INTRODUCTION TO COGNITIVE NEUROSCIENCE

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ABOUT THE NAME

- The expression “Cognitive Neuroscience” has been invented at the end of the Seventies by Michael Gazzaniga and George Miller.

- The idea has been conceived in NYC, on the back seat of a taxi that was taking them to a dinner with scientists from Rockefeller University and Cornell University.

- The meeting had been organized to discuss how the brain allows the mind to exist:

they had the object to study but not a name for it!

- CN is an umbrella that includes different research fields:

neuropsychology, cognitive science and neuroimaging

(including fMRI, TMS, tDCS & ERPs)

NEUROPSYCHOLOGY

- This is the study of the effects of lesions or dysfunctions of the Central Nervous System (CNS) on cognition and behaviour

- The regions of interest are the cortex of the two brain hemispheres, the sub-cortical structures (e.g. thalamus, basal ganglia, hypothalamus, and amygdala), and the main connecting white matter fibres

AIMS OF NEUROPSYCHOLOGY

- research → exploring the functional architecture of the mind and its neural correlates
- clinical → providing patients with a diagnosis and, possibly, with rehabilitative recommendations
- No plausible research is possible without a correct diagnosis

LOCALIZATION

- The history of neuropsychology is linked to the changing of concepts of functions' *localization*
- *Localization* → different parts of the brain are specialized in such a way so as to contribute to behaviour at various levels
- The most fundamental fact was established in ancient times when the Greeks first determined that the *brain* was the physical *seat* of the mind
- The one credited with making this basic advance in the *V century* B.C. is Alcmaeon of Croton, who came to this conclusion after observing brain damaged patients

THE CARDIOCENTRIC VIEW

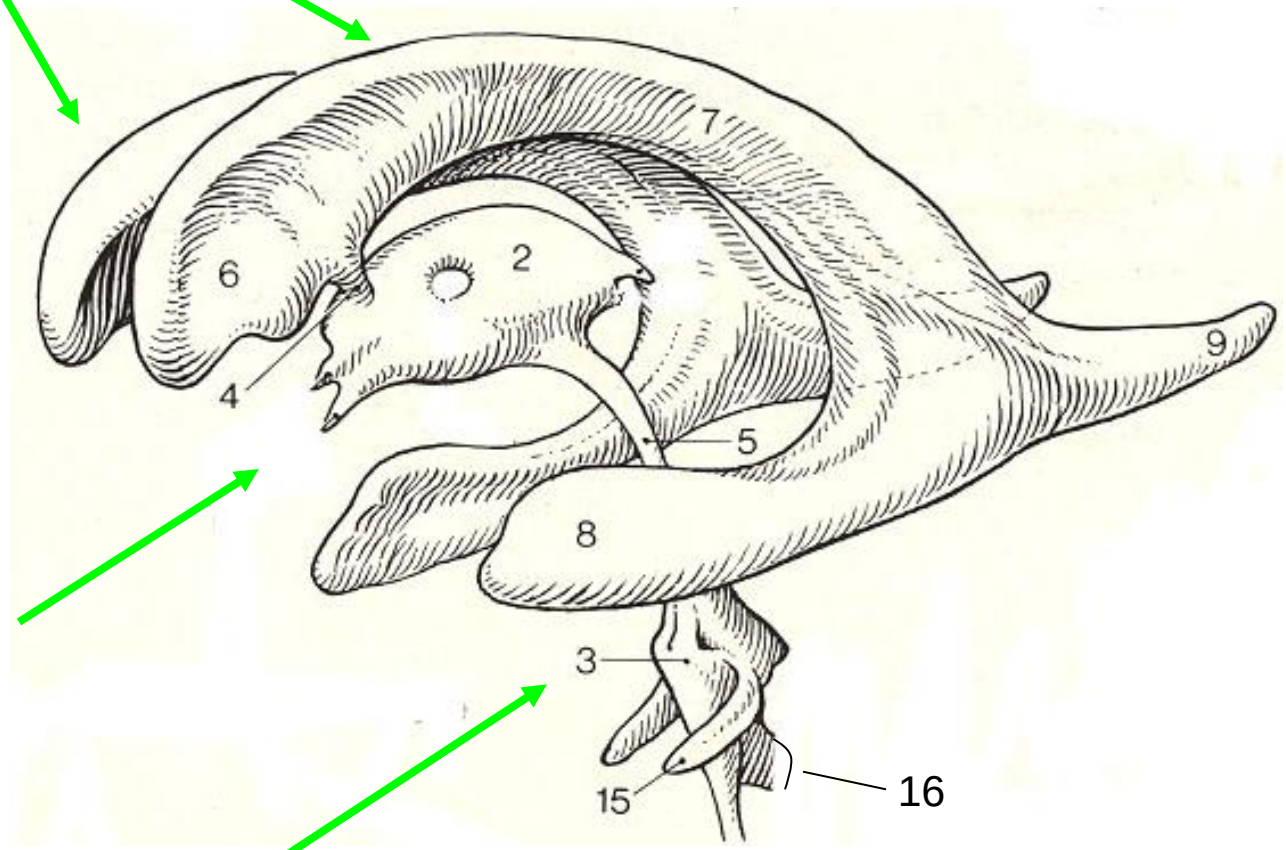
- The alternative hypothesis held the *heart* to be the organ responsible for sensation and thought
- This was the accepted view among ancient Egyptian writers and continued to attract adherents in ancient Greece
- Aristotle (ca 384-322 BC) maintained the *cardiocentric view* and suggested that the brain served to cool the blood

