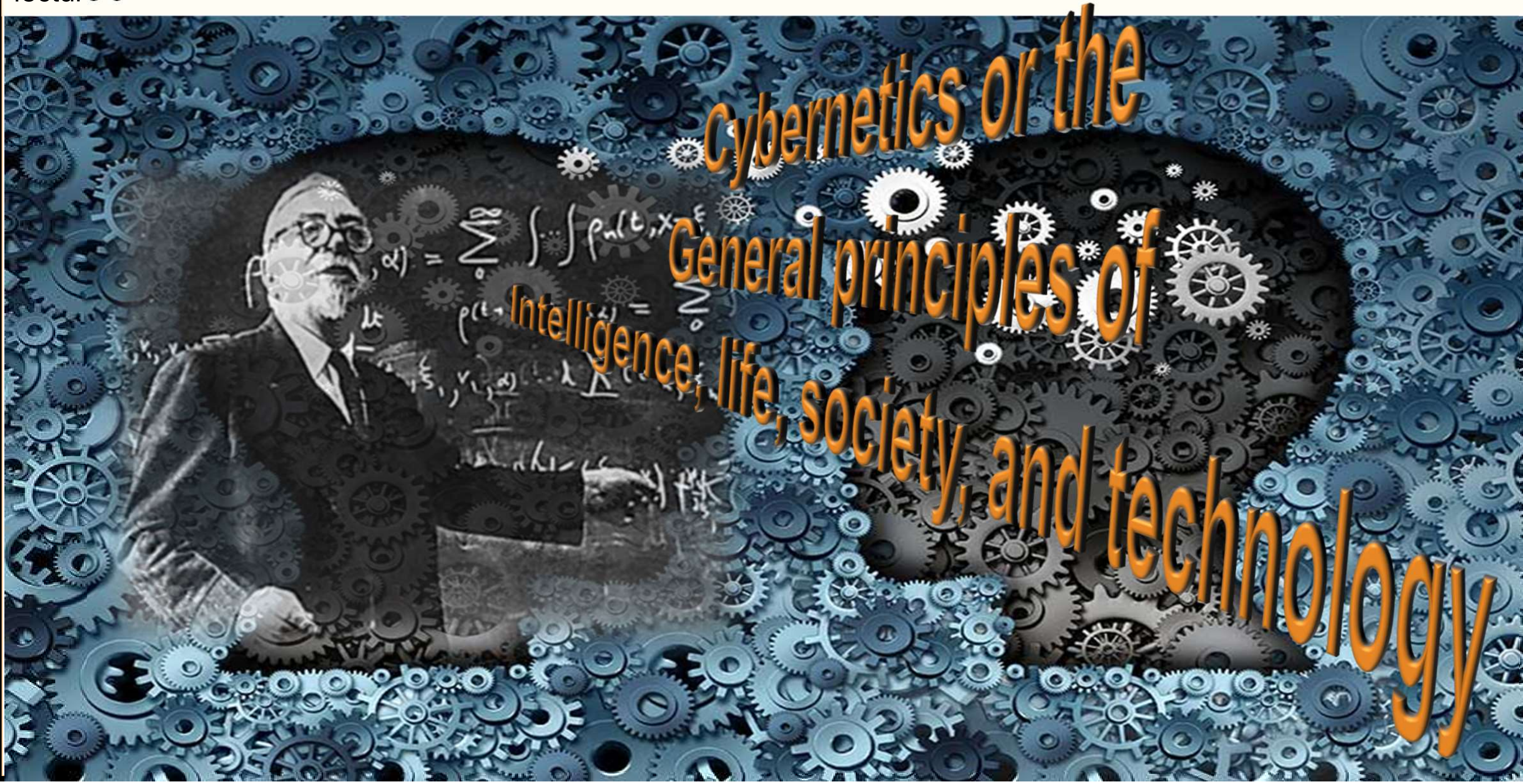
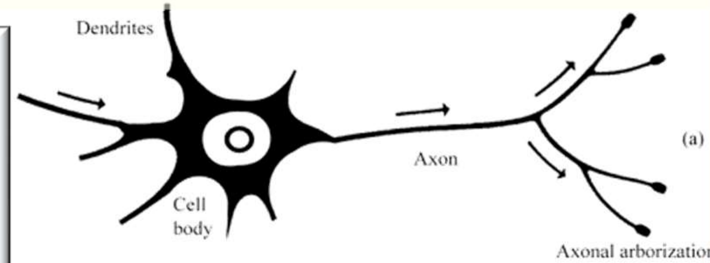
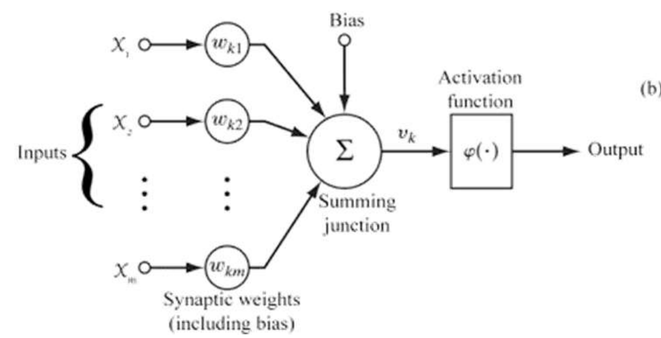
lecture 3

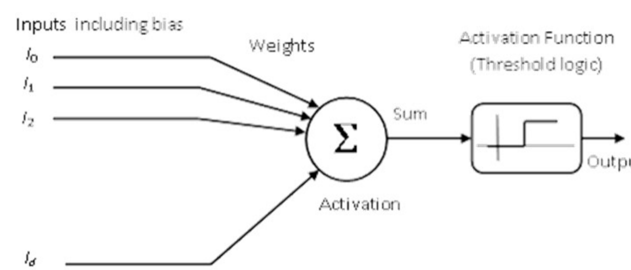

Cybernetics or the
General principles of
Intelligence, life, society, and technology

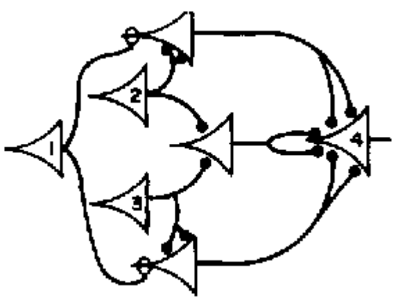
Memory can be maintained in circular networks of binary switches

