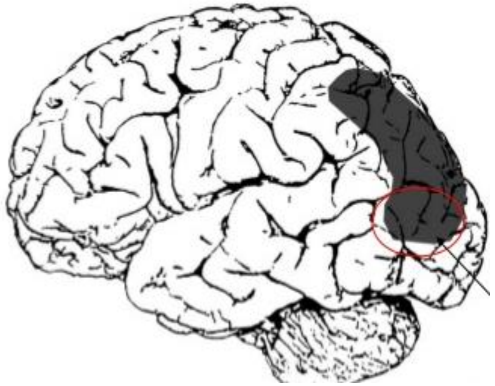
"TRANSCORTICAL"

- the lesion allows transmission across the cortex of information involving language reception and production
- links with mechanisms that subserve comprehension are not available
- links between the formulation of language and speech output are not available



Transcortical Sensory Aphasia

- the lesion associated - usually found in peri-Sylvian association cortex, around the junction of the parietal and temporal lobes
- sometimes known as the *isolation syndrome* - implying that the speech cortex has been isolated from other elements of the language system (this term is not used consistently and is sometimes applied only to complete transcortical aphasia, and sometimes only to the motor form)

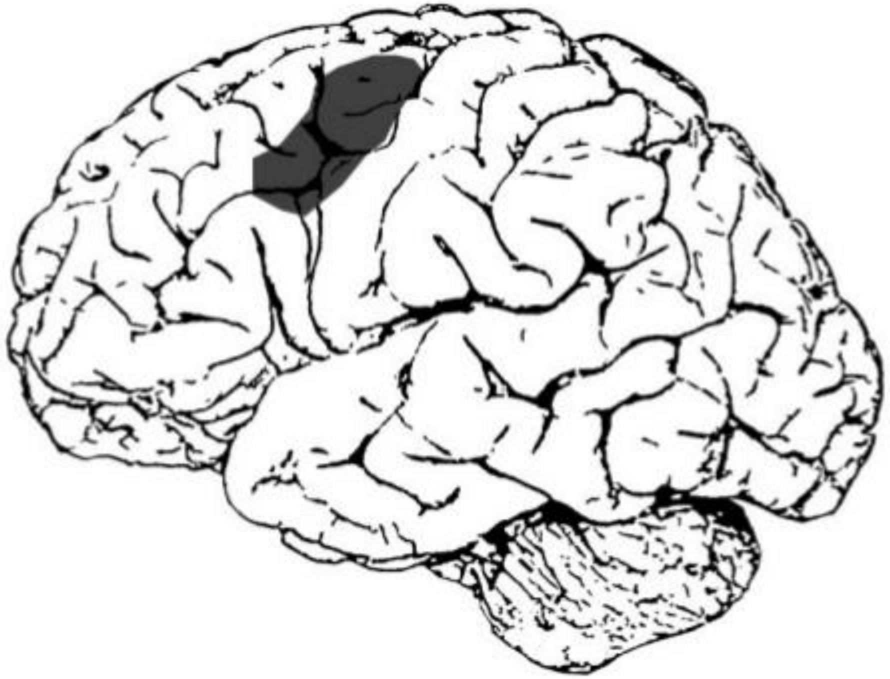


Transcortical Sensory Aphasia

- language reception is usually severely affected
- the ability to repeat is preserved
- patients can repeat what is said to them
- patients understand little of either what they repeat or what they read
- patients produce fluent speech output - often little more intelligible than that produced by the patients with Wernicke’s aphasia
- the response to a question may involve the direct repetition of elements that were in the question
- some patients may produce slightly more recognizable and meaningful answers
- the speech of patients is filled with jargon and paraphasias

Transcortical Motor Aphasia

- lesion in the frontal association cortex - anterior or superior to Broca's area



Transcortical Motor Aphasia

the impairment in speech output predominates

the patient preserves some auditory comprehension

the patient understands what is read

speech is normally fluent only during repetition of what is heard

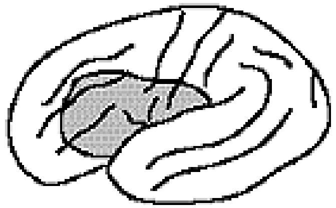
writing is impaired along with spontaneous speech

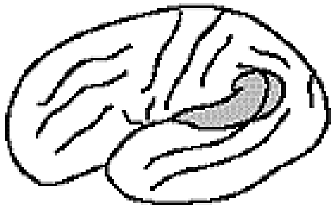
giving cues to assist with naming or to promote more fluent speech - helps most of these patients

Transcortical Motor Aphasia

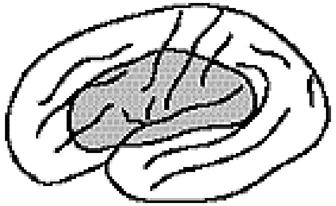
Preserved language ability:

1. able to complete proverbs
2. well-known sayings preserved
3. simple sentences preserved
4. singing preserved
5. the production of automatic phrases preserved
6. swearing preserved (in almost all of the aphasias)