THE THEORY OF THE VENTRICLES

- The nature of the mind-brain relation was poorly understood
- For centuries, the most important anatomical features of the brain were considered to be the *ventricles*
- This is probably because they contain the *cerebrospinal fluid* that was considered the *real substance* of the mind

VENTRICLES

lateral ventricles



3rd ventricle

4th ventricle

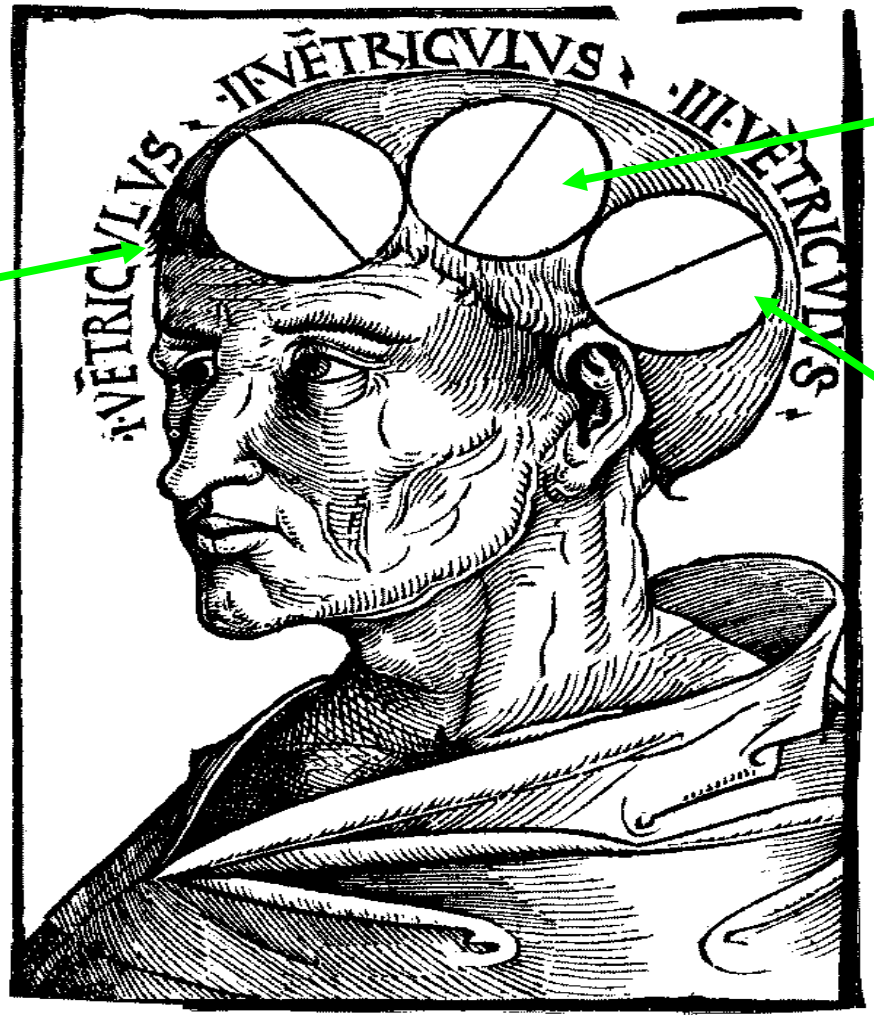
LOCALIZATION & VENTRICLES

Herophilus of Alexandria (ca 335-280 BC) Galen (130-200 AD) Nemesius Bishop of Emesia (ca. 390 AD)