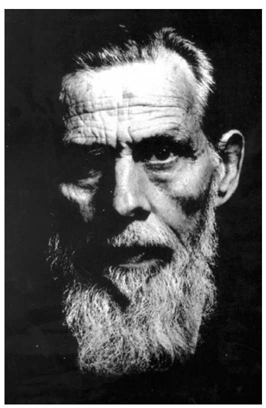
- McCulloch, W. and W. Pitts [1943], "A Logical Calculus of Ideas Immanent in Nervous Activity". *Bulletin of Mathematical Biophysics* **5**:115-133.
  - A Turing machine program could be implemented in a finite network of binary neuron/switches
    - Neurons as basic computing unit of the brain
    - Circularity is essential for memory (closed loops to sustain memory)
  - Brain (mental?) function as computing
- Others at Macy Meeting emphasized other aspects of brain activity
  - Chemical concentrations and field effects (not digital)
    - Ralph Gerard and Fredrik Bremmer











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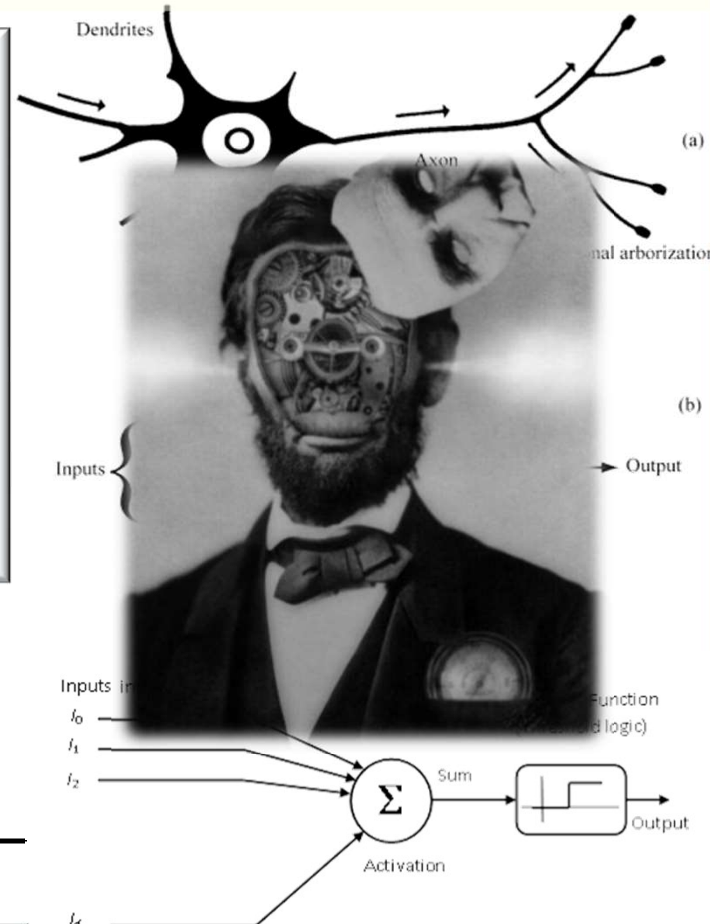

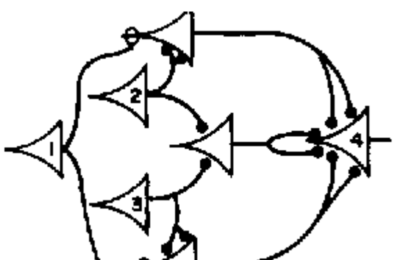

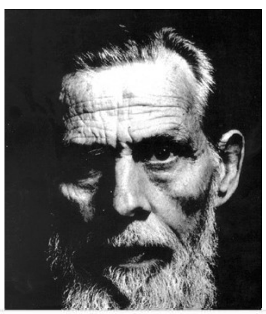

Optional Reading: McCulloch, W. and W. Pitts [1943], "A Logical Calculus of Ideas Immanent in Nervous Activity". *Bulletin of Mathematical Biophysics* **5**:115-133.

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post-war science

- Synthetic approach
  - Engineering-inspired
  - Supremacy of mechanism
- Postwar culture of problem solving
  - Interdisciplinary teams
  - Cross-disciplinary methodology
- All can be axiomatized and computed
  - Mculloch&Pitts' work was major influence
    - "A logical calculus of the ideas immanent in nervous activity". *Bulletin of Mathematical Biophysics* **5**:115-133 (1943).
    - A **Turing machine** (any function) could be implemented with a **network** of **simple binary switches** (if circularity/feedback is present)

Warren S. McCulloch

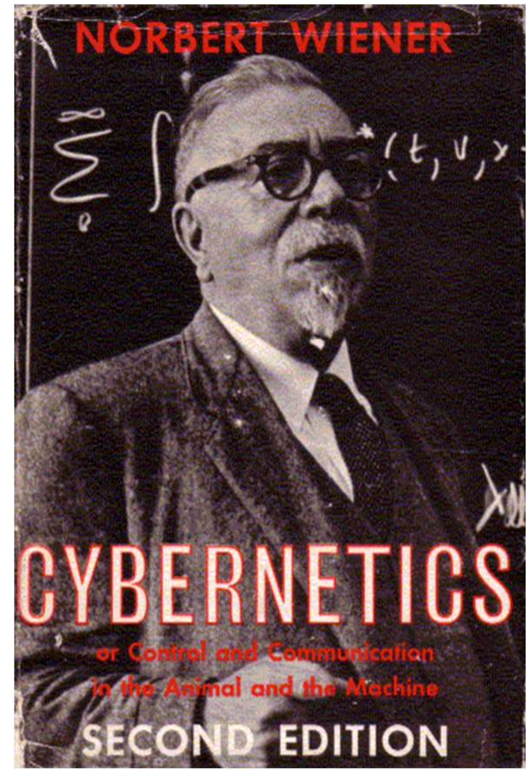
Margaret Mead

Claude Shannon

Heinz Von Foerster

Walter Pitts

Macy Conferences: 1946-**53**



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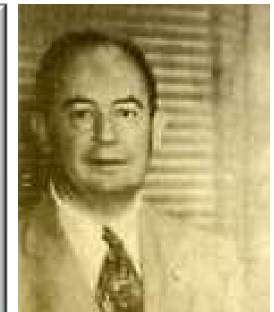
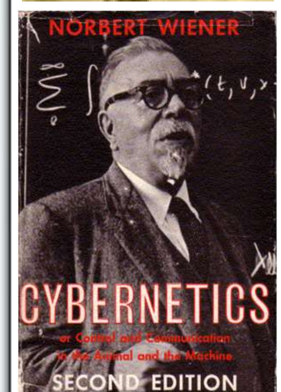
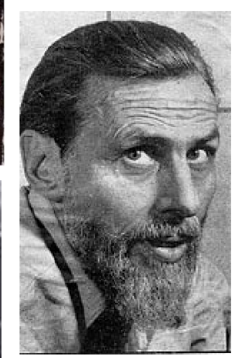
universal computers and general-purpose informatics