CHRONIC BROCA'S APHASIA


WERNICKE'S APHASIA


CONDUCTION APHASIA

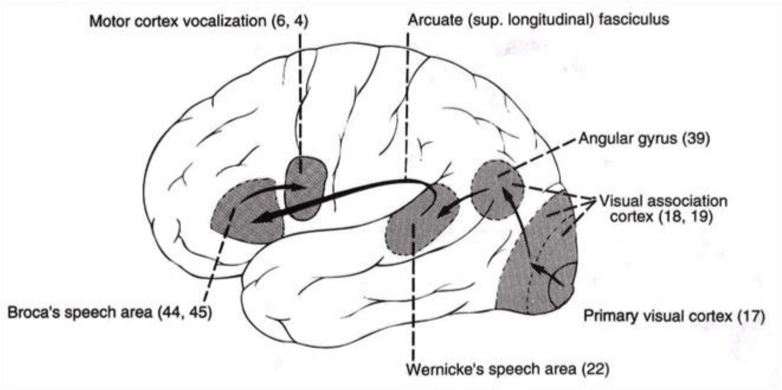

GLOBAL APHASIA


TRANSCORTICAL MOTOR APHASIA


TRANSCORTICAL SENSORY APHASIA

Alexia and Agraphia

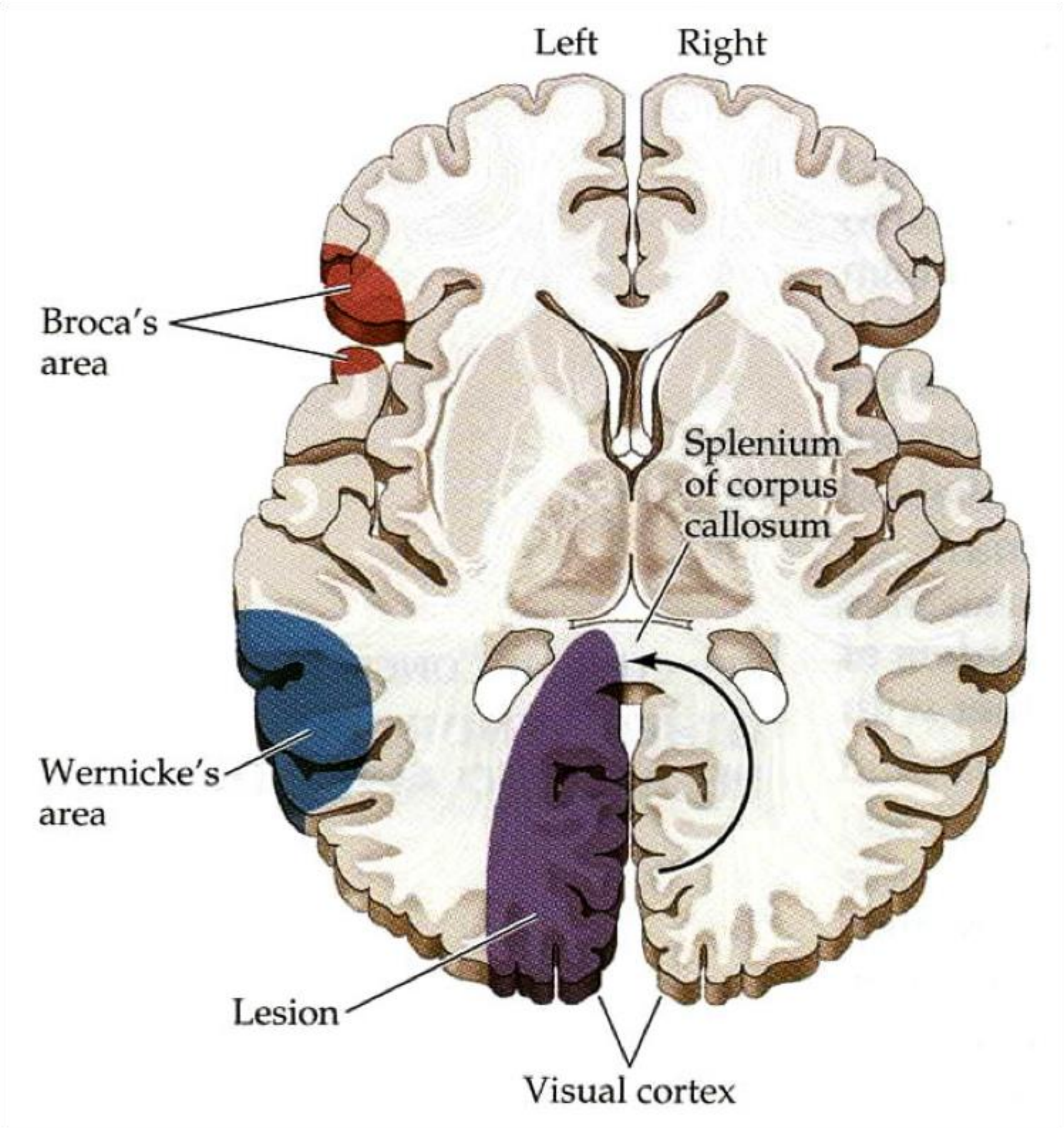
- reading and writing disorders
- occur as relatively isolated syndromes in which there is relatively little loss in the comprehension of spoken language or in speech production
- there is often some evidence for subtle linguistic deficits in modalities other than written language
- Both associated with lesions in the region of the angular and supramarginal gyri



NOTE

- ❖ *developmental dyslexia* - *acquired dyslexia*
- ❖ *developmental dysgraphia (rare without an associated DDL)* - *acquired dysgraphia*

- Alexia without agraphia
  - Cannot read as intact right occipital lobe is dissconnected of dominant hemisphere by lesion in the splenum corpus callosum
  - PCA infarct of dominant occipital cortex and cc
- Alexia with agraphia
  - usually a result of the angular gyrus lesion



