CHAPTER 3 – EARLY STUDIES OF THE CENTRAL NERVOUS SYSTEM

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Michelangelo’s “The Creation of Adam”

Completed in 1512 – Ceiling of the Vatican’s Sistine Chapel

Is there an image of the human brain surrounding God, as suggested by Meshberger and is God giving life to Intellect?
Sources of Information

- Dissection was prohibited for religious reasons but Michelangelo exchanged his art for the chance to study human anatomy.
  - Other ideas about the location of the mind were speculative not observation-based.

- The wars of the 17th & 18th centuries provided opportunities to observe head and spine injuries.
  - How did heads grin after decapitation on the guillotine?
  - Cabanis concluded all thought depends on the brain.
The Guillotine

Decapitation means cutting the head off. The guillotine was developed to do that efficiently, without error or excess suffering.
Spinal Cord Functions

- Robert Whytt (1714-1766) found that decapitated frogs would respond to a pinch by withdrawing the leg 15 min later.
  - This demonstration of spinal reflexes requires an intact spinal cord.

- Francois Magendie (1795-1855) showed the dorsal and ventral roots have different functions, dorsal controls sensation and ventral controls movement.
  - Bell successfully challenged the priority of Magendie’s discoveries; today this is called the Bell-Magendie law.
Magendie’s reflex arc provided later psychology with the paradigm of stimulus (sensation) and response (reflex) or S-R.
How do specific sensations occur?

- **Charles Bell** (1774-1842) suggested that the nerve imposes sensory specificity regardless of how it is stimulated.
  - Visual sensations can result from stimulation of the optic nerve by light or by pressing the eyeball (with eye shut)

- German physiologist **Johannes Peter Muller** (1801-1858) said the nerves must either communicate different impressions or project to different places in the brain which impose specificity.
  - Now we know different projection areas are involved.
The greatest 19th century physiologist, Helmholtz published definitive works on physiological acoustics and optics and a theory of color vision.

Helmholtz & James Clark Maxwell tested Thomas Young’s theory of trichromatic vision — that 3 distinct kinds of nerve fibers respond to primary colors.

Young-Helmholtz theory of trichromatic vision.

Helmholtz’s research on neural conduction was his most brilliant contribution to physiology.
Trichromatic Color Vision Theory

Opponent-Process Theory

Achromatic System

Chromatic System

Normalized absorbance

Wavelength (nm)

Violet Blue Cyan Green Yellow Red

420 498 534 564
Are nerve impulses electrical?

Galvani showed that natural electrical charges in storm clouds could cause a frog’s muscle to contract. He speculated that there was electricity generated by the brain.

DuBois-Reymond finally measured electrical voltages in the muscle of a frog and later, in his own arm.
Helmholtz Measured Neural Speed

- Helmholtz invented the myograph to trace a muscle contraction on a revolving drum.
- Helmholtz conducted the first reaction time experiments in which human subjects pressed buttons.
  - Reaction times to a sensation on the thigh were faster than on the toe.
  - Speed was 25 meters per second.
  - People rejected his ideas because nerve sensations seem immediate, not delayed.
This led to more questions...

- Is the impulse exclusively electrical or also chemical?
- Do different nerves conduct at different speeds.
  - Do different people’s nerves conduct at different speeds?
- Does the speed of the nerve impulse depend on the intensity of the stimulus.
  - Are nerves equally excitable at all times?
- A great deal of progress was made after this as the brain was studied directly in the 19th century.
Phrenology — a False Start

- Phrenology taught our field a great deal about how to be scientific and how to avoid the pitfalls of pseudoscience.
- Franz Joseph Gall (1758-1828) suggested that personality can be inferred from bodily appearance, especially features of the skull.
  - He noticed that people with protruberant (bulging) eyes tended to have good memories, so he looked for other associations between features and abilities.
  - His observations were compiled into a large catalog.
Well developed powers cause small bumps to appear on the skull; under developed powers cause indentations. Measurement of the skull can reveal strengths and weaknesses.
Johann Caspar Spurzheim (1776-1832)

- Phrenologists like Gall & Spurzheim considered themselves anatomists and scientists.
- Gall’s books were considered deterministic, materialistic and atheistic and placed on the Index of Prohibited Books by the Catholic church.
- After Gall’s death, Spurzheim & George Combe turned phrenology into a cult, giving theatrical demonstrations, ultimately in the USA.
- Ultimately, phrenology became big business.
Criticisms of Phrenology

- Circularity of arguments, e.g., opium produces sleep because it has a soporific (sleep-inducing) tendency.
  - This is a problem with all inductive research.
  - Circular predictions cannot be tested & proved false.
- In 1857, phrenology did stop seeking only corroborative examples and sought contradictory instances, but these were not accepted.
  - “Maybe Descartes [small forebrain] was not so great a thinker as many thought him to be.” Spurzheim said.
  - Magendie replaced Laplace’s brain with an imbecile’s.
Pierre Flourens’ Criticisms

- Flourens was a French surgeon & the foremost brain researcher of the mid-19th century.
- He published “An Examination of Phrenology” in 1843.
- Flourens’ studies showed that the contours of the skull do not correspond to the contours of the brain.
- Phrenologists had located amativeness (lust) to the cerebellum – Flourens found that ablating the cerebellum interferes with motor movements not sex.
Flourens used ablation as a technique to systematically test for localization of function.
- The parts studied should be anatomically distinct.
- He divided the brain into 6 separate areas.