- the Josiah Macy Jr. Foundation Meetings
  - post-war science
    - 1946-1953
- Interdisciplinary
  - Since a large class of ordinary phenomena exhibit circular causality, and mathematics is accessible, let's look at them with a war-time team culture
- Participants
  - **John Von Neumann**, Leonard Savage, **Norbert Wiener**, **Arturo Rosenblueth**, Walter Pitts, **Margaret Mead**, Heinz von Foerster, **Warren McCulloch**, **Gregory Bateson**, Claude Shannon, Ross Ashby, etc.
- Key concepts
  - **universal computation** (Turing, Von Neumann), **information** (Shannon, Wiener), **networks** (mcCulloch), homeostasis, **feedback**, complexity, self-organization
  - mind, society, life as general mechanisms

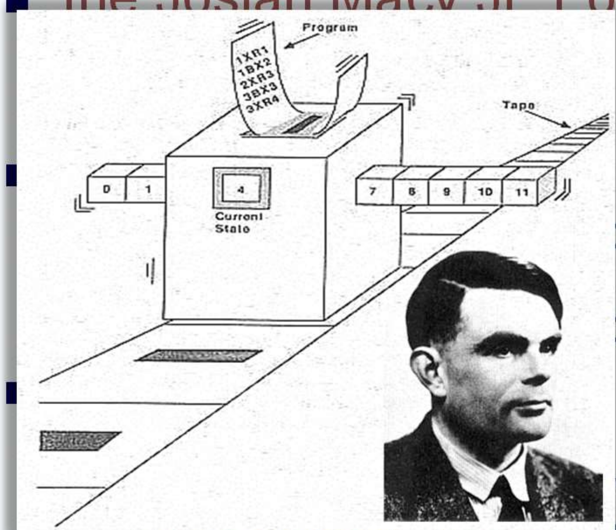


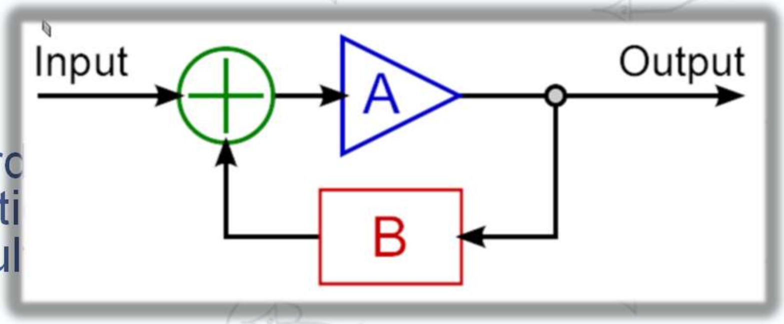




universal computers and general-purpose informatics

- the Josiah Macy Jr. Foundation Meetings





Leonard Savage, **Norbert Wiener**, Walter Pitts, **Margaret Mead**, Heinz von Foerster, **Warren McCulloch**, **Gregory Bateson**, Claude Shannon, Ross Ashby, etc.

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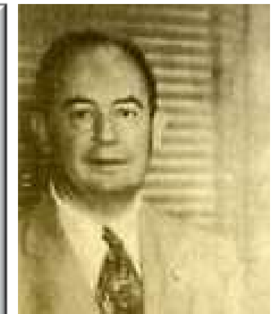
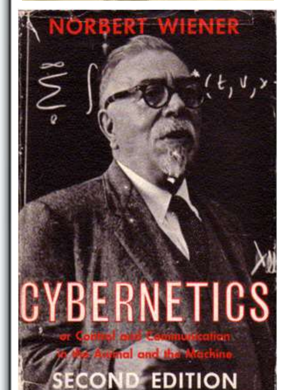
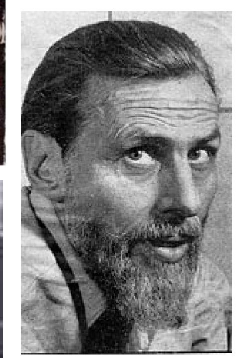
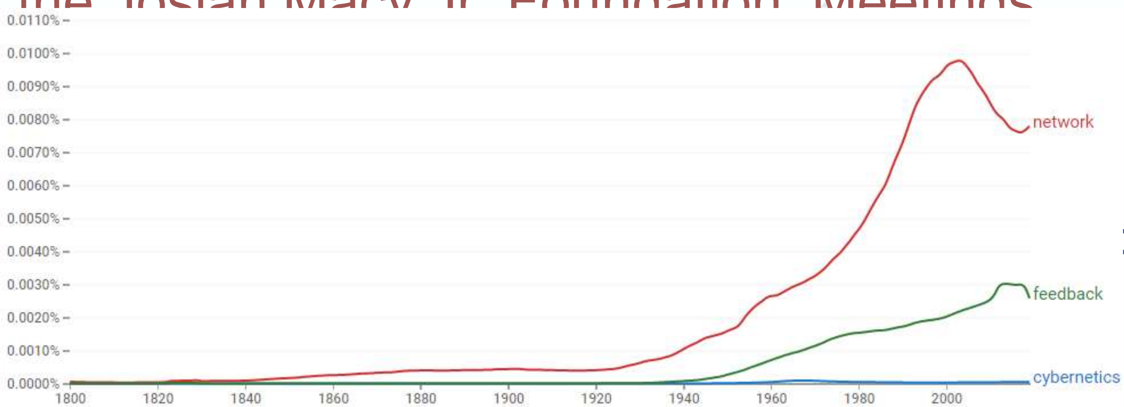