V. Language lateralization

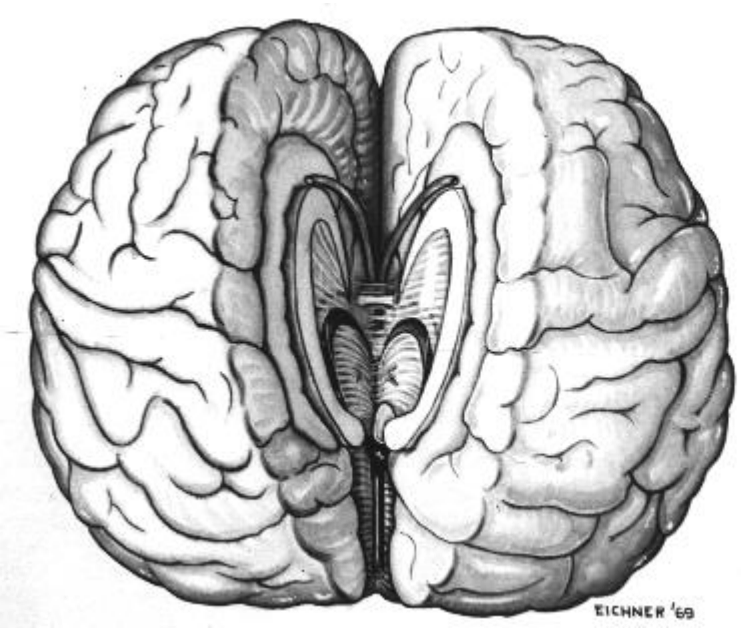
Vesalius 1542

Split-brain patients

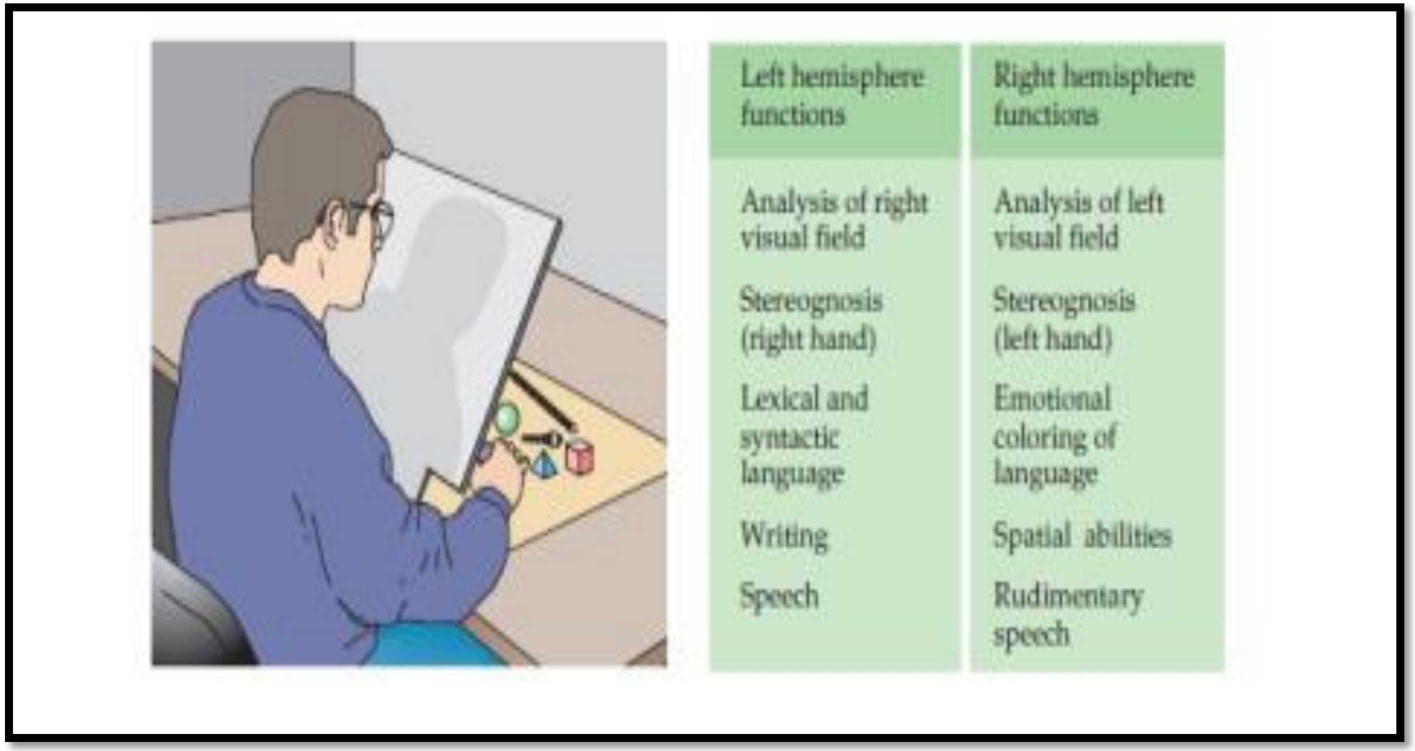
- Roger Sperry et al.
  - California Institute of Technology in the 1960s and 1970s
  - studies of patients **whose corpus callosum and anterior commissure** had been severed

- established the hemispheric lateralization of language beyond any doubt
  - this work also demonstrated many other functional differences between the left and right hemispheres

- **To evaluate the functional capacity of each hemisphere in split-brain patients, it is essential to provide information to one side of the brain only**



Split-brain patients
Sperry, Michael Gazzaniga et al.

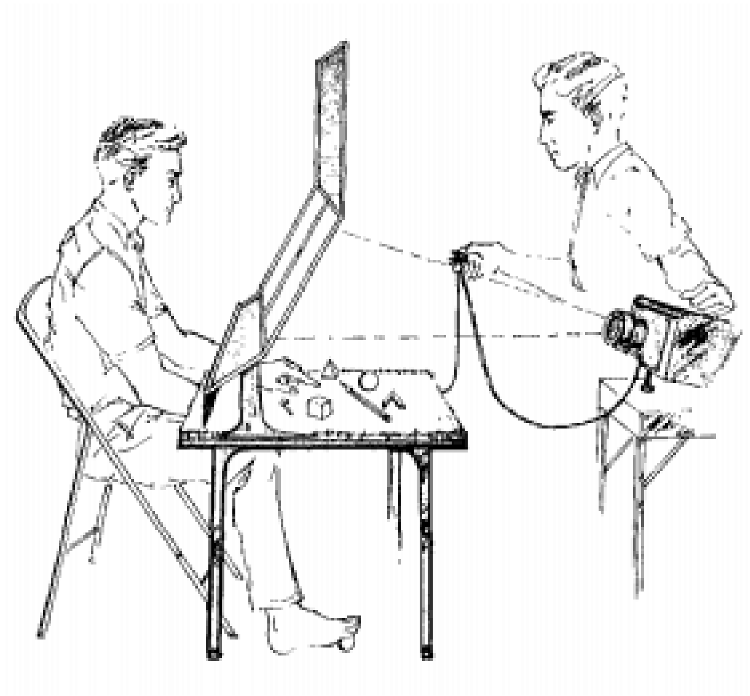


- the subject use each hand independently to identify objects without any visual assistance (somatosensory – L R)
- asked the subject to describe an item being manipulated by one hand or the other
  - the language capacity of the relevant hemisphere could be examined

