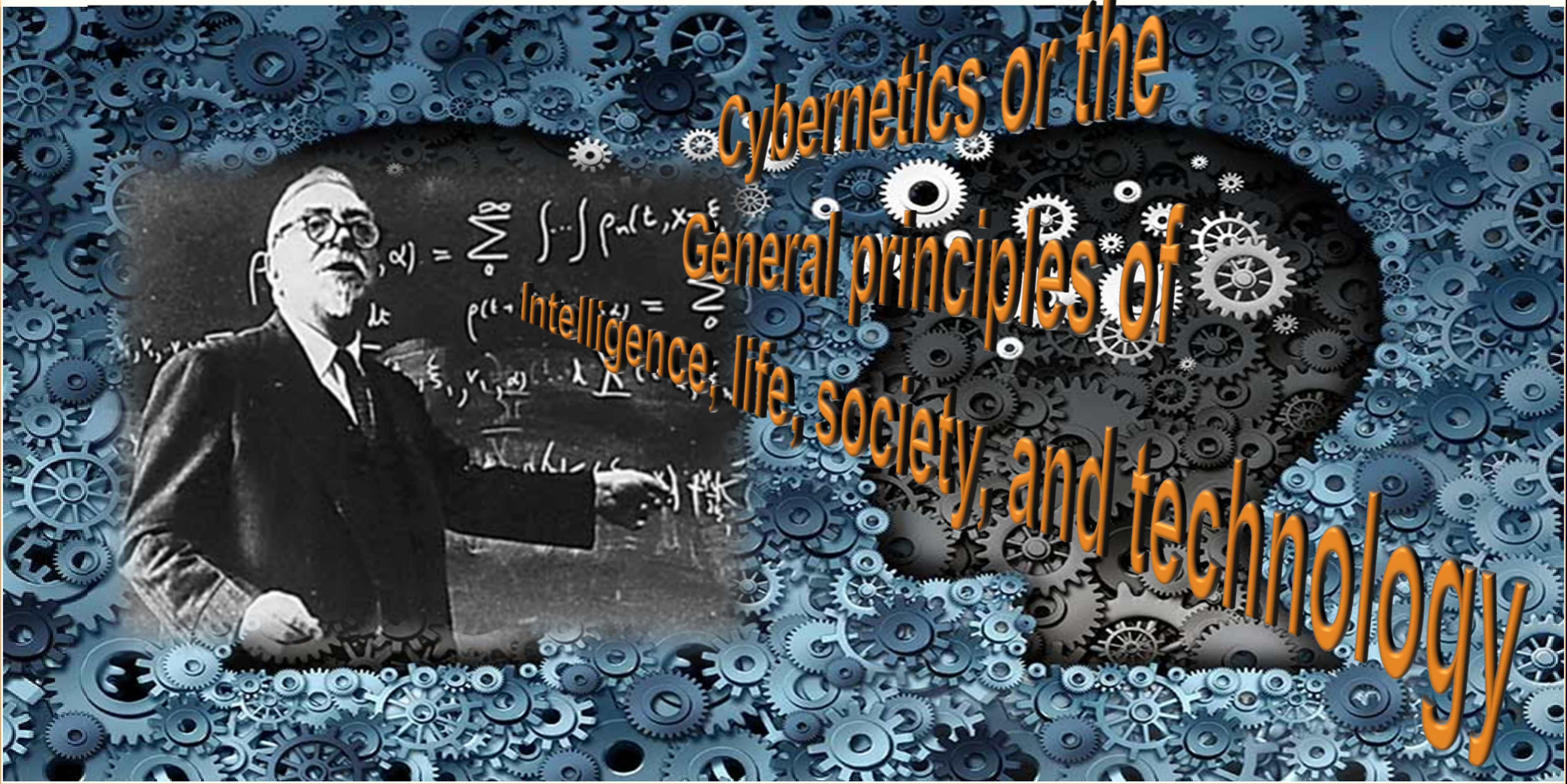
lecture 5


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

evaluation

- Participation: 20%.
  - class discussion, everybody reads and discusses every paper
  - engagement in class, including online
- Paper Presentation and Discussion: 20%
  - All students are assigned to a Reading and Discussion Group
  - **SSIE501** students in group present and discuss papers
    - all students are supposed to read and participate in discussion of every paper.
    - *section 01 groups* present in class, *section 20 groups* present via zoom or send a video
  - Presenter group prepares short summary of assigned paper (15 minutes)
    - no formal presentations or PowerPoint unless figures are indispensable.
  - Summary should:
    - 1) Identify the key goals of the paper (not go in detail over every section)
    - 2) What discussant liked and did not like
    - 3) What authors achieved and did not
    - 4) Any other relevant connections to other class readings and beyond.
  - **ISE440** students in group participate as lead discussants
    - not to present the paper, but to comment on points 2-3) above
  - Class discussion is opened to all
    - lead discussant ensures important paper contributions and failures are addressed
  - Post presentation 1-2 page report uploaded to Brightspace
    - 1-4) plus 5) statement of individual contributions
- Black Box: 60%
  - Group Project (2 parts)
    - Assignment I (25%) and Assignment II (35%)

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more upcoming readings (check brightspace)

- Paper Presentation: 20%
  - Present (501) and lead (501&440) the discussion of an article related to the class materials
  - *section 01* presents in class, *section 20* (Enginet) posts videos on Brightspace (exceptions possible)
- Tuesday, September 12th
  - Reading and Discussion Group 2
    - Savannah Sidoti, Akshay Gangadhar, et al
      - Brenner, Sydney. [2012]. "History of Science. The Revolution in the Life Sciences". *Science* **338** (6113): 1427-8.
      - Brenner, Sydney. [2012]. "Turing centenary: Life's code script. *Nature* **482** (7386) (February 22): 461-461.