universal computers and general-purpose informatics

- the Josiah Macy Jr. Foundation Meetings



…it circular
…ok at them

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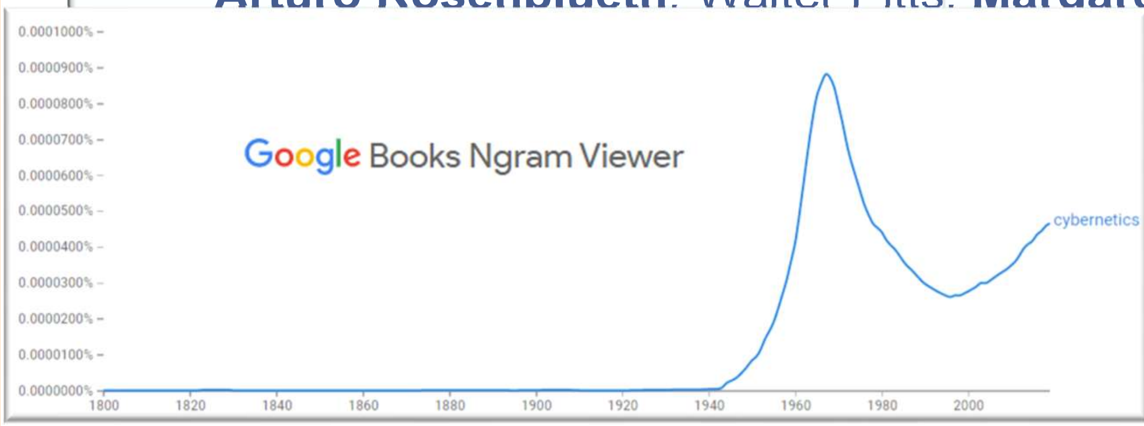
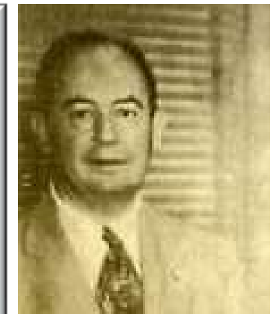
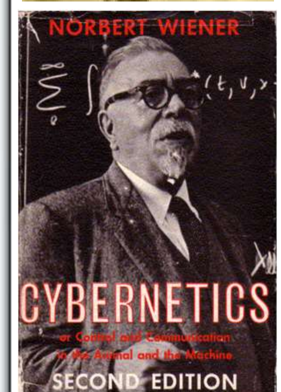
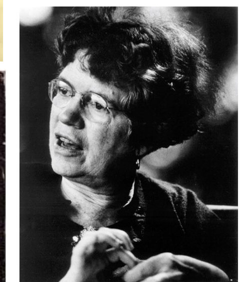
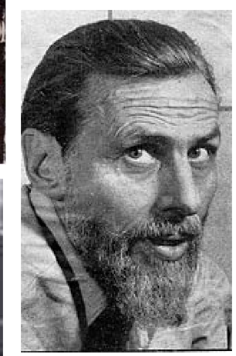


…ann),
…(mcCulloch),
…ganization









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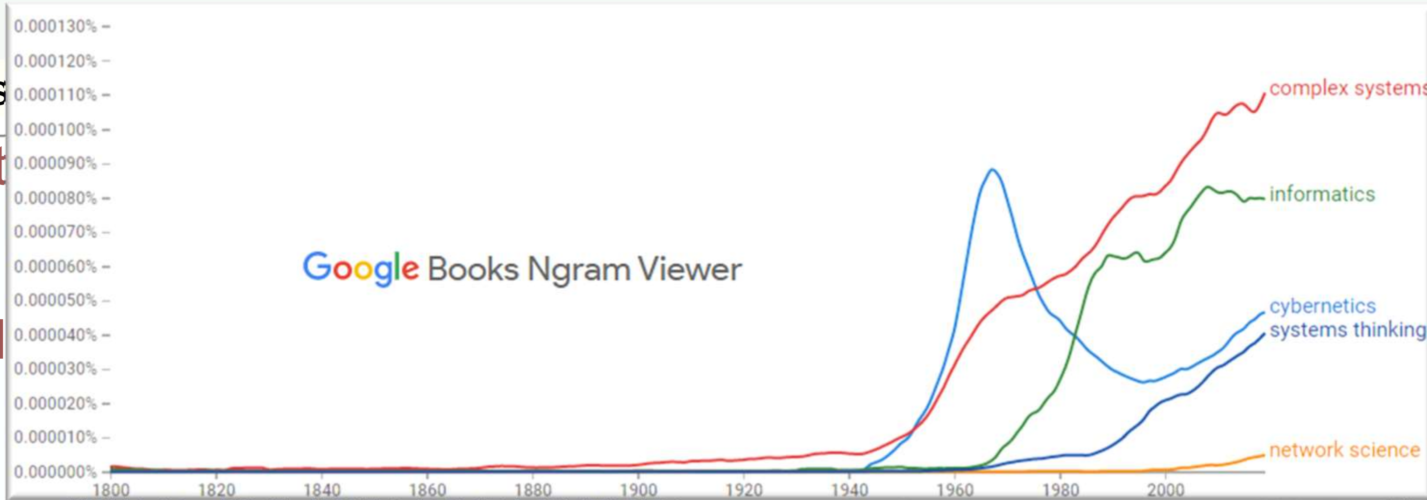
univers



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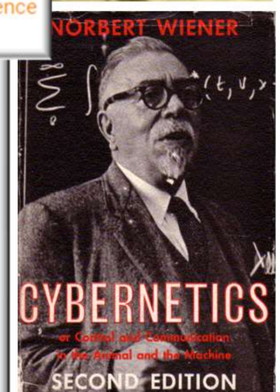