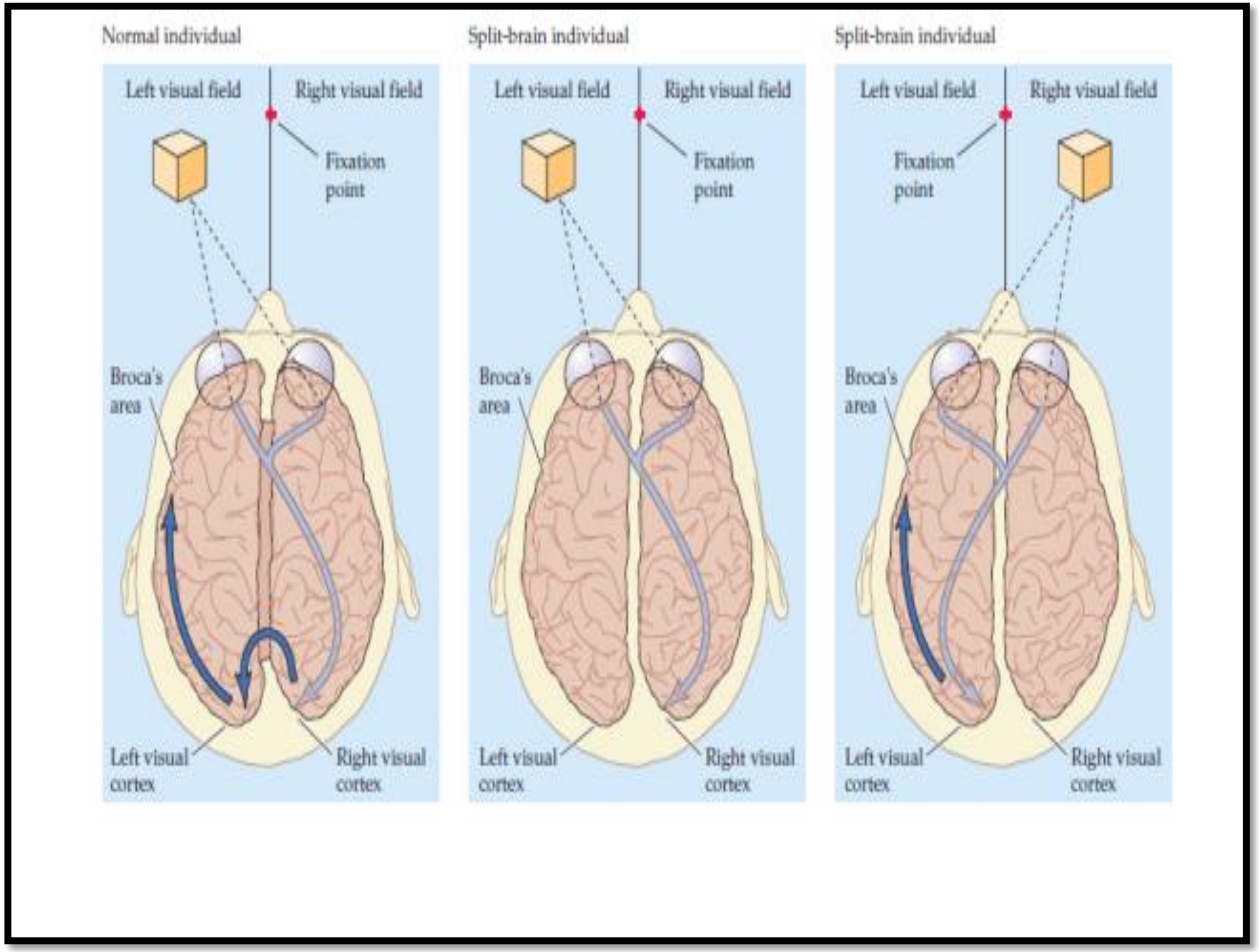
Tachistoscopic presentation

- special techniques to present visual information to the hemispheres independently
- the left hemisphere can respond to written commands
- the right hemisphere can typically respond only to nonverbal stimuli (e.g., pictorial instructions, or, in some cases, rudimentary written commands)

- The tachistoscope has a focal point in the middle and two areas where stimuli was presented.
  - The participants using the tachistoscope would have one eye covered and were instructed to stare at the focal point.
- Information presented to the left of the focal point would be seen in the left visual field which would then travel to the right hemisphere.



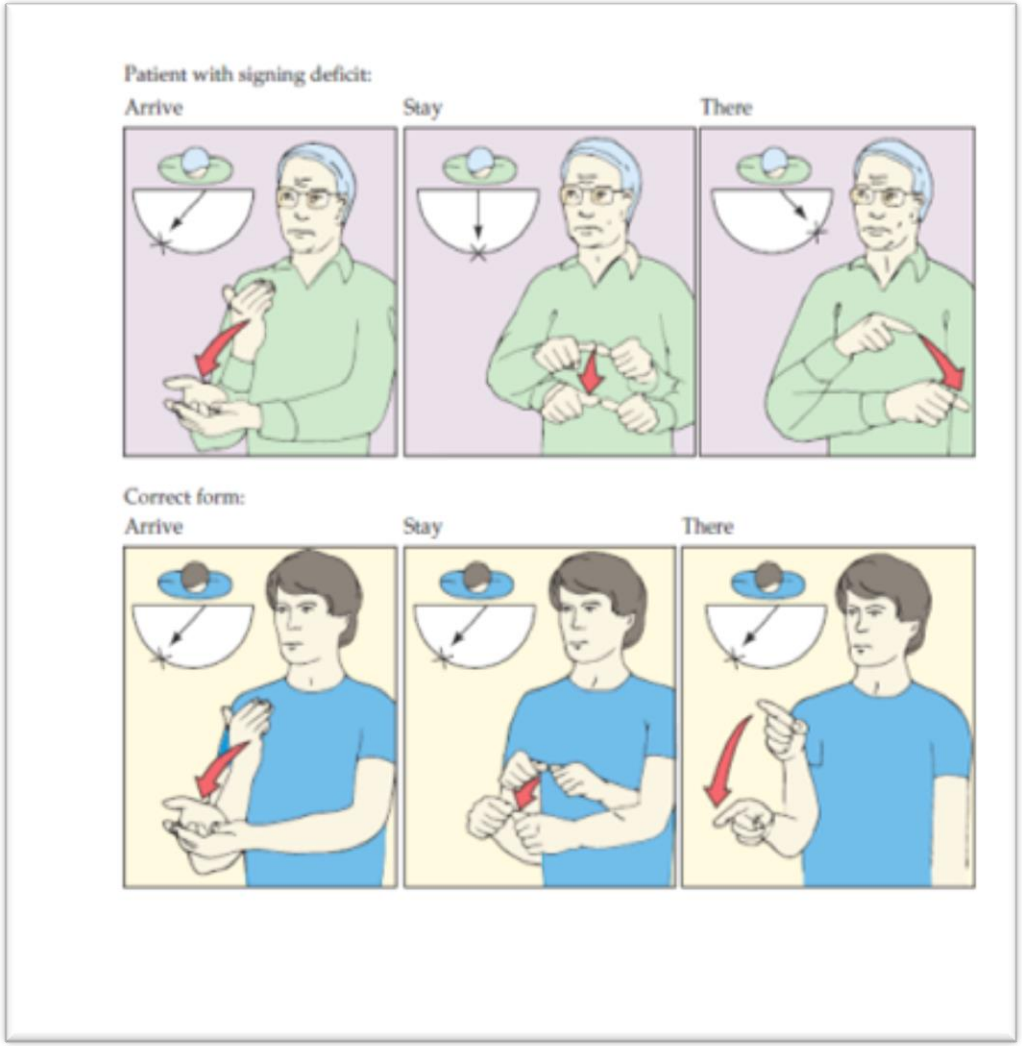
- Information presented to the RVF could be described in speech and writing.
- If the same information is presented to the LVF (right hemisphere), the participant insisted he either did not see anything or that there was only a flash of light on the left side - the information could not be described in speech or writing.
- The participant could point with his left hand (controlled by the right hemisphere) to a matching picture / object presented among a collection of pictures / objects.