      - Cobb, Matthew. [2013]. "1953: When Genes Became 'Information'." *Cell* **153** (3): 503-506.
        - Optional: Searls, David B. [2010]. "The Roots of Bioinformatics". *PLoS Computational Biology* **6**(6): e1000809.
      - Weaver, W. [1948]. "Science and Complexity". *American Scientist*, **36**(4): 536-44. Also available in Klir, G.J. [2001]. *Facets of systems Science*. Springer, pp: 533-540.
- Future Modules
  - See brightspace

more upcoming readings (check brightspace)

- Paper Presentation: 20%
  - Present (501) and lead (501&440) the discussion of an article related to the class materials
  - *section 01* presents in class, *section 20* (Enginet) posts videos on Brightspace (exceptions possible)
- Module 2: Systems Science
  - Reading and Discussion Group 3 (Enginet) - Tuesday or Thursday, September 19/21
    - Sarah Donovan, Nicole Dates, et al:
      - Klir, G.J. [2001]. *Facets of systems Science*. Springer. Chapters 1 and 2.
        - Optional:
        - Rosen, R. [1986]. "Some comments on systems and system theory". *Int. J. of General Systems*, **13**: 1-3. Available in: Klir, G.J. [2001]. *Facets of systems Science*. Springer. pp: 241-243.
        - Wigner, E.P. [1960], "The unreasonable effectiveness of mathematics in the natural sciences". Richard courant lecture in mathematical sciences delivered at New York University, May 11, 1959. *Comm. Pure Appl. Math*, **13**: 1-14.
      - Klir, G.J. [2001]. *Facets of systems Science*. Springer. Chapter 3.
  - Reading and Discussion Group 4
    - Emma Bachyrycz, et al:
      - Klir, G.J. [2001]. *Facets of systems Science*. Springer. Chapter 8.
        - Optional: Klir, G.J. [2001]. *Facets of systems Science*. Springer. Chapter 11
      - Schuster, P. (2016). The end of Moore's law: Living without an exponential increase in the efficiency of computational facilities. *Complexity*. **21**(S1): 6-9. DOI 10.1002/cplx.21824.
      - Von Foerster, H., P. M. Mora and L. W. Amiot [1960]. "Doomsday: Friday, November 13, AD 2026." Science **132**(3436):1291-5.
- Future Modules
  - See brightspace