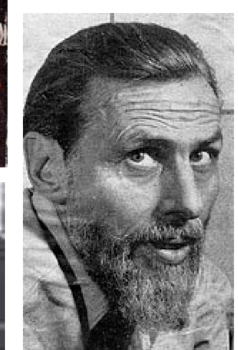

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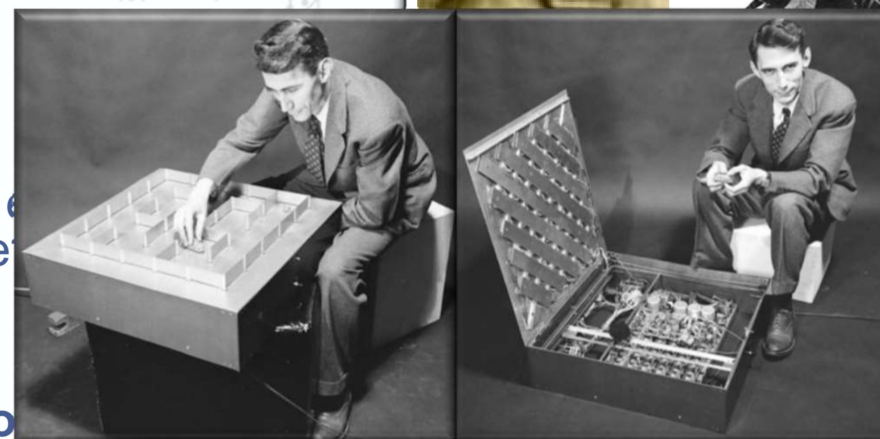

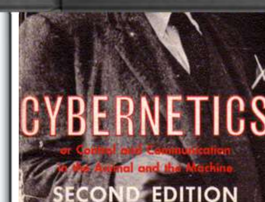

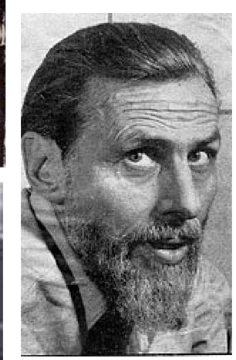

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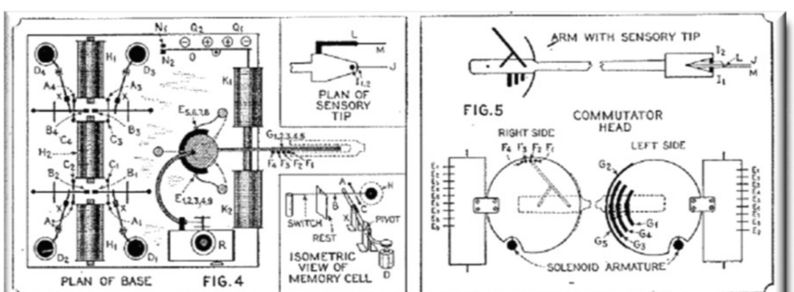
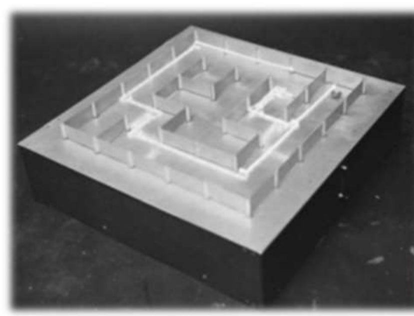
controlling information to achieve life-like behavior

- trial and error algorithm
  - information as reduction of uncertainty in the presence of alternatives (combinatorics)
- lifelike behavior
  - trial and error to **learn** path from many alternatives
  - adapts to new situations
- how is learning achieved?
  - Correct choices, **information** gained from reduced uncertainty, must be **stored in memory**
- **memory of information** as a design principle of intelligence in uncertain environments
  - 75 bit memory
  - stored in (telephone) switching relays
    - Brain as (switching) machine



Details of the various parts of the "memory cells" and actuating mechanisms



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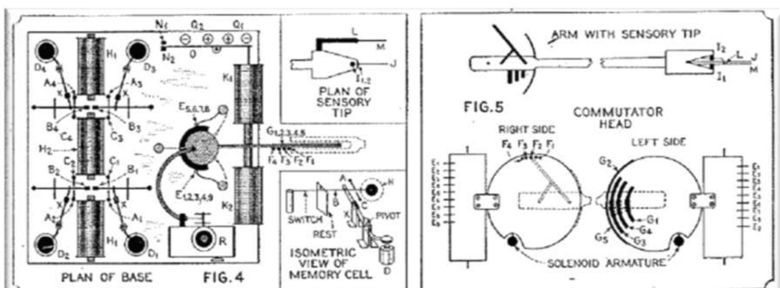
controlling information to achieve life-like behavior



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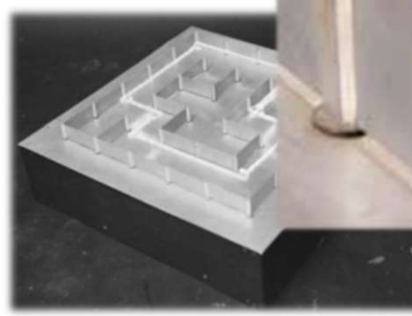

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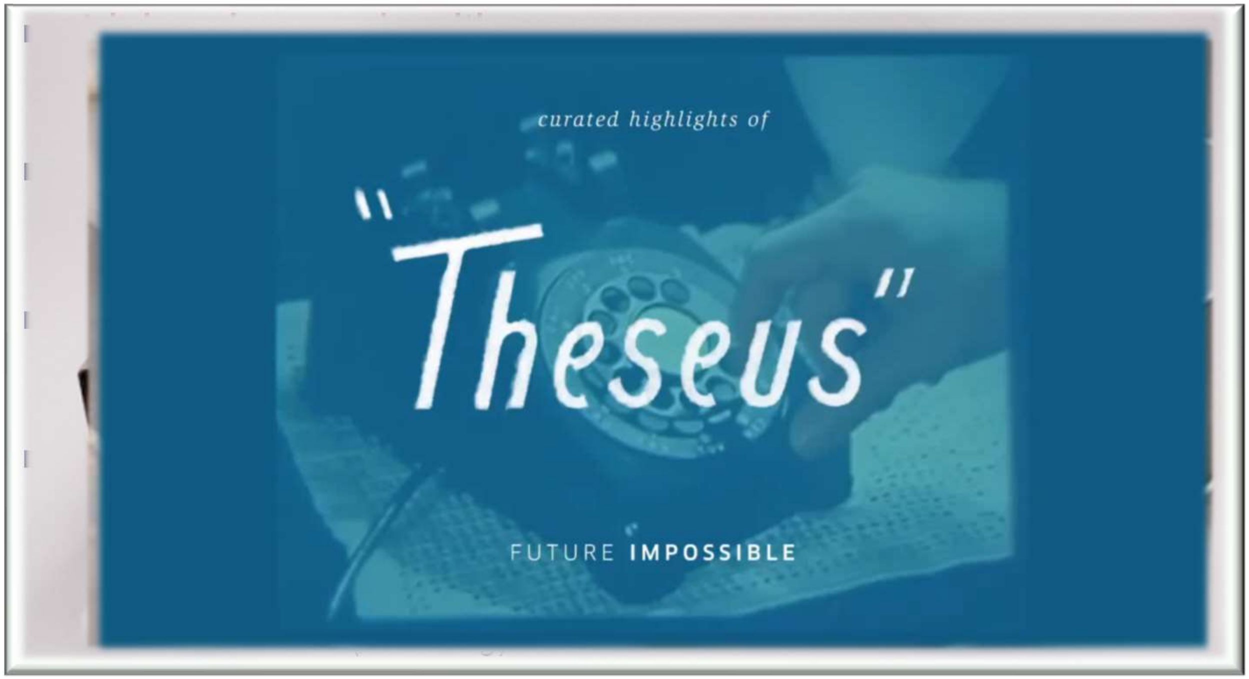