1st Ventricle

Perception

Imagination



2nd Ventricle

Reason

3rd Ventricle

Memory

Albertus Magnus, *Philosophia naturalis*, 1506

WHITE MATTER

- After the XVI century, it was accepted that the encephalon was the site of mental functions but the critical structure was held to be the *white matter*, whereas the *gray matter* was considered as the external, protecting layer

RISE OF THE THEORY OF PHRENOLOGY

FRANZ JOSEPH GALL (1757-1828)

- *faculties* are localized in specific regions (*organs*) of the cerebral cortex
- the more a faculty is developed, the larger the organ
- by measuring the skull of an individual, one can infer the dimension of single faculties

Shortcomings of phrenology

– too many faculties (27) ill-defined

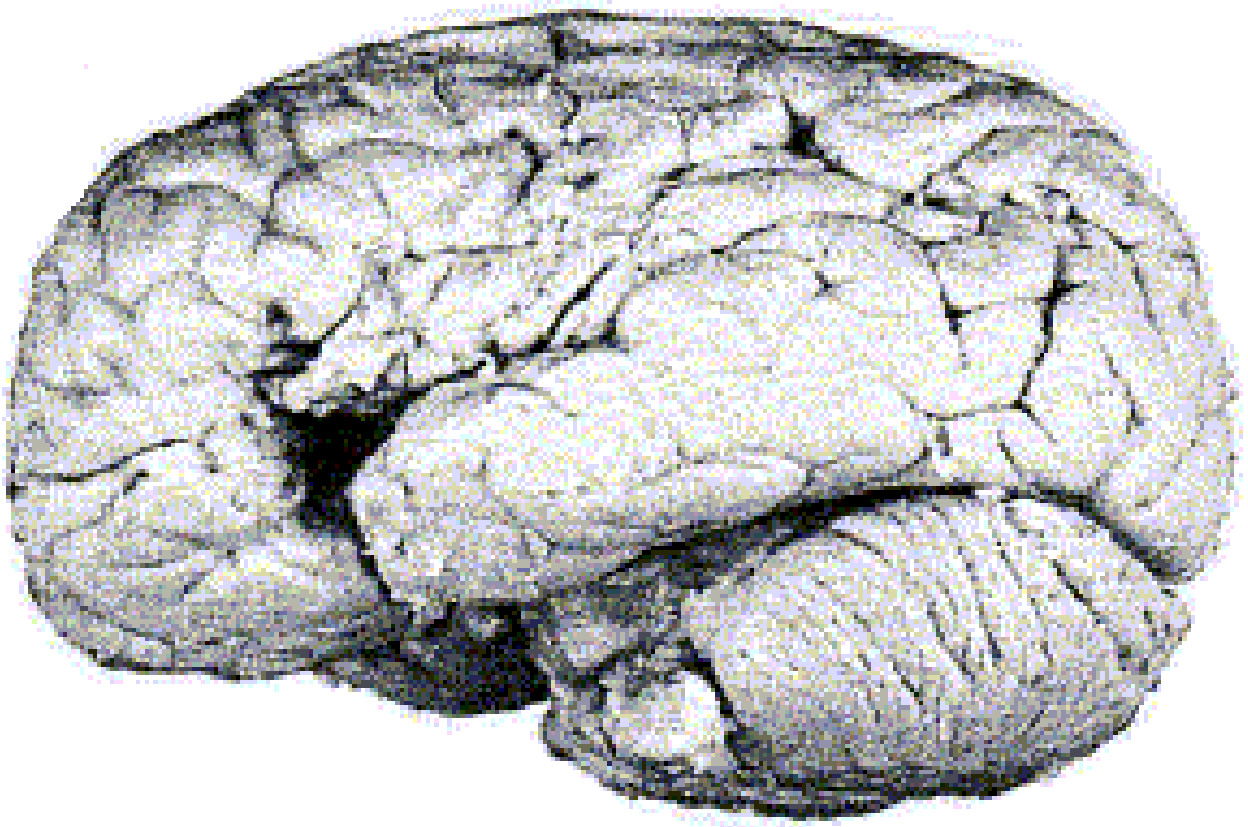
– impossible to reliably localize them