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more upcoming readings (check brightspace)

- Paper Presentation: 20%
  - Present (501) and lead (501&44
  - *section 01* presents in class, *section 2*
- Module 2: Systems Science
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        - Optional:
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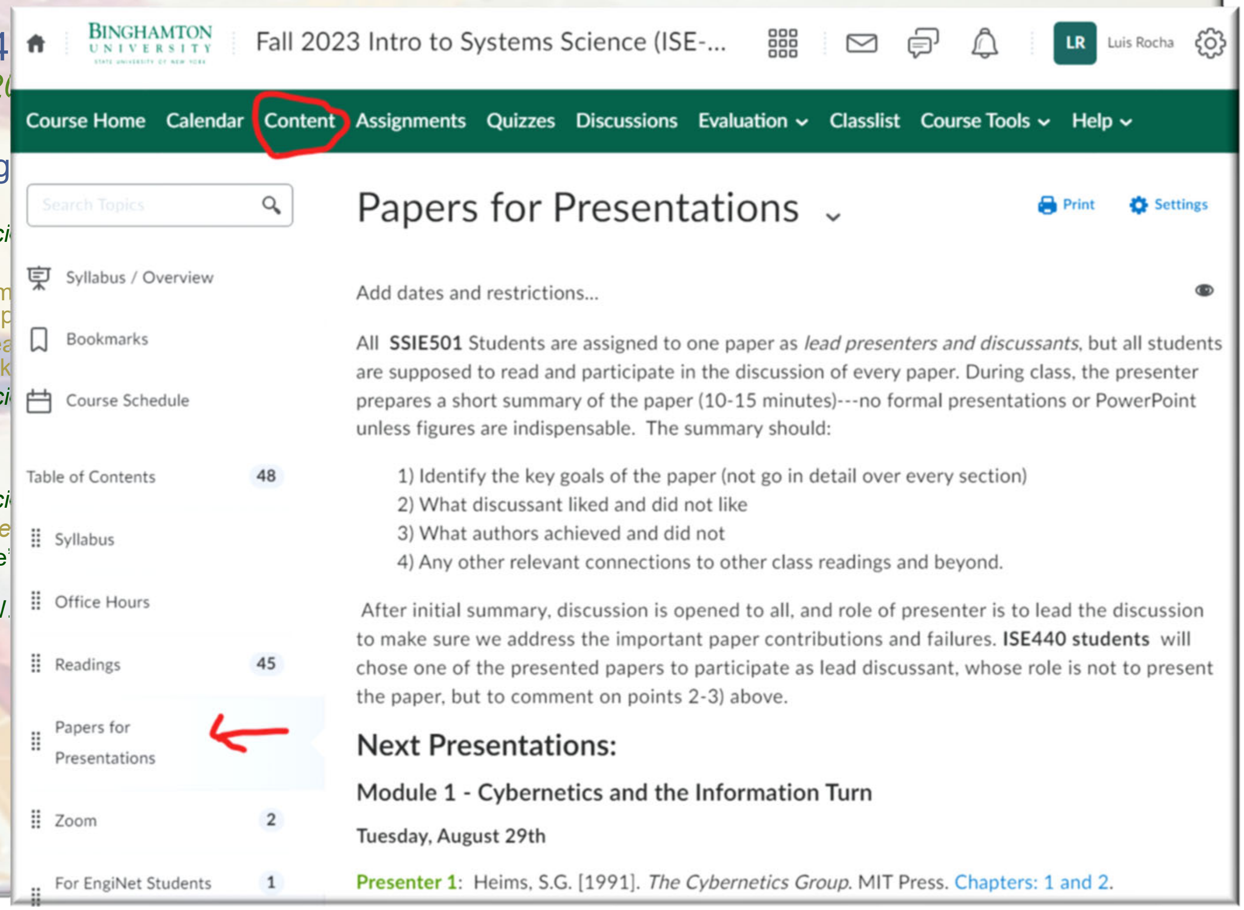
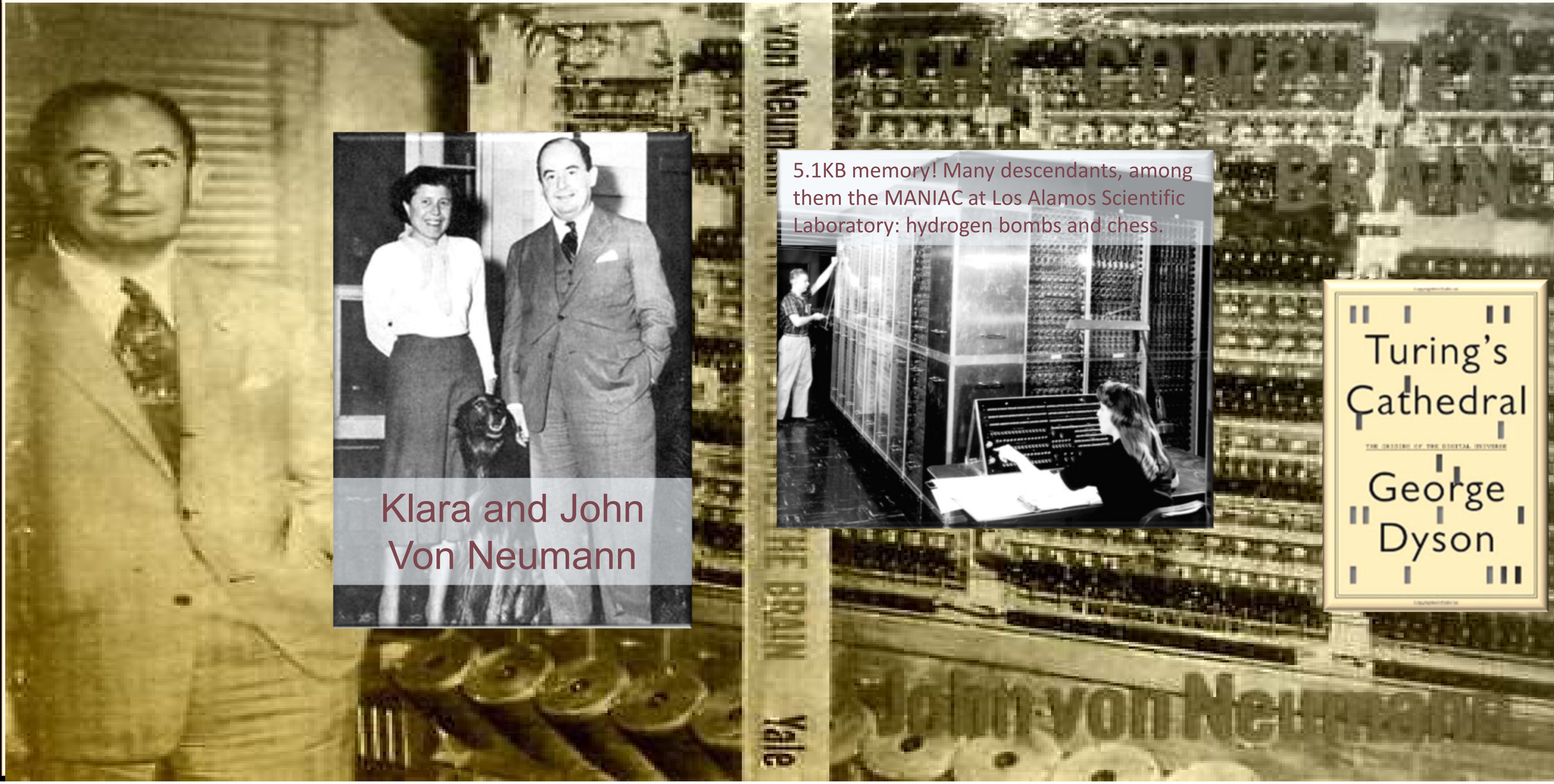