Sign Language evidence for language lateralization

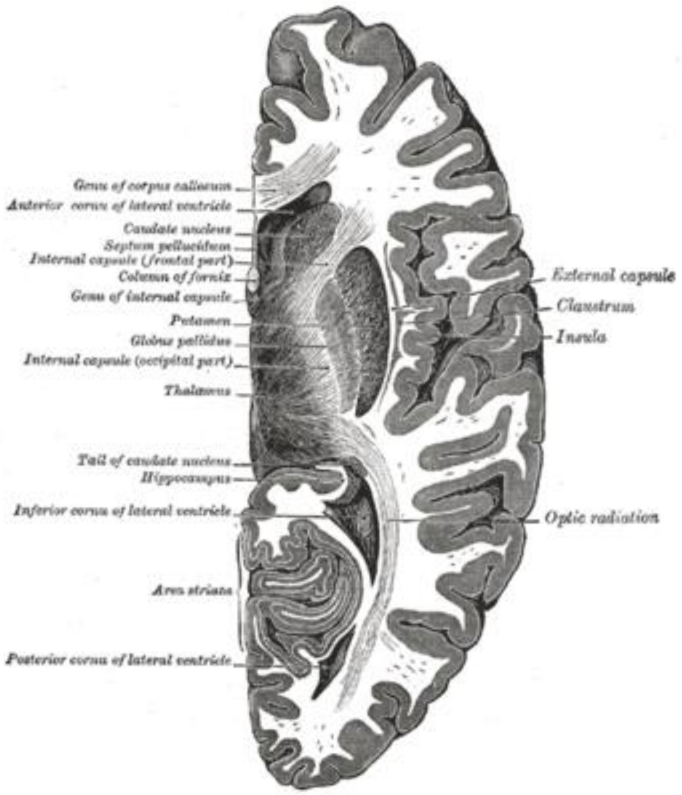
- Left-hemisphere lesions of the language areas of the frontal and/or temporal lobes resulted in **measurable deficits in sign production and comprehension** when compared to normal signers of similar age
- Right hemisphere lesions - no signing “aphasias”
    - visuospatial processing, emotional processing and the emotional tone evident in signing were impaired

- CONCLUSION: The capacity for signed and seen communication is evidently represented predominantly in the left hemisphere, in the same areas as spoken language



The Role of the Right Hemisphere in Language

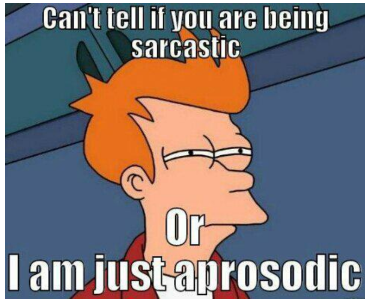
- the same cytoarchitectonic areas exist in the cortex of both hemispheres
    - so what do the comparable areas in the right hemisphere actually do?
    - language deficits often *do* occur following damage to the right hemisphere
    - the result is most often an absence of the normal emotional and tonal components of language—**prosodic elements**—that impart additional meaning to verbal communication
    - “coloring” of speech - critical to the message conveyed, and in some languages (e.g., Mandarin Chinese) is even used to change the literal meaning of the word uttered



The century-long controversy about language lateralization

- work of Sperry and his colleagues
  - in most individuals, the left hemisphere is unequivocally the seat of the major language functions

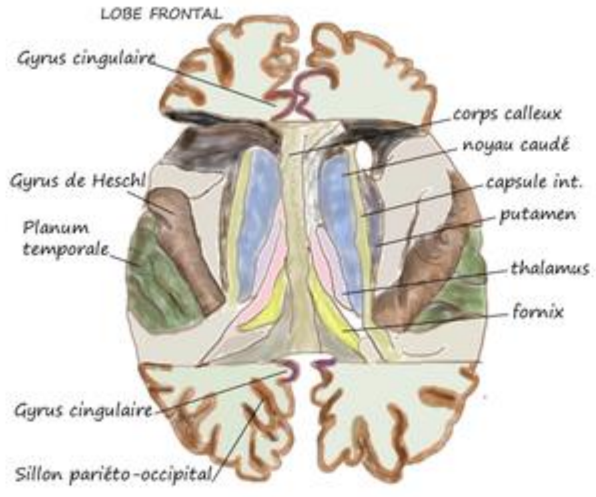
  - The right hemisphere:
    - can produce rudimentary words and phrases
    - it is normally the source of emotional coloring of language
    - in many split-brain patients understands language to a modest degree
      - since these patients can respond to simple visual commands presented tachistoscopically in the left visual field
      - **Aprosodias**