Merits

– correlation between the *cortex (i.e. grey matter)* and *mental functions*

– speech housed in the front part of the cerebral cortex

APHASIA: PAUL BROCA

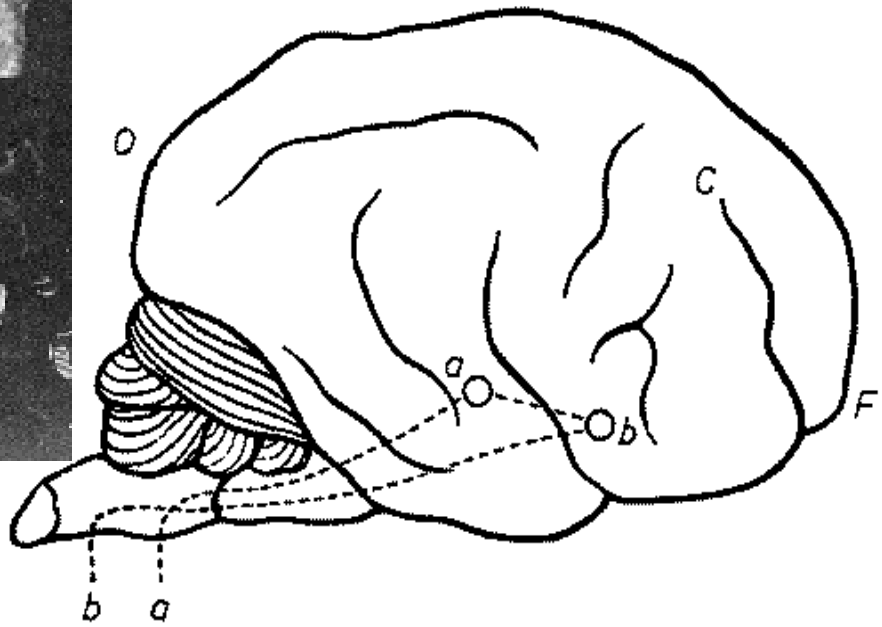


1861 Broca found that the lesion of Monsieur Leborgne, nicknamed "*Tan*", who was aphasic and had hemiplegia of the right arm, was at *the foot of the third frontal convolution of the left hemisphere*

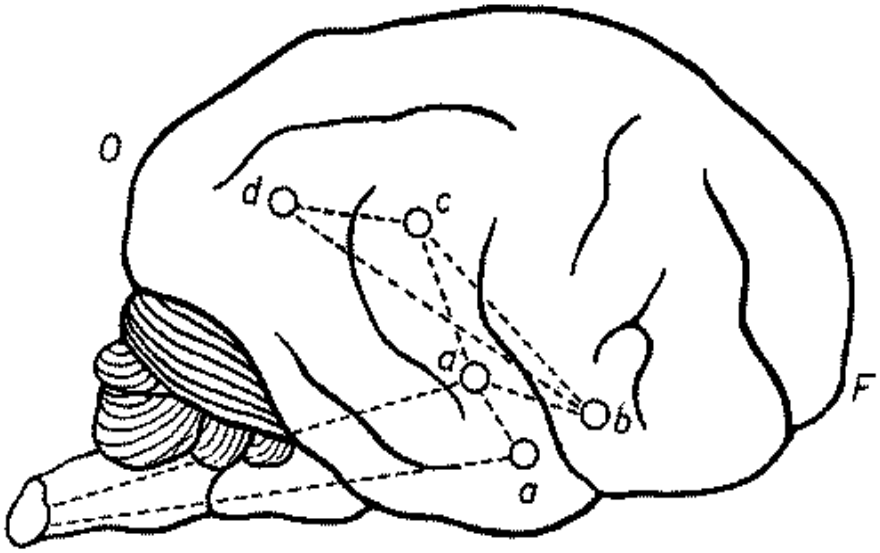
- In 1865, Broca proved that language was a *function lateralized in the left hemisphere*

Wernicke

proposed a general model (1874) of language that could explain a number of different aphasic syndromes by means of lesions to different centers and connections to centers.



With few basic centers and connections he could explain a wide variety of higher functions



