Using Metaphors to Understand the Brain

"The brain, the masterpiece of creation, is almost unknown to us." -- Nicolaus Steno, 1669

Philosophy *of* Neuroscience

- Neuroscience, resulting from the integration of the various disciplines that studied the brain (neuroanatomy, neurophysiology, genetics, etc.), took form in the 1960s
- Philosophy *of* neuroscience studies neuroscience and neuroscientists
  - How do neuroscientists study the brain?
  - What can we learn about brains from organisms with no brains or much simpler brains?
  - What counts as a neuroscientific explanation?
  - Do neuroscientific explanations require reduction to a foundational level? If so, which level?
  - What role do representations play in neural explanations?
  - Does our brain determine who we are?

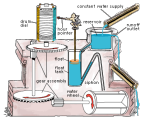
The Human Brain: 3 Pounds of What?

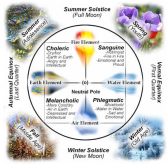
- What does the brain do?
- What are its parts?
- What do they do?
- How are these parts organized?

- To study the brain, scientists need tools
- But equally, they need ideas in terms of which they can describe what they discover
  - In developing ideas for new domains we typically draw on domains we already know
    - Analogies and metaphors are a means to achieve this

Hydraulic Metaphors of the Body

- Grounded in the water technology of the Greeks
  - Water clock
- Applications to physiology
  - Hippocrates--four humors: black bile yellow bile, phlegm, and blood
  - Must be kept in balance
    - Otherwise, disease results
- Galen
  - linked humors to temperaments: sanguine, choleric, melancholic, phlegmatic
  - Nerves: conveyed animal spirits (fine fluid) between tissues dominated by the humors



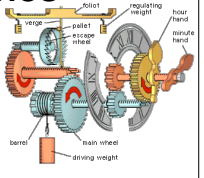


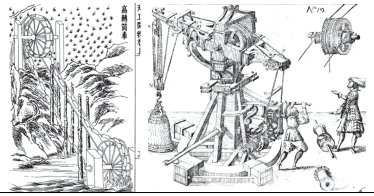
Freud: Continuing the Hydraulic Metaphor

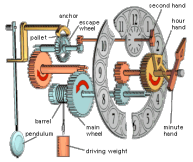
- Initially set out to develop a neural account of mental function, but found it failed to help him understand the conditions of his psychiatric patients
- Psychodynamic accounts of the struggles within the unconscious mind
  - Mind contains desires, some of which are unacceptable
    - These may be repressed, but, like steam pressure, can only be held down so long without exploding
      - must be re-channeled into safe areas

Clocks and Other Early Modern Machines

- Weight driven clocks were developed in the 13th century
- Pendulum clocks appeared in the 17th century
- Practical machines for lifting weights 14th and 17th century

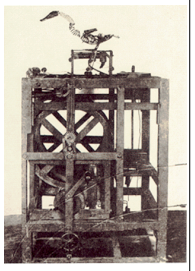


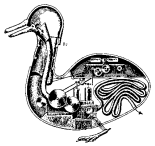




Machines as Models of Organisms

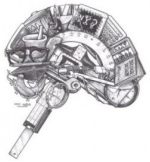
- Jacques de Vaucanson's (1739) mechanical duck, created as an entertainment piece
- Although biological organisms are not composed out of metal parts, the idea that they are machines captivated many biologists
  - Crucial idea that diverse parts, each performing its own operation, work together to achieve the activities of living organisms
  - Example: cells viewed as factories with different organelles performing different tasks





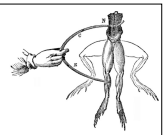
Applying the Machine Metaphor to Thought

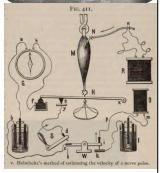
- Hobbes: ideas and associations result from minute mechanical motions in the head
- La Mettrie in *L'Homme machine* (1748):
  - the human body is "a machine that winds its own springs - the living image of perpetual motion ... man is an assemblage of springs that are activated reciprocally by one another."



Electricity, Muscles, and Nerves

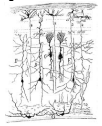
- Electricity at first a curiosity--static electricity generators to shock people
- The ability of electricity to cause muscle contraction played an important role in Galvani's and Volta's pioneering research on electricity in the 1790s
- Researchers such as du Bois Reymond developed the galvanometer to measure electric currents in animals--frogs and humans
- Helmholtz: measured the speed of electrical transmission
- Nerve electricity linked with chemical processes involved in the generation of action potentials at the beginning of 20th century

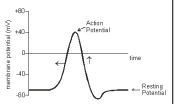




Telegraph and Telephone Metaphors for the Nervous System

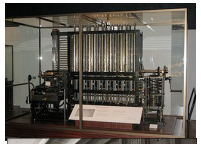
- The first microscopic images of neurons emphasized their axons and dendrites
  - Helmholtz proposed the telegraph metaphor
- A century later, Hodgkin and Huxley borrowed the mathematics developed for signal propagation in wires to model the generation of action potentials
- Telephone switchboard model of brain activity gained currency in the 20th century





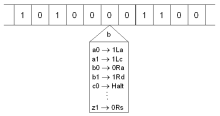
Computation and Thinking

- In the 19th century Charles Babbage designed the difference engine to tabulate polynomial functions (only actually built in the 20th century)
- World War II provided incentives to perform complex calculations quickly, leading to the creation of ENIAC (commissioned in 1946)
  - Soon after von Neumann and others developed computers that employed stored programs



Human as the Model for the Electronic Computer

- The model that Turing employed in developing the idea of computation was the human activity of calculation
- The Turing Machine metaphorically extended the idea of applying rules to symbols on paper to a machine
  - Finite state device reads, applies rules, and writes numbers on a tape
  - The surprising result is that such a device can compute any computable function

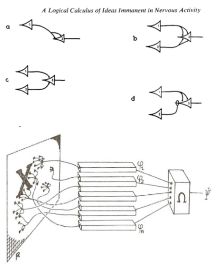


Applying the Computer Model to the Brain

- Boole articulated the idea that thought consists of the application of rules to symbols
  - With the advent of computers in the 1950s, the idea that computers could think became very attractive
- Artificial intelligence developed as a field
  - Newell and Simon's Logic Theorist served as an exemplar
  - Winning the world chess championship became the holy grail.
- While especially prominent in cognitive science, the idea that the brain computes became attractive to parts of neuroscience
  - The idea of a central processor manipulating symbols seems problematic
    - Rather, theorists often view individual brain areas as computing functions

Neural Network Models

- Pitts and McCulloch (1943) proposed that neural networks could implemented logic functions
- They and others soon came to focus on combining information in ways not dependent on logic
  - Rosenblatt's perceptron--connections between inputs and outputs enable generation of output function
    - These connections can be "learned"



Moving Beyond the Electrical and Computer Metaphors?

- Cells: Chemical regulation
  - transcriptional regulation
  - post-translational regulation
- Chemical signaling
  - hormones and peptides
- Sub-threshold electrical oscillations
  - couple activity of neurons with each other
  - resulting in waves of activation through the brain