IAS Machine (1952)

electronic digital (stored-program) computer with 40 bit word (IAS, Princeton)



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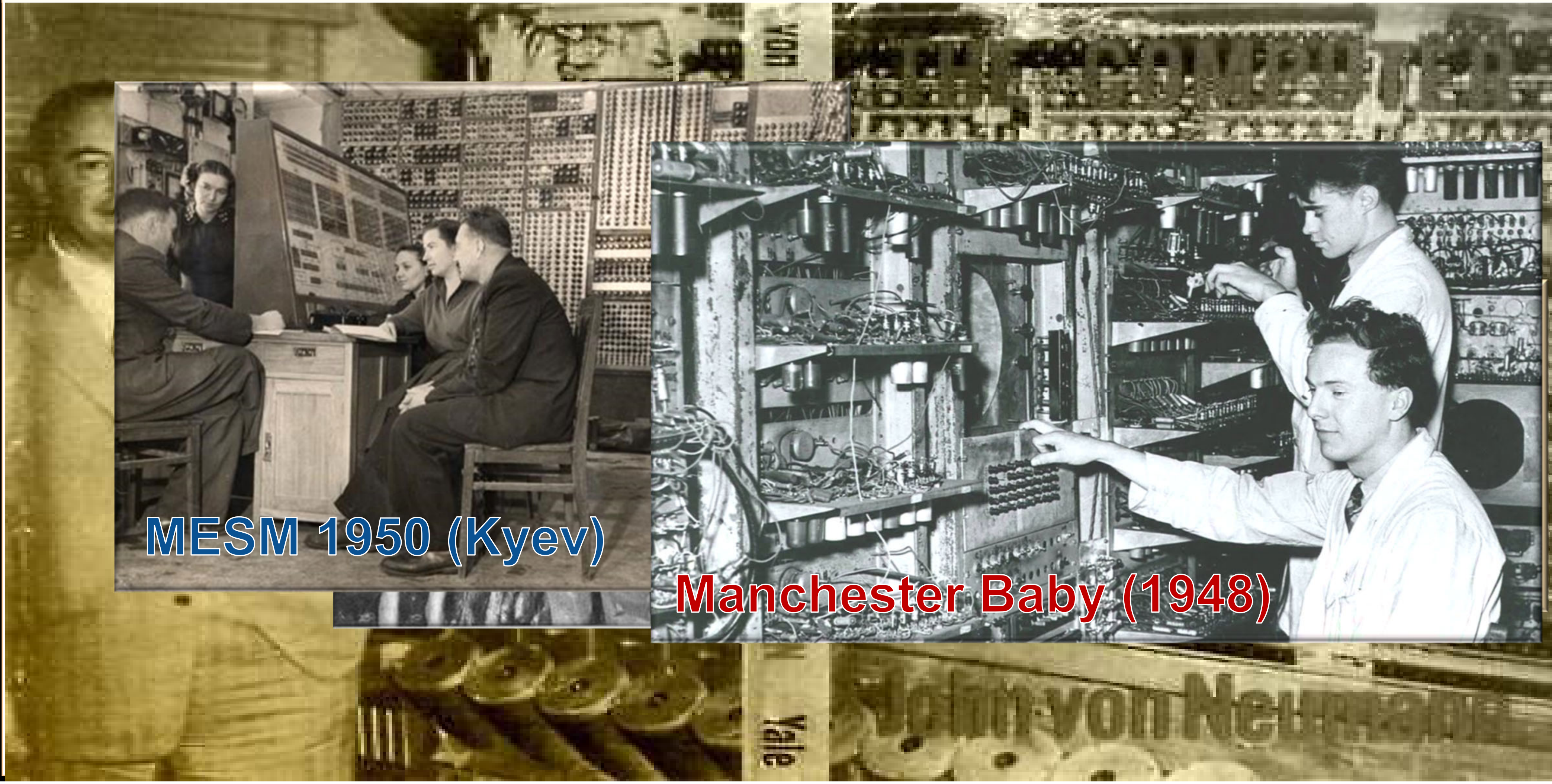
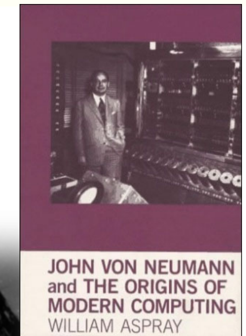
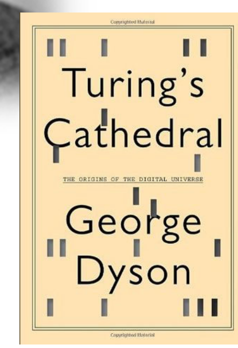