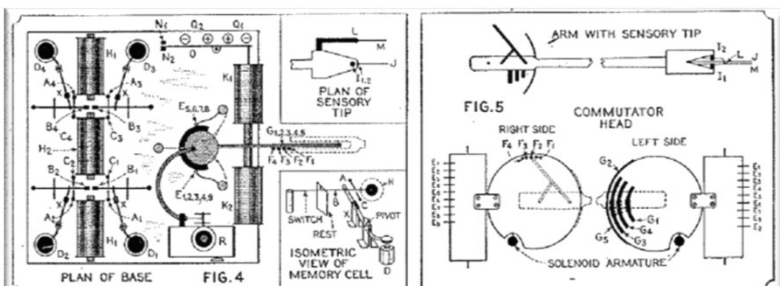

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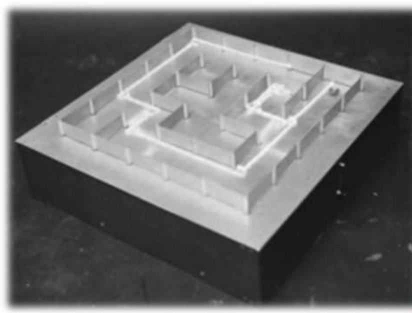

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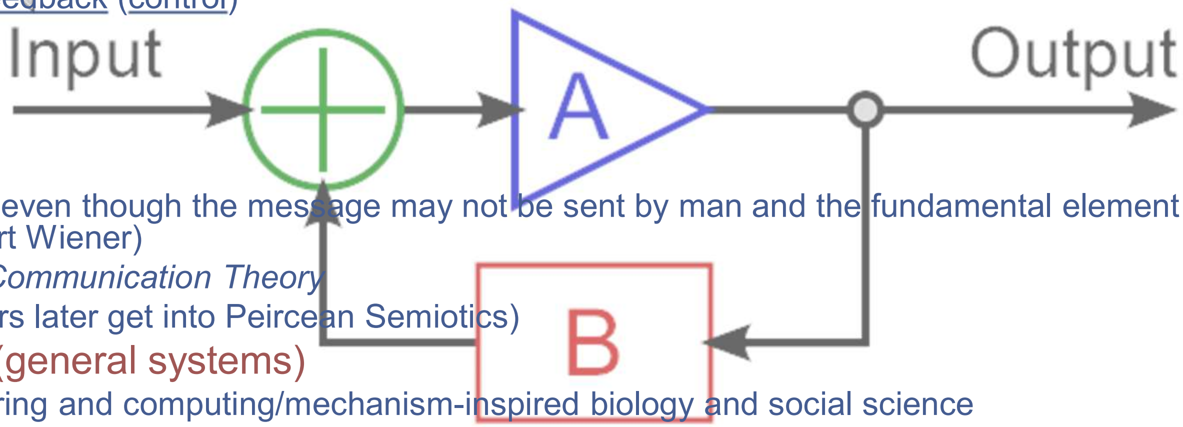
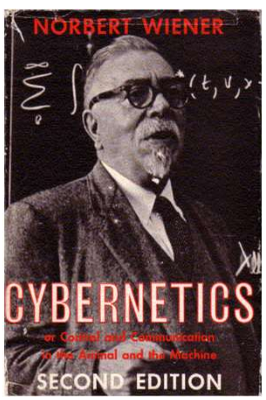
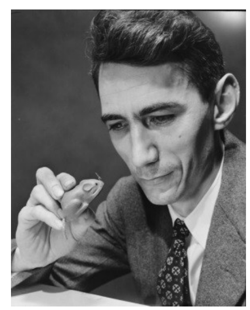
other key concepts

at the Macy meetings

- Norbert Wiener and Arturo Rosenblueth
  - Goal-directed behavior and negative feedback (control)
  - Homeostasis and circular causality
    - In machines and biology
- Automata Theory (Von Neumann)
- Communication and Information
  - The fundamental idea is the message, even though the message may not be sent by man and the fundamental element of the message is the decision" (Norbert Wiener)
  - *Shannon's Information and Wiener's Communication Theory*
  - Natural semiotics (McCulloch and others later get into Peircean Semiotics)
- "functional equivalence" of systems (general systems)
  - Bio-inspired mathematics and engineering and computing/mechanism-inspired biology and social science







at the Macy meetings

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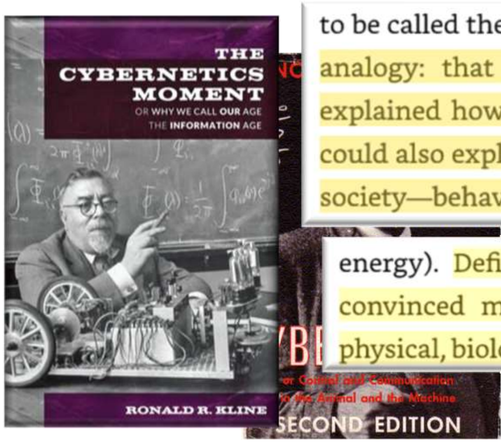
Input

