Studying the brain 1. Lesion and stimulation studies

Epistemology of Neuroscience

- Epistemological question: How do we come to possess knowledge?
- Often the epistemological problem is put in terms of justification:
  - How, given the evidence, can we justify our beliefs?
- But a further problem is:
  - How do we get evidence in the first place?
- The challenge: identifying sources that can give us reliable information about what we want to know

Franz Gall and Phrenology

- Around 1800 Gall proposed a way to link mental processes to the brain
  - Divide the mind into mental faculties and propensities
    - Capabilities that some people are better and some are worse at
  - Identify differences in people's skulls
    - Attribute bumps on the skull to increased growth in the underlying brain area
  - Relying especially on individuals with especially developed mental traits (good or bad), correlate faculties with bumps on their skulls
    - thereby revealing the brain regions responsible for the faculty or propensity

Clicker Questions

What role do animals play in Gall's discussion of faculties?

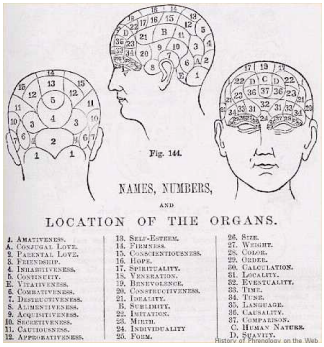
A. He performed experiments on their brains to identify what happened when parts were removed
B. He treated different species as exhibiting high levels of different faculties that corresponded to the parts of their brains that were large
C. They are never mentioned since he thought mental activity occurred only in humans
D. Other

Faculties and Brain Regions

- Different species of animals have different behavioral propensities
- Different people show greater development in specific propensities (some are better at arithmetic, some faster to anger, etc.)
  - Propensities are due to different regions of the brain
  - Propensities are stronger when the responsible brain region is larger
  - Propensities are lost when the corresponding brain region is absent or damaged

A phrenological map

- Note the sort of mental states that are localized on the map
  - amativeness
  - combativeness
  - hope
  - time
  - language



The Popularity of Phrenology

- Phenology became very popular with the public—people would pay to have their skull read
  - Why?

Gall's Chief Opponent: Pierre Flourens

- "The entire doctrine of Gall is contained in two fundamental propositions, of which the first is, that understanding resides exclusively in the brain, and the second, that each particular faculty of the understanding is provided in the brain with an organ proper to itself. Now, of these two propositions, there is certainly nothing new in the first one, and perhaps nothing true in the second one."

Clicker Question

What did Flourens discover from his lesion studies with animals

A. Specific lesions produced specific deficits in their intelligence
B. Some animals seemed to be more intelligent as a result of lesions
C. Lesions had absolutely no effect on the intelligence of the animals
D. The more tissue lesioned, the greater the loss of intelligence

Flourens: Limited Localization

- Four Functionally Separate Parts of the Brain
  - Cerebellum: regulates locomotion
  - Tubercula quadrigemina (inferior and superior colliculus): involved in vision
  - Medulla oblongata (part of the brain stem): involved in respiration
  - Brain proper (cerebral hemispheres or neocortex): “the exclusive seat of intelligence”

No Divisions in the Hemispheres

- In the cerebral cortex, no lesion results in a specific loss of intelligence
  - “As has been shown by my late experiments, that we may cut away, either in front or behind, or above, or on one side, a very considerable slice of the hemisphere of the brain, without destroying the intelligence. Hence it appears, that quite a restricted portion of the hemispheres may suffice for the purposes of intellection in an animal.”
- But overall intelligence is reduced proportional to the amount removed
  - “On the other hand, in proportion as these reductions by slicing away the hemispheres are continued, the intelligence becomes enfeebled, and grows gradually less; and certain limits being passed, is wholly extinguished. Hence it appears, that the cerebral hemispheres concur, by their whole mass, in the foil and entire exercise of the intelligence! As soon as one sensation is lost, all sensation is lost; when one faculty disappears, all the faculties disappear. There are not, therefore, different seats for the different faculties, nor for the different sensations.”