Turing machines beyond the decision problem

" 'Words' coding the orders are handled in the memory just like numbers" --- distinction between *numbers that mean things* and *numbers that do things*.

- realizing the power of Turing's tape
  - physical (electronic) computers
  - emphasized the importance of the ***stored-program computer*** concept (the external tape)
    - EDVAC (1951), IAS Machine (1952) - binary
  - allows machine to modify its own program
    - von Neumann architecture: The functional **separation** of storage from the processing unit.
      - programs can exist as data (two roles)
    - Converts tape to fixed-address memory (random-access memory)
  - Ultimate ***general-purpose*** machines





"Let the whole outside world consist of a long paper tape".
—John von Neumann, 1948

John Von Neumann (1903-1957)

Turing machines beyond the decision problem

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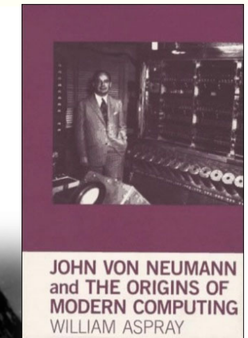
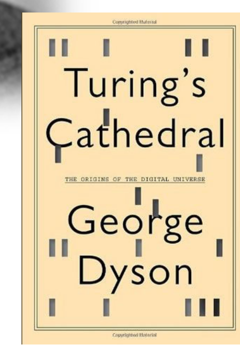
  - ...onal ...sing unit. ...les) ...y
    (random-access memory)
  - Ultimate ***general-purpose*** machines

“Since Babbage’s machine was not electrical, and since all digital computers are in a sense equivalent, we see that this use of electricity cannot be of theoretical importance.… The feature of using electricity is thus seen to be only a very superficial similarity.” (Alan Turing)





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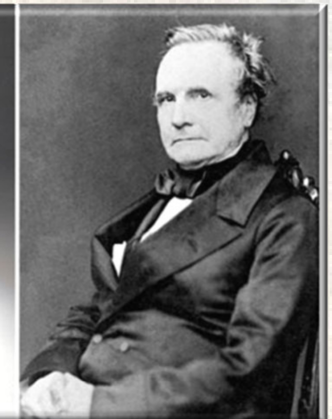
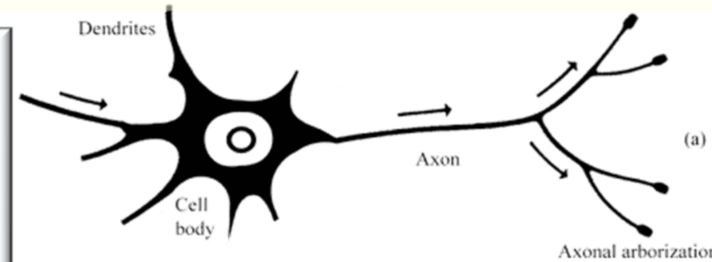
Babbage/Lovelace first to try to build it (before Turing)