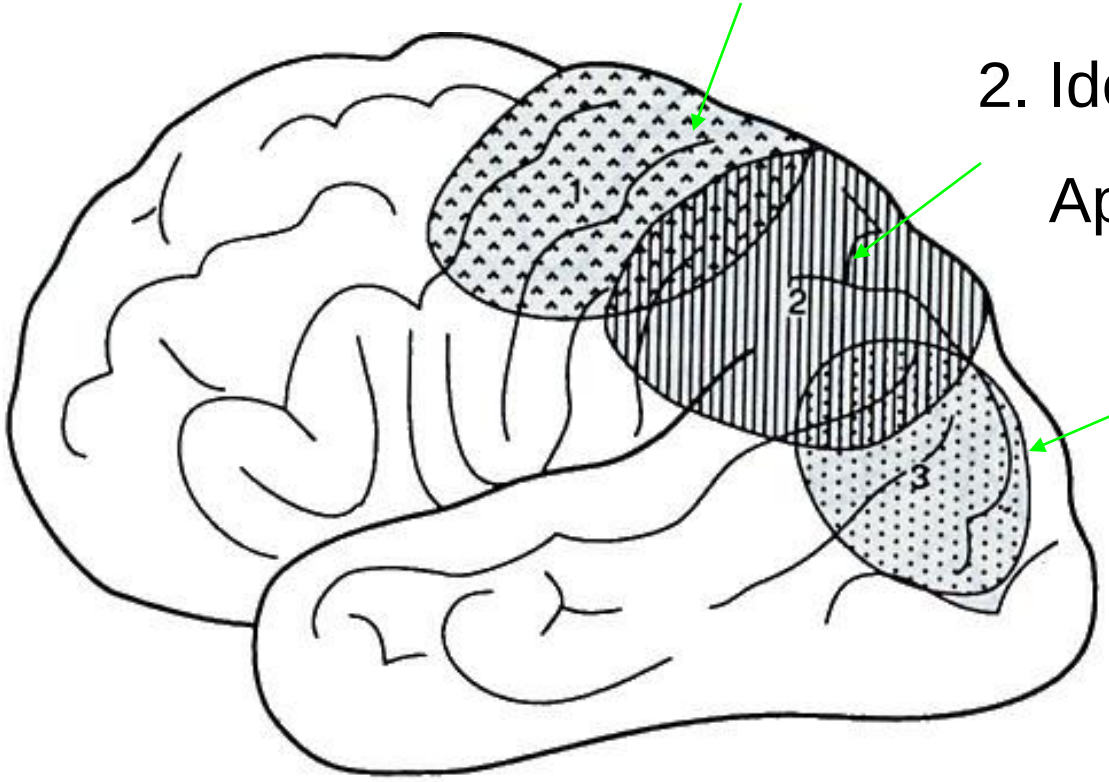
AGNOSIA : LISSAUER (1890)

LIEPMANN (1905;1920)

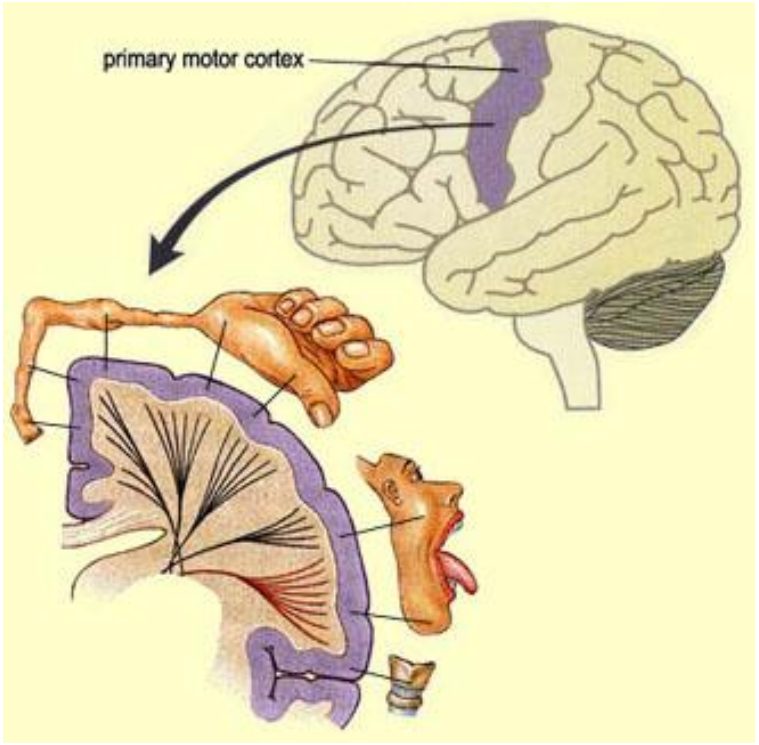
1. Motor Apraxia

2. Ideomotor Apraxia

3. Ideational Apraxia



LOCALIZING MOTOR FUNCTIONS



- Fritsch & Hitzig (1870) found that, depending on what part of the dog's primary motor cortex (M1) they stimulated electrically, a different part of the body contracted
- They also found that if they destroyed the same small area of M1, the corresponding part of the body became paralyzed:
- every part of the body has a particular region of M1 that controls its movement
- body parts that can make the finest movements take up much more space than others (Penfield, in man)

