The deficit-lesion method for studying brain function

- Before functional neuroimaging techniques became available, the only ways to study brain function were
  - Animal research.
  - The deficit-lesion method: Studying the behavior of brain damaged patients and determining the site of the damage in a post-mortem analysis.

- Logic:
  - If a patient cannot do X, then the execution of X must depend on the lesioned area.
The deficit-lesion method for studying brain function

- Since language is a uniquely human capability, the history of the cognitive neuroscience of language is deeply rooted in deficit-lesion studies.

- Language problems as a result of brain damage: APHASIA.

- Study of aphasic patients: APHASIOLOGY.
Paul Broca & Broca’s aphasia

- First localization of language function (1861).
- Patient could only produce a single syllable “tan”.
- Severe production problem.
  - Broca’s aphasia
- Lesion in the posterior part of the left inferior frontal gyrus
  - Broca’s area
Paul Broca & Broca’s aphasia

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Production problems of Broca’s aphasia

- Slow, laborious, non-fluent speech. Output limited to short utterances of less than four words.
- Speech understanding and reading may be relatively intact, but writing is limited.

Broca’s aphasic writing sample.
Broca’s Aphasia
Wernicke’s aphasia

- A language problem distinct from Broca’s aphasia first described by Carl Wernicke (1874).
- Damage to the boundary of the temporal and parietal lobes --> Wernicke’s area.
- Fluent but disordered speech. Similar writing.
- Impaired understanding of speech. Impaired reading.
Wernicke’s aphasics
The classic model / Wernicke-Lichtheim model

Broca’s aphasia (non-fluent aphasia):
Ah ... Monday ... ah Dad and Paul [patient’s name] ... and Dad ... hospital. Two ... ah doctors ..., and ah ... thirty minutes ... and yes ... ah ... hospital. And, er Wednesday ... nine o’clock. And er Thursday, ten o’clock ... doctors. Two doctors ... and ah ... teeth. Yeah, ..., fine. (Goodglass, 1976)

Wernicke’s aphasia (fluent aphasia):
Examiner: What kind of work did you do before you came into the hospital?
Patient: Never, now mista oyge I wanna tell you this happened when happened when he rent. His - his kell come down here and is - he got ren something. It happened. In thesse ropiers were with him for hi - is friend - like was. And it just happened so I don’t know, he did not bring around anything. And he did not pay it. And he roden all o these arranjen from the pedis on from iss pescid. (Kertesz, 1981)
The classic model: Conduction aphasia

- Lesion to the arcuate fasciculus (= the bundle of nerves connecting Wernicke’s and Broca’s areas).
- Results in inability to repeat words, especially nonwords.
1900-1950

- Heyday of Behaviorism (mind is a “black box”) and Gestalt Psychology (the whole is greater than the sum of its parts).
- Wernicke-Lichtheim model is out of vogue.
1965

- Norman Geschwind revives and popularizes the classic model.

Wernicke-Lichtheim-Geschwind model

1. Information about the sound is analyzed by primary auditory cortex and transmitted to Wernicke’s area.

2. Wernicke’s area analyzes the sound information to determine the word that was said.

3. This information from Wernicke’s area is transmitted through the arcuate fasciculus to Broca’s area.

4. Broca’s area forms a motor plan to repeat the word and sends that information to motor cortex.

5. Motor cortex implements the plan, manipulating the larynx and related structures to say the word.

Lesions of the arcuate fasciculus disrupt the transfer from Wernicke’s area to Broca’s area, so the patient has difficulty repeating spoken words, but may retain comprehension of spoken language (because of intact Wernicke’s area) and may still be able to speak spontaneously (because of intact Broca’s area).
What’s right about the classic model

- The participation of (roughly) Wernicke’s area in the understanding of words.

- Many areas of the left temporal lobe participate in aspects of lexical access, with the relative contributions of different areas still not very well understood. But Wernicke’s area is certainly part of this network.
Problems with the classic model

- Limited to the lexical level.
- Broca’s aphasia not just a production problem.
- Early characterization (Goodglass & Kaplan, 1983): Broca's aphasics "may be confused by more complex spoken messages".
Syntactic constructions that Broca’s aphasics... 