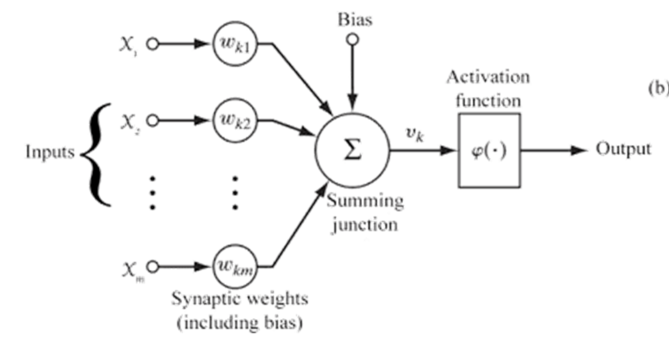


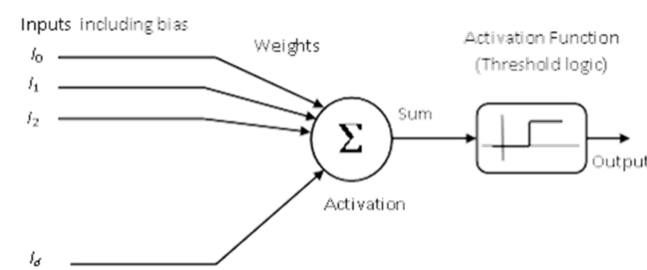
distinction between *numbers that mean things*
and *numbers that (do things) move matter*

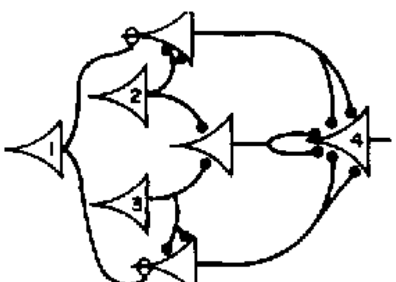
Memory can be maintained in circular networks of binary switches

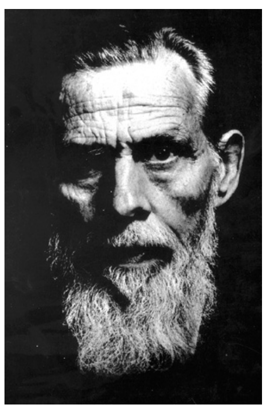
- McCulloch, W. and W. Pitts [1943], "A Logical Calculus of Ideas Immanent in Nervous Activity". *Bulletin of Mathematical Biophysics* **5**:115-133.
  - A Turing machine program could be implemented in a finite network of binary neuron/switches
    - Neurons as basic computing unit of the brain
    - 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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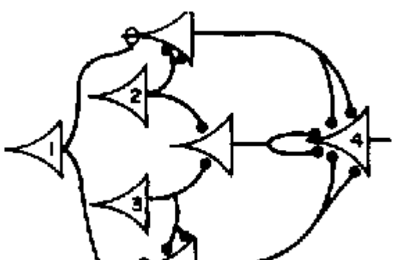