Phrenology Falls into Disrepute

- Despite its popularity with the general public, the scientific community rejected phrenology as quackery
  - Why?
    - What is the difference between defending a claim judged to be incorrect and quackery?
- The rejection of phrenology put a damper on any attempts to localize mental activities in the neocortex
  - Those who did embrace any claim to localize functions in the cortex were labeled *neophrenologists*

Clicker Question

What was the language deficit that Broca identified in his patient Leborgne (Tan)?

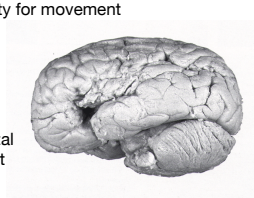
A. All language abilities were lost
B. Tan could not produce any vocal sounds
C. Tan could not produce articulate words
D. Tan could neither produce words nor understand those spoken to him

Aphemia: Loss of Articulate Speech

- Broca begins by identifying a specific kind of loss of intellectual capacity: the loss of the ability to produce articulate speech
  - Not the loss of all language: Tan could still understand language
  - Not the loss of general intelligence: Tan could still perform tasks requiring intelligence
- Cannot fully resolve whether this is a loss of learned coordination of motor activity or of a higher cognitive capacity

Leborgne (Tan)

- Became Broca's patient only when already close to death at the age of 50
- Had experienced epilepsy from youth and lost the capacity for articulate speech at about 30
  - No loss of understanding or of intelligence
- Around 40 began to lose the capacity for movement
- Died soon after coming under Broca's care and, upon death, Broca performed an autopsy
  - Massive amount of damage
    - Broca argued that the damage was centered on the third frontal convolution and that is where it originated



Discussion Question

You open the hood of your car, remove something, and your car will no longer drive in reverse. You conclude that you have removed the reverse engine. How could you be wrong?

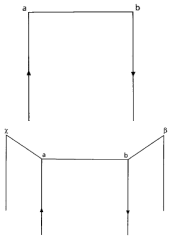
A. There is a possibility that the part you removed only connects the reverse engine to the wheels
B. The car may not have a reverse engine—it has only one engine whose torque is applied either in moving forward or backwards
C. You might have removed the controls that activate the reverse engine, which is still perfectly functional
D. Other

Ongoing Challenge

- There is no question that the damage to the region Broca identified (there is some question as to where precisely it is located) results in language deficits
- But what exactly do the deficits consist in and what does the region do?
  - Broca—center for articulate speech
  - 1970s—center for syntactic processing
    - in recognition that Broca's patients do experience some comprehension deficits
  - And other proposals

Wernicke: Not Localization But "Connectionism"

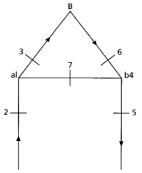
- Model for mimicking speech
  - (a) Center for "acoustic images"
  - (b) Center for "motor speech images"
  - Connection between them
    - damage results in conduction aphasia



- To account for reading and writing, one might add centers for visual letter imagery and graphic motor imagery
- All the rest due to connections: "Any higher psychic process, exceeding these mere primary assumptions, could not, I reasoned, be localized, but rested on the mutual interaction of these fundamental psychic elements mediated by means of their manifold connections via the association fibers."

Wernicke: Classification of Aphasias

- Adds a concept center B
- Identifies 7 different possible aphasias (likewise alexias and agraphias)
  1. Cortical sensory aphasia
  2. Subcortical sensory aphasia
  3. Transcortical sensory aphasia
  4. Cortical motor aphasia
  5. Subcortical motor aphasia
  6. Transcortical sensory aphasia
  7. Conduction aphasia



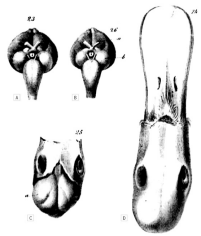
Empirical question: do all of these occur?

Localizationism vs. Connectionism

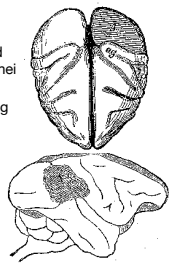
- Gall and Broca sought to explain different mental abilities by localizing them in the brain
  - Each region responsible for a different mental ability
    - differences in the ability due to different size, blood flow, etc.
- Flourens and Wernicke drew limits to localzationism
  - Flourens appealed to mass action
  - For Wernicke, many deficits resulted from failed associations between areas, not areas themselves
- To appreciate the difference, ask
  - What is required to develop a new ability?