- David Ferrier (1843-1928) performed electric stimulation on the monkey brain

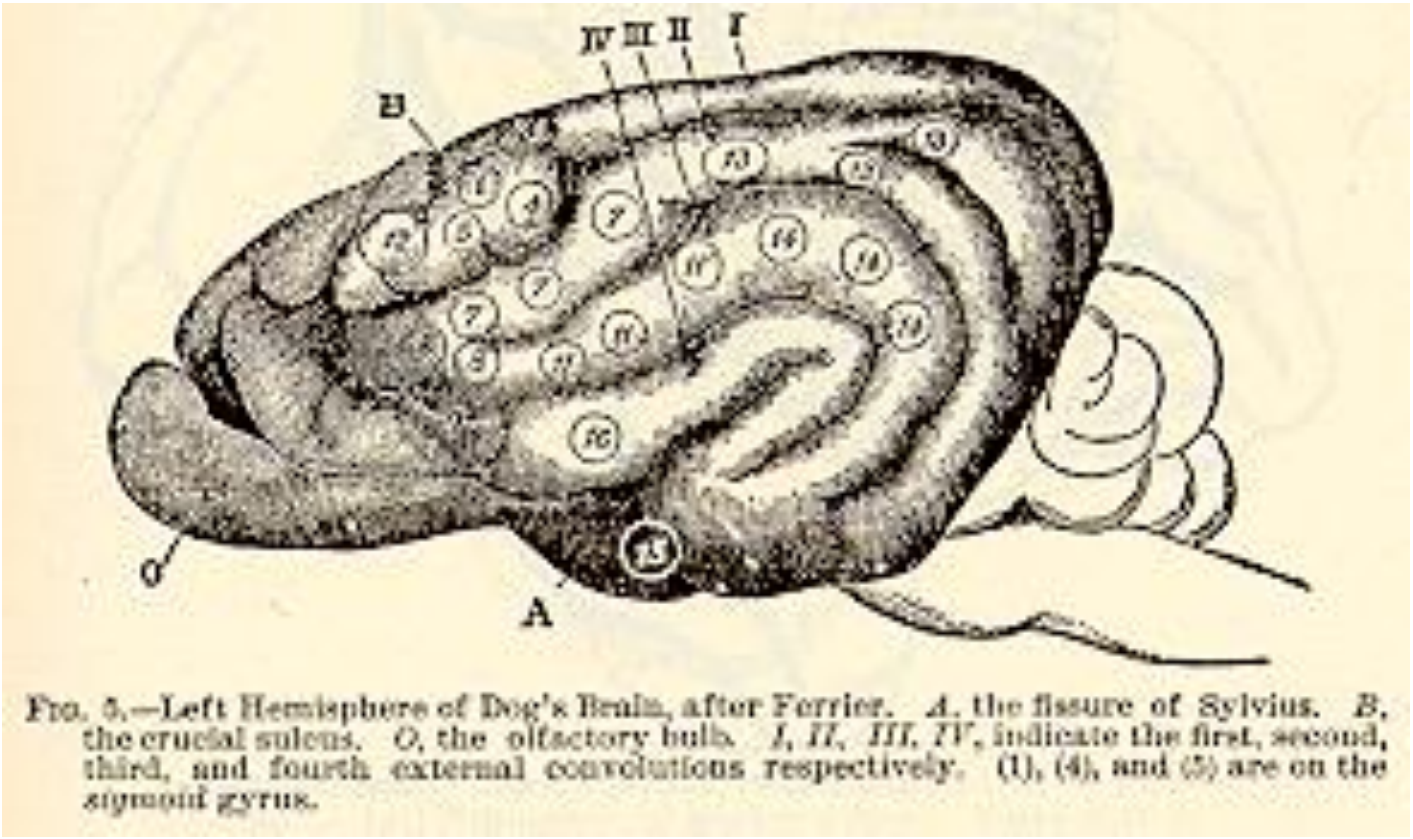
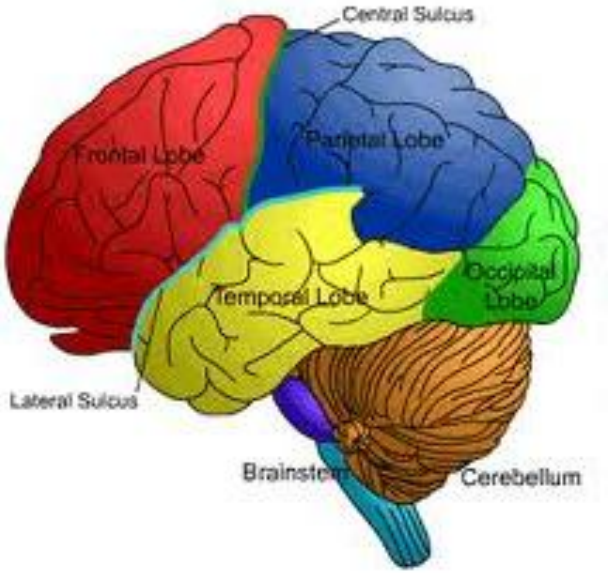


FIG. 5.—Left Hemisphere of Dog's Brain, after Ferrier. *A*, the fissure of Sylvius. *B*, the crucial sulcus. *O*, the olfactory bulb. *I*, *II*, *III*, *IV*, indicate the first, second, third, and fourth external convolutions respectively. (1), (4), and (5) are on the *sigmoid gyrus*.