... have trouble understanding (chance performance):

- The boy was chased _ by the girl ...
- The boy who the girl chased _ ...
- It was the boy who the girl chased _

... do OK on:

- The girl chased the boy.
- The girl who _ chased the boy...
- It was the girl who _ chased the boy...
Syntactic constructions that Broca’s aphasics...

... have trouble understanding (chance performance):

- Passives:
  The boy was chased _ by the girl ...
- Object relatives:
  The boy who the girl chased _ ...
- Object clefts:
  It was the boy who the girl chased _

... do OK on:

- Actives
  The girl chased the boy.
- Subject relatives:
  The girl who _ chased the boy...
- Subject clefts:
  It was the girl who _ chased the boy...
Trace Deletion Hypothesis (Grodzinsky)

- Broca’s area supports the interpretation of displacement. The boy who the girl chased ...

- Here the object of chase, the boy, occurs outside the canonical object position.

- The canonical object position is empty. In syntactic theory, it is said to contain a trace of the object, which has moved to the beginning of the sentence.

- According to the Trace Deletion Hypothesis, Broca’s aphasics cannot represent the fact that the fronted element is actually the object of the sentence. For them, there is no trace after chased. Thus they end up guessing the meanings of sentences containing displacement.
Broca’s aphasia and syntax more widely

- The Trace Deletion Hypothesis attributes an extremely specific function to Broca’s area.

- More often, Broca’s aphasia is described as a more general syntax problem, involving impaired use and comprehension of function morphemes.
  - “agrammaticism”
  - Speech lacking in function morphemes: “telegraphic speech”
Diagnosis of aphasia

- Always done on the basis of performance on a battery of language tests, such as the Boston Diagnostic Aphasia Examination or the Western Aphasia Battery.

- Lesion site does not play into the diagnosis.

- Thus it is possible to have Broca’s aphasia without having damage to Broca’s area and Wernicke’s aphasia without damage to Wernicke’s area.
Broca’s area and Broca’s aphasia

- Only 85 percent of patients with chronic Broca’s aphasia have lesions in Broca’s area.

- Only 50-60 percent of patients with lesions in Broca’s area have a persisting Broca’s aphasia. (N. Dronkers, *Brain and Language*, 2000)
Recovery

- During the first three months after stroke, lots of reorganization can happen, even complete, spontaneous recovery.
- The subjects in aphasia studies are not recent stroke victims but rather patients whose situations have stabilized.
- Huge variability in the extent to which recovery occurs later on.
Proposed functions of Broca’s area

- Representation of displacement/traces (Grodzinsky)
- Hierarchical structure building (Friederici)
- Semantic retrieval (Wagner)
- Selection among competing alternatives (Thompson-Schill)
- Phonological processing
- The human mirror neuron system (Iocoboni, Rizzolatti, Arbib)

**Broca’s area is probably the most highly debated region in cognitive neuroscience!**
Mirror neuron selectively discharging (A) during observation of a grasping movement done by the experimenter and (B) during monkey grasping movements.
Mirror neurons in the monkey

Broca’s area the human homologue of F5
Rizzolatti & Arbib on Broca’s area:

“... it is probably no coincidence that the area which links action recognition and action production in the monkey brain is exactly the same area that in humans has been linked to speech production ... the development of human speech was made possible by the fact that F5, the precursor of Broca's area, was endowed with this mirroring mechanism for recognising actions made by others. This ... was a prerequisite for the development of communication and ultimately of speech. It made us "language-ready"...”

http://www-inst.eecs.berkeley.edu/~cs182/readings/ns/article.html
Limits of aphasiology as a method for the cognitive neuroscience of language

- Research driven by region as opposed to by process
  - The questions that one can investigate are completely determined by the patient population one happens to have access to.
  - One’s ability to study the neural bases of a specific process, say, phonological categorization, is dependant on finding a patient with a specific problem in exactly that process. But you might never find one!

- In functional neuroimaging, the experimenter is in charge and can set up an experimental situation where exactly one type of process is manipulated.