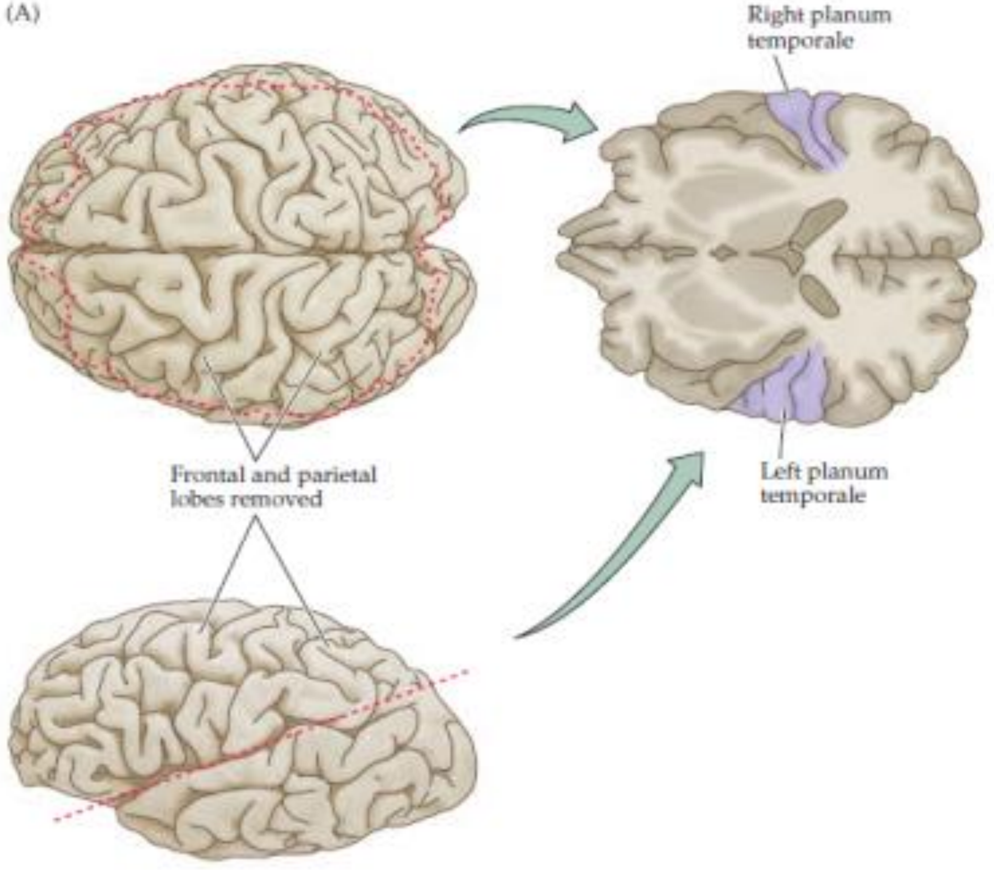
VI. Anatomical Differences between the Right and Left Hemispheres

Anatomical Differences between the Right and Left Hemispheres

- neurologists and neuropsychologists in search for a structural correlate of this behavioral lateralization
- 1960s Norman Geschwind et al. at Harvard Medical School
    - asymmetry in the superior aspect of the temporal lobe - the **planum temporale**

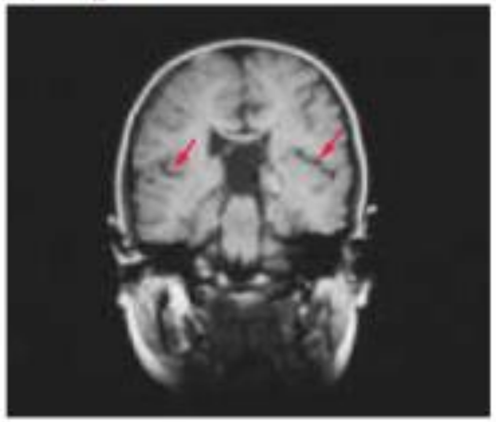


Planum temporale



(B)

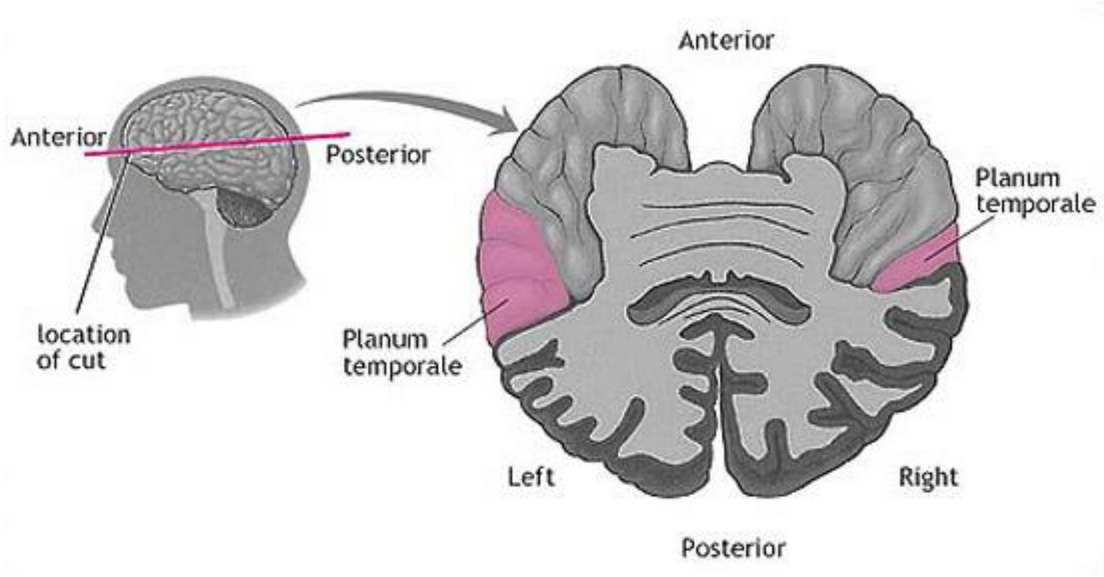
Planum temporale measurements of 100 adult and 100 infant brains		
	Left hemisphere	Right hemisphere
Infant	20.7	11.7
Adult	37.0	18.4



- (A) The superior portion of the brain has been removed as indicated to reveal the dorsal surface of the temporal lobes in the right-hand diagram (which presents a dorsal view of the horizontal plane). A region of the surface of the temporal lobe called the planum temporale is significantly larger in the left hemisphere of most (but far from all) individuals.
- (B) Measurements of the planum temporale in adult and infant brains. The mean size of the planum temporale is expressed in arbitrary planimetric units to get around the difficulty of measuring the curvature of the gyri within the planum. The asymmetry is evident at birth and persists in adults at roughly the same magnitude (on average, the left planum is about 50% larger than the right).
- (C) A magnetic resonance image in the frontal plane, showing this asymmetry (arrows) in a normal adult subject.