ASSOCIATING VISION & OCCIPITAL CORTEX



- Munk ablated bilaterally the occipital lobes of dogs and monkeys (1878, 1881)

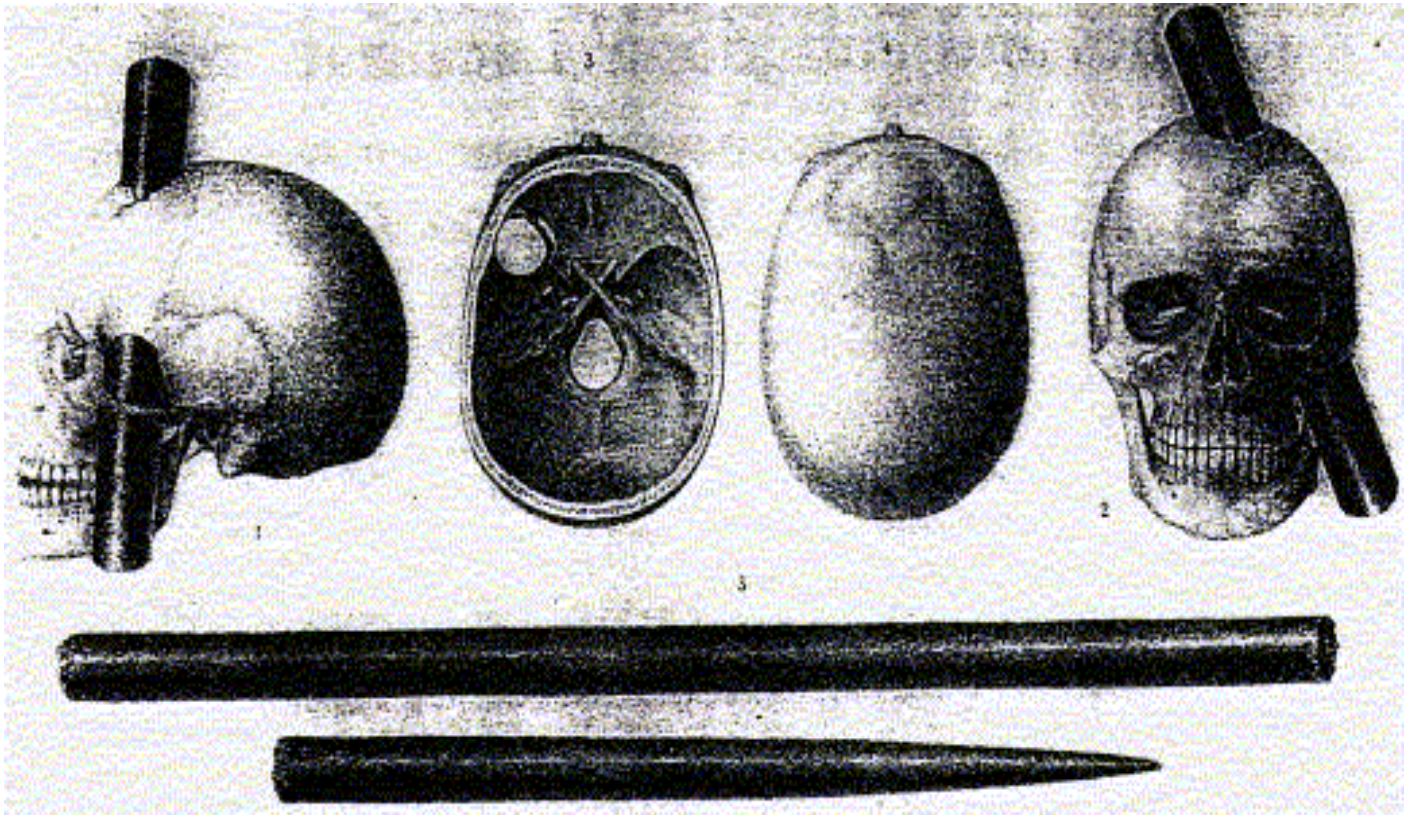
- The ablation produced an impairment of the animals' ability *to recognize objects,* although they were still able to navigate in the environment