Localization of Vision

- Common assumption that visual processing must occur in the front of the brain near the eyes
- Tracing the effects of destruction of the eyes in a variety of species of fish, birds, and mammals Bartolomeo Panizza, arrived at the rear of the brain
- He further found that destroying region at the rear of the brain produced blindness
- In addition, Panizza showed that human patients with damage to the rear of the brain exhibited visual pathologies



Competing Localizations of Vision



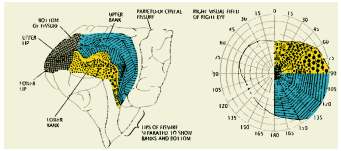
- In the 1870s and 1880s several investigators reported visual deficits in patients with damage to the rear of thei brains
  - Hermann Munk developed techniques for removing small regions of animal brains and identified the occipital lobe as the one responsible for vision
- David Ferrier, perhaps the leading neurologist of the period, obtained different results
  - lesions to the occipital lobe did not generate blindness
  - but those to the angular gyrus did
- Vast majority of findings supported Munk
  - In retrospect, Ferrier probably cut deeply into conduction pathways in lesioning the angular gyrus
    - And left much of the occipital lobe in tact in his lesions
- But such assessments can only come later once researchers settled on Munk's view

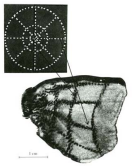
More Precise "Surgical" Instruments; More Specific Deficits

- During the Russo-Japanese War, Tatsuji Inouye, a young Japanese ophthalmologist, was assigned to assess visual loss in Japanese soldiers who had suffered brain injury so as to determine how large their pensions would be
  - He decided to make the job more interesting and map deficits in particular parts of the visual field onto the area damaged
- The situation was set up by the fact that the Russians had developed a new high-velocity rifle (Mosin–Nagant Model 91) that fired a 7.62-mm hard-jacketed bullet.
  - This bullet pierced the skull without shattering, leaving tidy entrance and exit wounds
- This made it possible to trace the trajectory and compare the location where the occipital lobe was damaged with the part of the visual field in which the patient lost vision

Retinotopic map of the visual field

- In a study of 29 patients with focal brain injuries, Inouye correlated the parts of the visual field in which his patients were blind with areas of brain damage, and mapped the visual field onto the visual cortex
- Gordon Holmes (1918) constructed a similar map based on studies of soldiers injured during World War I
- Using radioactive markers, Tootell et al. (1982) had an anesthetized monkey look at a pattern as it died and then "developed" its brain, revealing topographic map





Lesion Studies

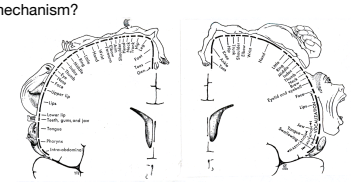
- Brain damage such as Leborgne experienced is one source of lesions in humans
  - Surgery is another (HM)
- Challenges in interpreting lesion studies
  - Lesions do not typically align with boundaries between functional areas in the brain
  - From deficits it is not straight forward to predict what the removed area does when not damaged
    - It is assumed to contribute to the capacity that is lost, but that capacity may depend on many other areas as well

Stimulation Studies

- Stimulation was first employed by Fritsch and Hitzig in 1870 to find localized centers in the dog's brain that results in specific movements
- Guiding idea:
  - If a brain region is responsible for a given activity, then stimulating it should affect (typically increase, but perhaps impair) that ability
    - But again, the converse doesn't hold:
      - Stimulation of an area may have a specific effect, but it not be responsible for that effect
- If an area is active in a given task, lesioning it should eliminate the ability to perform the task, and stimulating it should increases that ability
  - It seems increasingly likely that it plays an important role in that task
    - Although it may not be the only area involved!

Stimulation Studies

- Just as eliminating a functioning component should change behavior in a determinate manner, so should enhancing its activity by additional stimulation
  - Challenge 1: What part of the brain is altered by the added stimulation?
  - Challenge 2: Just what does the stimulated component contribute to the mechanism?



The sensory and motor "homunculi" identified by Penfield by using electrical stimulation. From Penfield and Rasmussen, 1950

Delgado's Bull Experiment

- Delgado claimed he found a center that inhibited aggression
- Valenstein: Delgado really activated a pathway that controlled movement