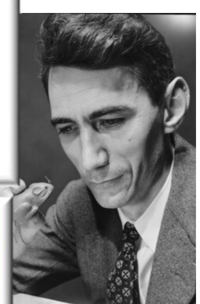
B

and, sometimes, for creating the theory of information based on this concept. The attributions "Shannon-Wiener" or "Wiener-Shannon" are common in these accounts.[8] John von Neumann, who knew both men, disputed this pedigree by noting that a physicist, Leo Szilard, had equated information with entropy in the 1920s.[9] Many commentators acknowledge that Shannon drew on Wiener's statistical theory of communication, as Shannon himself stated in the 1948 paper, but credit Shannon with founding the discipline of information theory because of how extensively he mapped out the subject in that paper.[10] Some American information theorists went further and

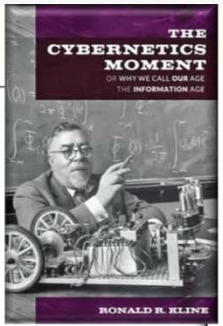


to be called the information age. The premise of cybernetics was a powerful analogy: that the principles of information-feedback machines, which explained how a thermostat controlled a household furnace, for example, could also explain how all living things—from the level of the cell to that of society—behaved as they interacted with their environment.

energy). Defining information in terms of one of the pillars of physics convinced many researchers that information theory could bridge the physical, biological, and social sciences. The allure of cybernetics rested on its

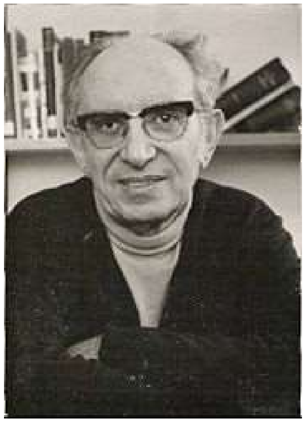


at the Macy meetings



- **Gregory Bateson and Margaret Mead**
  - Homeostasis and circular causality in society
    - Transvestite ceremony to diffuse aggressive action in Iatmul culture
  - Learning and evolution
    - Can a computer learn to learn?
  - A new organizing principle for the social sciences (control and communication)
    - As much as evolution was for Biology
- **Lawrence Frank**
  - The new interdisciplinary concepts needed a new kind of language
    - Higher generality than what is used in single topic disciplines
    - A call for a science of systems
- **Yehoshua Bar-Hillel**
  - Optimism of a new (cybernetics and information) age
    - "A new synthesis […] was destined to open new vistas on everything human to help solve many of the disturbing open problems concerning man and humanity".


Gregory Bateson & Margaret Mead

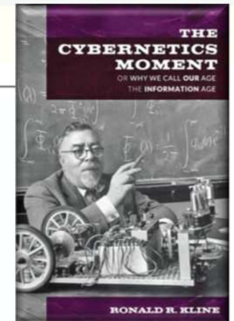


Optional Reading: Heims, S.G. [1991]. *The Cybernetics Group*. MIT Press. Chapters: 11 and 12.

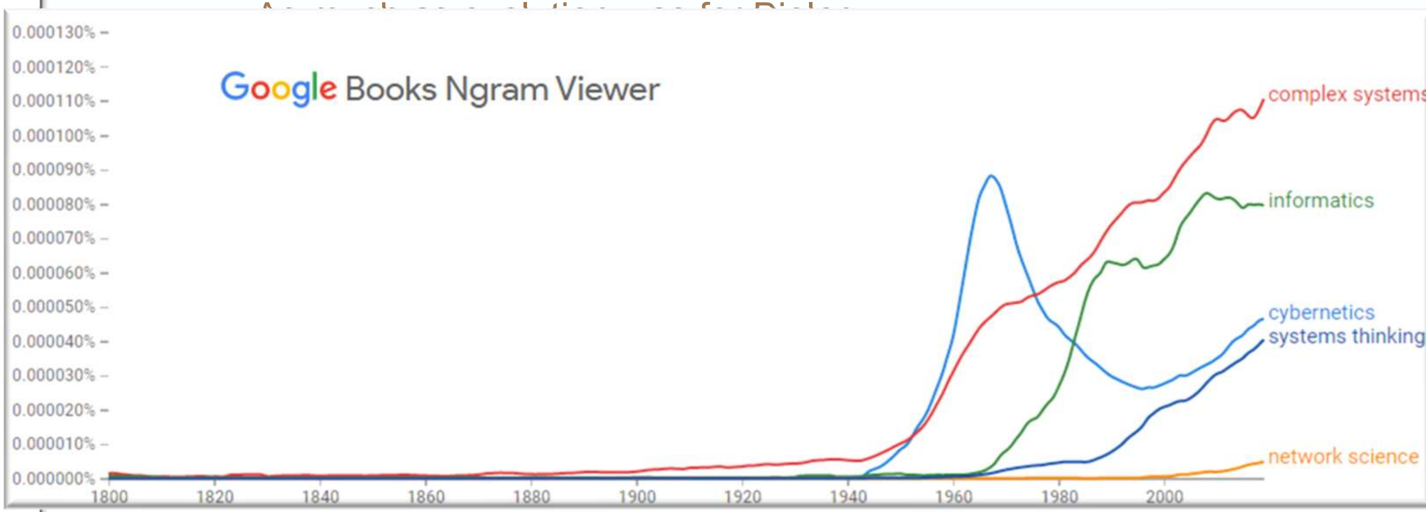
at the Macy meetings

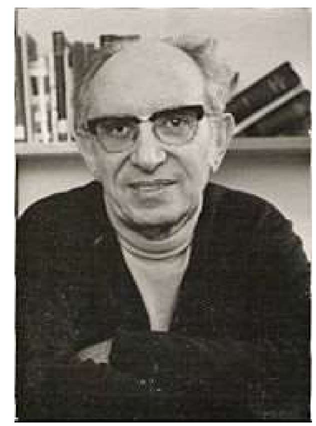
- Gregory Bateson and Margaret Mead

thrived when the cybernetics moment ended. In adopting the language and concepts of cybernetics and information theory, scientists turned the metaphor of information into the matter-of-fact description of what is processed, stored, and retrieved in physical, biological, and social systems. Engineers used the theories to invent



Kline, Ronald R. *The cybernetics moment: Or why we call our age the information age*. JHU Press, 2015. Chapters 1-2.