Anatomical Differences between the Right and Left Hemispheres

- near the regions of the temporal lobe that contain cortical areas essential to language (i.e., Wernicke’s area and other auditory association areas)
  - initially suggested that this leftward asymmetry reflected the greater involvement of the left hemisphere in language



- unlikely to be an anatomical correlate of the lateralization of language functions
  - a detectable planum asymmetry is present in only 67% of human brains
  - the preeminence of language in the left hemisphere is evident in 97% of the population

VII. Methods in the study of fiber pathways and language functions

Mapping Language Functions

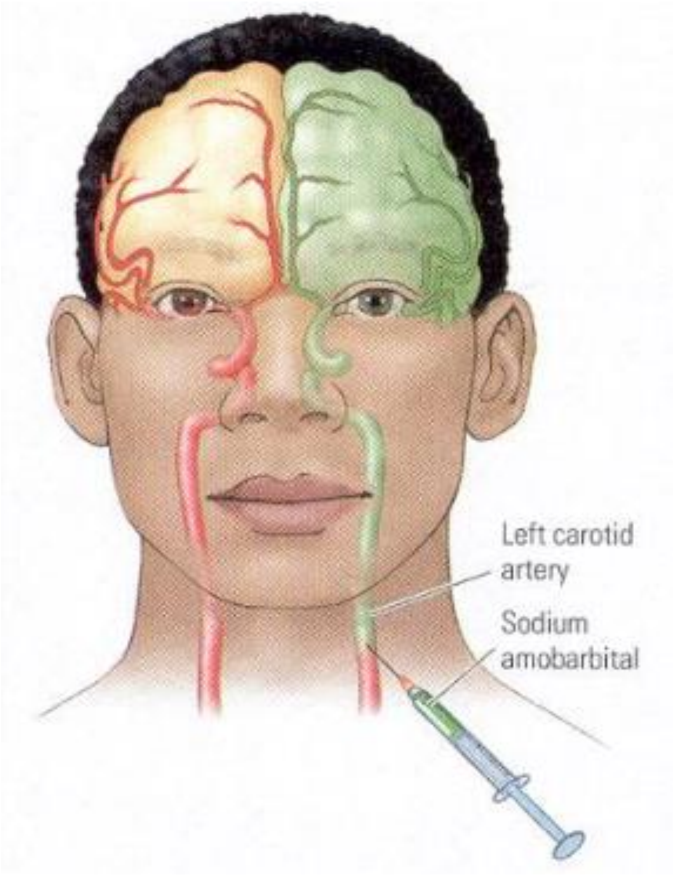
1. Wada test
2. PET
3. fMRI
4. Tachistoscopic presentation
5. TMS

Wada test

- devised in the 1960s
    - Juhn Wada at the Montreal Neurological Institute

- Method: a short-acting anesthetic (e.g., sodium amytal) injected into the left carotid artery
    - transiently “anesthetizes” the left hemisphere
    - tests the functional capabilities of the affected half of the brain
    - if the left hemisphere is indeed “dominant” for language, then the patient becomes transiently aphasic while carrying out an ongoing verbal task like counting

- the anesthetic is rapidly diluted by the circulation, but not before its local effects on the hemisphere on the side of the injection can be observed
- potentially dangerous, its use is limited to neurological and neurosurgical patients



Wada Test Procedure

THE WADA TEST

STEP 1

The patient is settled in a neuro-angiography suite. Under no sedative, a catheter is placed in the femoral artery and guided to either the left or right side of the brain. A dye is injected into the catheter. This allows the radiologist to view either side of the brain in the search for abnormalities, particularly of a vascular nature.

THE WADA TEST

STEP 2

The neuropsychologist screens the patient's responses before amobarbital is injected into the catheter. Afterward, the neuropsychologist asks the patient to raise both hands and point all ten fingers to the ceiling while naming objects in the patient's view.

THE WADA TEST

STEP 3

Once the neuropsychologist has enough information to proceed, the radiologist injects 100 mg of amobarbital into the catheter. This puts the left side of the patient's brain to sleep. The patient's right hand drops, which indicates that the patient's left hemisphere has been adequately anesthetized. The neuropsychologist then asks the patient to name objects and read from cards.

THE WADA TEST

STEP 4

The neuropsychometrist scores the patient's responses and compiles the data obtained from the score sheet. This data allows the physicians to determine how they will proceed with surgery.

THE WADA TEST

STEP 5

After a few minutes, the amobarbital wears off and the left hemisphere of this patient's brain wakes up. The first half of the Wada is completed.

THE WADA TEST

STEP 6

The catheter is repositioned in the right side of the brain and dye is again injected into the catheter. X-rays are taken of the right side of the brain and once the x-rays have been reviewed, amobarbital is again injected into the catheter. The neuropsychologist repeats the steps in phase 1.

STEP 6

The catheter is repositioned in the right side of the brain and dye is again injected into the catheter. X-rays are taken of the right side of the brain and once the x-rays have been reviewed, amobarbital is again injected into the catheter. The neuropsychologist repeats the steps in phase 1.

THE WADA TEST

STEP 7

The patient's left hand falls as the right side of the brain is put to sleep. Objects are shown to the patient. The patient is asked to read a card and then is asked to recall a word.