THE RIGHT HEMISPHERE

- Hughlings Jackson (1876) first recognized the right hemisphere might have specialized functions of its own

- Based on the clinical observation of a single patient, he argued that whilst the left hemisphere might be “dominant” for language, the right hemisphere was critical for visuo-perceptual abilities

Harlow (1848) Phineas Gage



- This was the beginning of the association between frontal lobes and more abstract intellectual functions

LIMITS OF TRADITIONAL NP

- With a few exceptions, patients were poorly described
- They often suffered from multiple deficits
- Patients were grouped into *syndromes* because they shared symptoms (e.g., patients with Broca's aphasia, Wernicke's aphasia, etc.)
- The psychological concepts and tests available were inadequate
- The techniques were too few

DIAGRAMS

- Between 1870 and 1910, traditional neuropsychologists made a great use of diagrams

- Diagrams were used to explain different forms of language disorder in terms of damage either to the centres themselves or to the pathways connecting them

Lichtheim's Model (1885)

is the best known

A = centre of auditory *representations of words*

B = centre of auditory *representations of words*

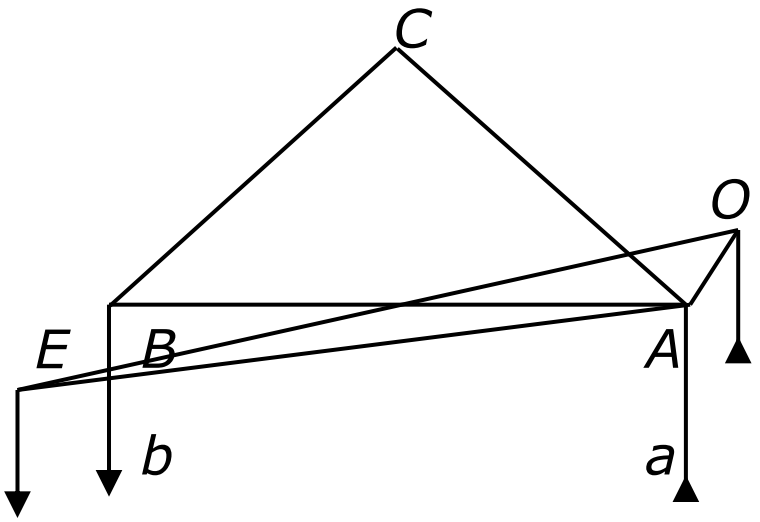
a = *auditory analysis*

b = *articulatory programming*

C = conceptual knowledge

O = *visual engrams* (reading)

E = *hand motor engrams* (spelling)



LIMITS OF DIAGRAMS

- They were only of real use in interpreting disorders that affected comprehension, production, repetition of single words
- They had little to say about:
  - disorders affecting e.g. grammatical processes involved in sentence construction
  - how the centres might actually work
- They were constrained only by neuropsychological evidence and often changed to fit new patterns

COGNITIVE NEUROPSYCHOLOGY

- A revolution occurred when patient-based neuropsychology and cognitive psychology eventually came together.
- The main tenet of cognitive science is that mental activity (i.e. cognition) is information processing.
- By varying stimuli and instructions to the subjects, and by measuring their responses, cognitive scientists make inferences about the information processing that intervenes between stimulus and response (*the black box* of *Behaviorism*).

COGNITIVE NEUROPSYCHOLOGY

- seeks to explain the patterns of impaired and intact cognitive performance seen in brain-injured patients in terms of damage to one or more components of a theory of normal cognitive functioning

- draws conclusions about normal, intact cognitive processes from observed disorders

NEUROIMAGING
(PET, fMRI)

- The fundamental assumption is that to an event corresponds an hemodynamic response

- By measuring these changes we aim at measuring brain functions

fMRI

- *Functional Magnetic Resonance Imaging* (fMRI) by measuring changes in oxygenated blood allows us to infer changes in metabolic activity of different parts of the brain

- Some parts of the brain reliably alter their activity under certain conditions, and scientists have used this fact, along with information drawn from other techniques in both humans and animals, to document which brain area is associated with which cognitive function

GOOD THINGS ABOUT NEUROIMAGING

- Healthy brains (no reorganization after brain damage)
- Whole brain and not region by region
- Fast data collection

CORRELATION, NOT CAUSALITY

- Neuroimaging data are correlational:
  - a given area is activated in response to a particular stimulus or task
  - neuroimaging does not seem to be able to establish whether the activated area(s) plays a causal role in determining the cognitive process at study

INTEGRATIVE NEUROSCIENCE

- Neuropsychology and TMS allow causal explanations

- This is why a successful program in CN is one that combines all these approaches