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Turing as cybernetician

- The Ratio Club (starting in1949)
  - British cybernetics meetings
    - William Ross Ashby, W. Grey Walter, Alan Turing. etc
  - "computation or the faculty of mind which calculates, plans and reasons"
  - Also following Wiener's use of "*Machina ratiocinatrix*" in Cybernetics (1948), following Leibniz' "*calculus ratiocinator*"

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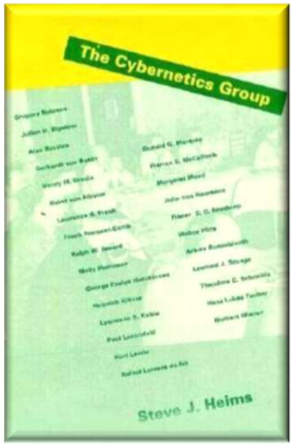
Notes: Back row (from the left): Harold Shipton, John Bates, William Hick, John Pringle, Donald Sholl, John Westcott, and Donald Mackay; middle row: Giles Brindley (guest), Turner McLardy, Ross Ashby, Thomas Gold, and Albert Uttley; front row: Alan Turing, Gurney Sutton (guest), William Rushton, George Dawson, and Horace Barlow
Source: Image courtesy of the Wellcome Library for the History and Understanding of Medicine, London

information as its own thing, functional equivalence of mechanisms, and modelling



Heims, S.G. [1991]. *The Cybernetics Group*. MIT Press.

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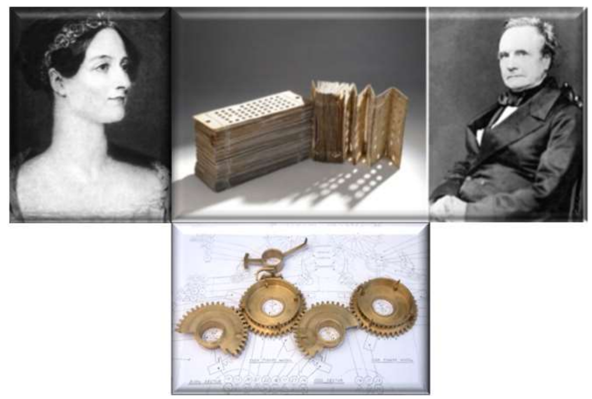
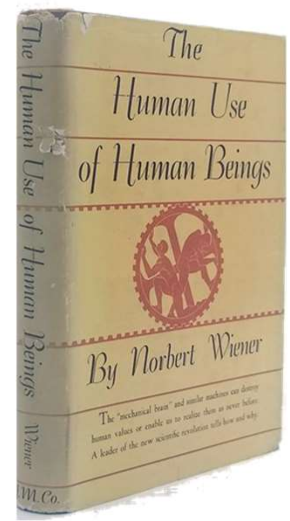
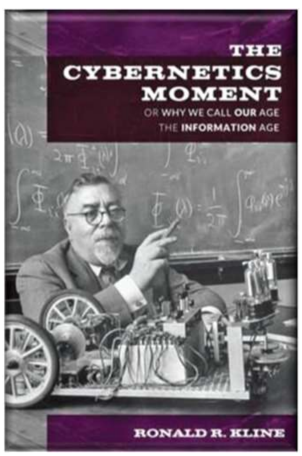
rmation: A History, a Theory, a Flood. Random House.



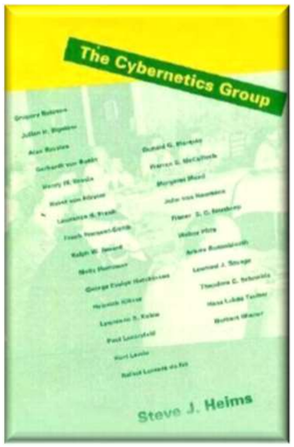


"Information is information, not matter or energy. No materialism which does not admit this can survive at the present day." That is, the amount of information was related to a choice among messages (a pattern), not to the material basis or the energy involved in its communication. In discussing the societal implications of cybernetics,



Kline, Ronald R. *The cybernetics moment: Or why we call our age the information age*. JHU Press, 2015.

information as its own thing, functional equivalence of mechanisms, and modelling



Theseus illustrates the blurring of boundaries between animals and machines that has fascinated commentators on cybernetics since the 1950s.[59] But the editors of the conference proceedings—von Foerster, Mead, and Teuber—noted a major problem with Shannon's model. Goal-seeking devices such as guided missiles had "intrigued the theorists [of cybernetics] and prompted the construction of such likeable robots as Shannon's electronic rat." Yet the "fascination of watching Shannon's innocent rat negotiate its maze does not derive from any obvious similarity between the machine and a real rat; they are, in fact, rather dissimilar. The mechanism, however, is strikingly similar to the *notions* held by certain learning theorists about rats and about organisms in general." Theseus thus modeled a theory of learning, rather than how real mice learned to run mazes. The editors concluded that the "computing robot provides us with analogues that are helpful as far as they seem to hold, and no less helpful whenever they break down." Empirical studies on nervous systems and social groups were necessary to test the relationships suggested by the models. "Still, the reader will admit that, in some respects, these models are rather convincing facsimiles of organismic or social processes—not of the organism or social group as a whole, but of significant parts [of it]."[60]

Flood. Random House.

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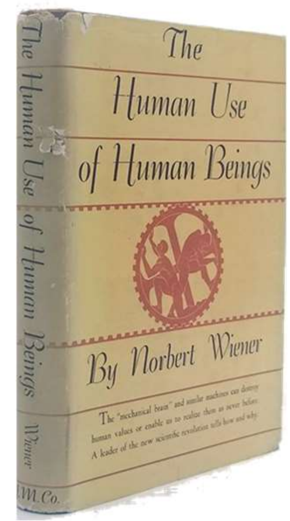

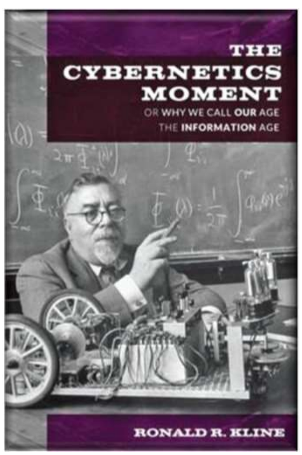

Kline, Ronald R. *The cybernetics moment: Or why we call our age the information age*. JHU Press, 2015.