THE WADA TEST

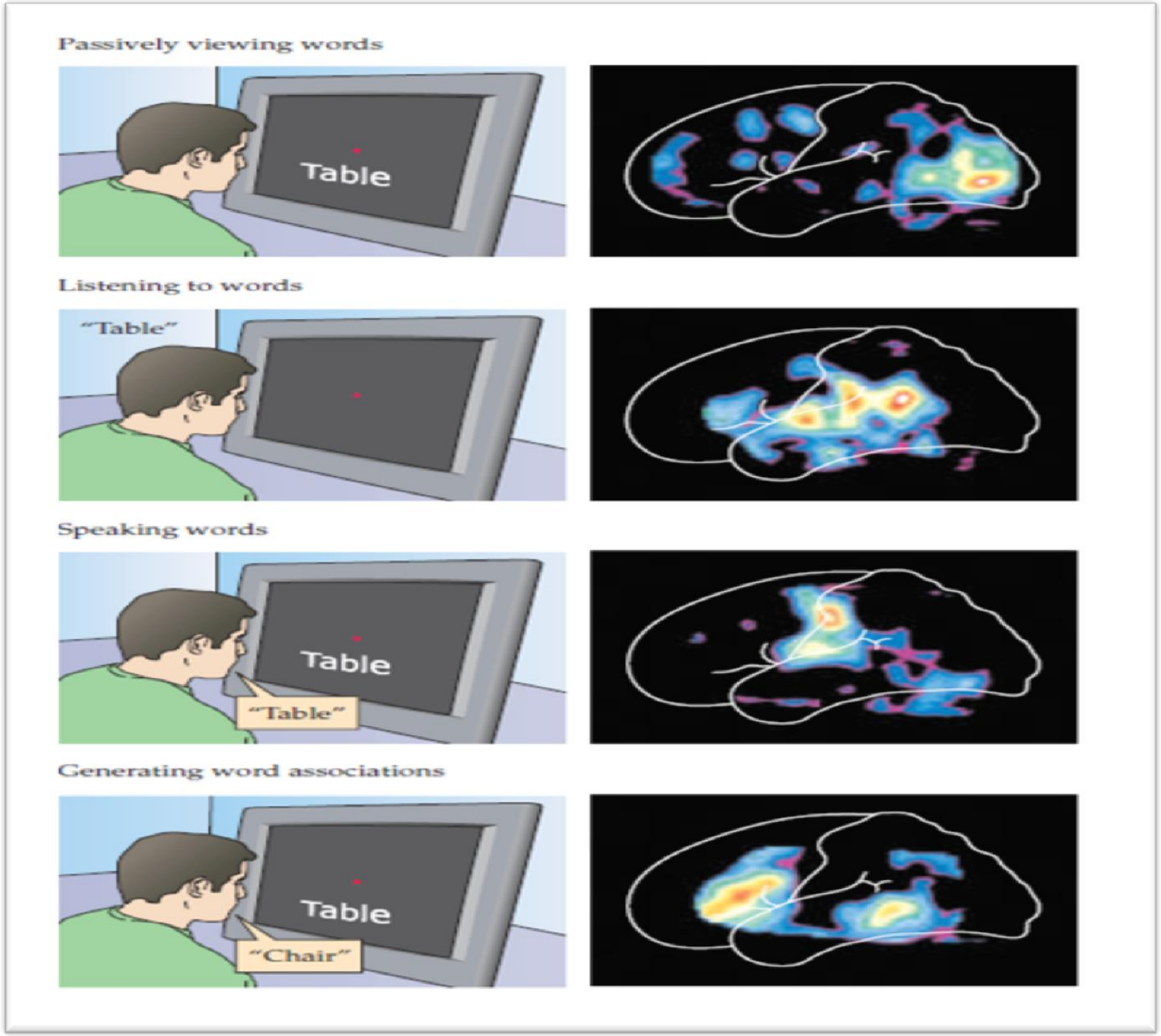
STEP 8

The test is almost completed. The patient's right brain has woken up and she now can follow instructions, name objects correctly, read cards accurately, and recall objects.

Noninvasive brain imaging (fMRI and PET)

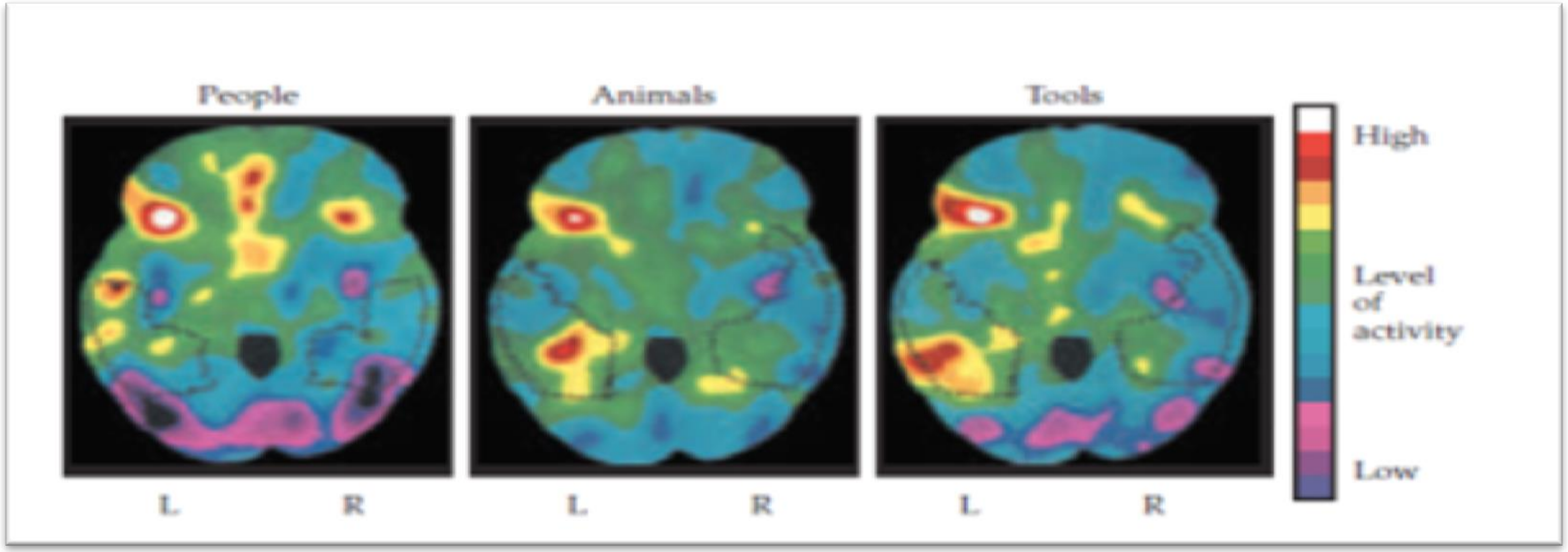
- allow the investigation of the language regions in normal subjects
- reveal the areas of the brain that are active during a particular task
  - the related electrical activity increases local metabolic activity and therefore local blood flow

Noninvasive brain imaging (fMRI and PET)



- Subjects reclined within the PET scanner and followed instructions on a special display.
- The left panels indicate the task being practiced prior to scanning. The PET scan images are shown on the right.
- Language tasks such as listening to words and generating word associations elicit activity in Broca's and Wernicke's areas, as expected.
    - However, there is also activity in primary and association sensory and motor areas for both active and passive language tasks. These observations indicate that language processing involves cortical regions in addition to the classic language areas. (From Posner and Raichle, 1994.)

Noninvasive brain imaging (fMRI and PET)
Category effect in word naming



- Hanna Damasio at the University of Iowa
  - distinct regions of the temporal cortex are activated by tasks in which subjects named particular people, animals, or tools
    - when a relatively limited region of the temporal lobe is damaged (usually by a stroke on the left side), language deficits are sometimes restricted to a particular category of objects
  - consistent with Ojemann's electrophysiological studies, indicating that language is apparently organized according to categories of meaning rather than individual words

TMS

- **Transcranial magnetic stimulation** (**TMS**)
- a magnetic method - stimulates small regions of the brain using a magnetic field generator
  - placed near the head of the person receiving the treatment
  - produces small electric currents in the region of the brain just under the coil via electromagnetic induction

Conclusion

- Language development
- Hemispheric differences in language
- Aphasia subtypes

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