His method was to:
- First observe an animal’s behavior.
- Second remove one of the brain’s units and let the animal heal.
- Third, observe the animal’s behavior again.
Flouren’s Findings with Animals

- The cerebral lobes are the seat of all voluntary actions — only reflexes exist without them.
  - The cerebral lobes are also the seat of perception and higher mental functions such as memory, will, judgment.
- Animals can survive damage to the cerebrum and cerebellum but not to the medulla oblongata.
- His Grand Principle -- the brain is an interconnected, integrated system with a common action.
  - Small areas can recover from damage without loss.
Parts of the Brain

Cerebral lobes
The accidental damage to Phineas Gage provided empirical evidence to show that Flouren’s findings with animals apply to humans too.

After the accident, Gage became fitful, irreverent, profane, impatient of restraint or advice conflicting with his desires, obstinate, unable to plan or make decisions – “no longer Gage.”

Characteristic of people with frontal lobe damage.
Localization of Speech

- First evidence came from impairment after stroke.
- Based on experience with military injuries, Gall identified the regions just behind the eyes.
  - Gall’s student, Bouillaud offered 500 franc challenge.
- Broca’s patient “Tan” seemed to be a disorder of speech without damage behind the eyes.
  - However, Broca’s autopsy showed a lesion to the left frontal lobe in the area specified by Bouillaud and Aubertin (his pupil).
  - Broca named this expressive aphasia “aphemie”
Examples of Expressive Aphasia

- http://www.csun.edu/~vcoao0el/de361/de361s52_folder/expAphasiamov.html
Broca’s Findings

- Pierre-Paul Broca (1824-1880) asserted that this only confirmed that the lesion caused the disorder, not that speech was localized to that region.

- Broca found 25+ more cases with lesions of the left hemisphere but no damage to the right frontal lobe.
  - This puzzled him because it contradicted the law of organic duality.

- Broca’s findings radically changed the debate over the localization of functions in the brain.

- Wernicke identified & localized another aphasia.
Language Centers in the Brain

- Posterior language area
- Meanings of words
- Perceptions and memories
- Broca's area (speech production)
- Wernicke's area (word recognition)
- Meanings of words
Direct Stimulation of the Brain

- First attempts at directly stimulating parts of the brain of animals were crude and often lethal.
- Electrical stimulation was first accomplished by Gustav Fritsch (1839-1927) & Edward Hitzig (1838-1907) to produce motor movements.
  - Stimulation of one hemisphere always produced movement on the opposite side of the body.
- David Ferrier (1843-1928) implanted electrodes and produced precise localization maps of monkeys and later human brains.
Ferrier’s Findings

- Ferrier discovered that representation of the different body parts in the brain is proportional to their function, not body mass.
- He identified the sensory and motor cortical regions.
- His collaborator, John Hughlings-Jackson (1835-1911) studied epileptic seizures.
  - He developed a conceptual model of brain organization involving higher level cortical inhibitory control.
- Both researchers studied animals, not humans.
Roberts Bartholow had a patient with a hole in her skull and used it to stimulate the underlying brain. He replicated the animal findings about localizations. He used too much electricity the second time and caused the patient’s death 4 days later, creating a scandal.

Since then, observations of patients whose brains are exposed for treatment purposes have increased scientific knowledge, resulting in brain maps. Stereotaxic instruments are guided by 3-D coordinates.
Neurons: Golgi versus Cajal

- **Camillo Golgi** (1843-1926) discovered a technique for staining cells that revealed cell structure (cell bodies, dendrites, axons).
  - He proposed that nerve impulses are propagated in a continuous process through networks of interlaced cells.

- **Ramon y Cajal** (1852-1934) disagreed with Golgi, suggesting that neurons were separate and distinct.
  - The nerve impulse must cross a gap between neurons.

- Cajal showed that axons end in terminals.
Staining Made Neurons Visible

Golgi-stained tissue from Monkey cortex

Golgi-stained tissue from human cortex

Cajal-stained embryonic tissue shows the axon terminals

Unstained brain tissue is gray in the cortex and white underneath
Other Attempts at Localization

- Attempts to localize such functions as learning, memory and intelligence were less successful.
- Karl Lashley (1890-1958) spent 30 years unsuccessfully searching for memory engrams, the physical or chemical changes underlying memory.
  - No matter where he lesioned, memory was affected.
  - Recent neuroscience has found such changes.
- Neuroscience still relies on behavioral studies to relate brain functioning to human behavior.