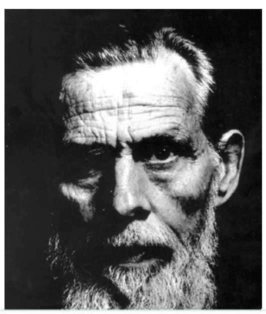

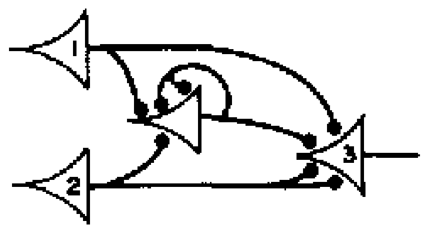

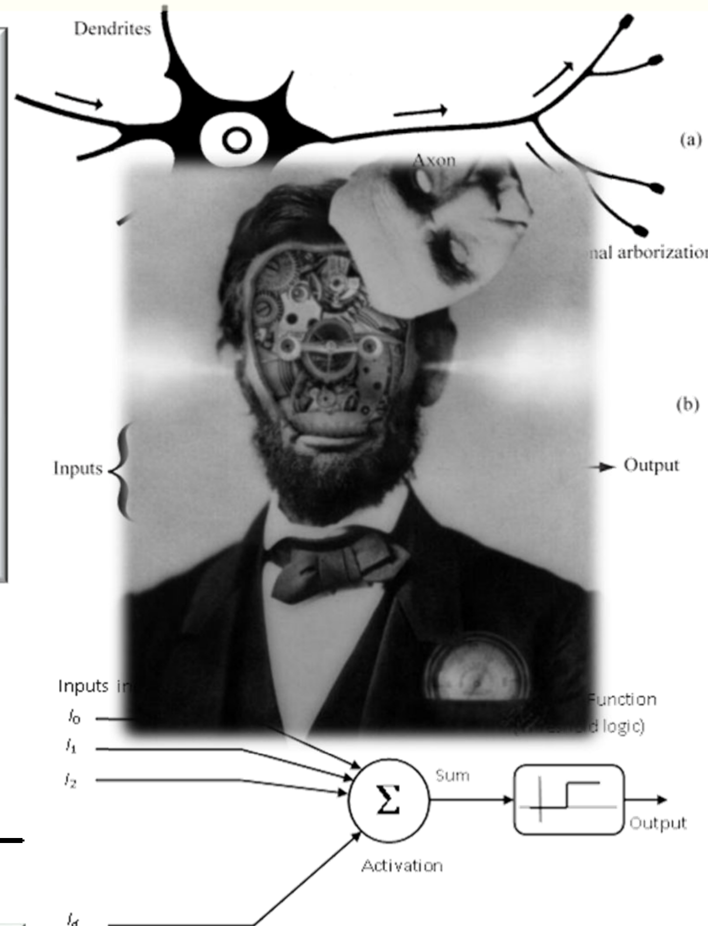

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post-war science

- 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)

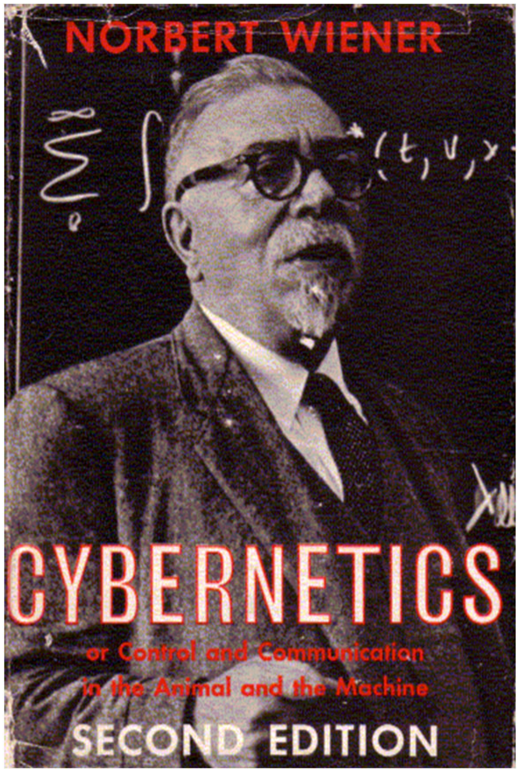
Warren S. McCulloch

Margaret Mead

Claude Shannon

Heinz Von Foerster

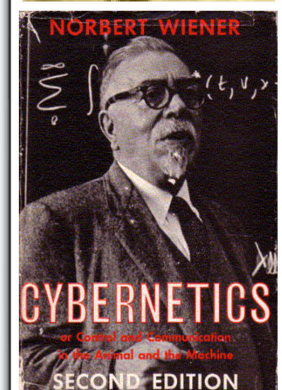
Walter Pitts

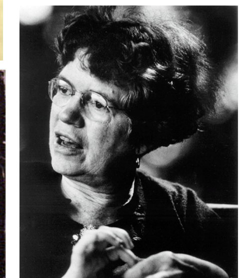


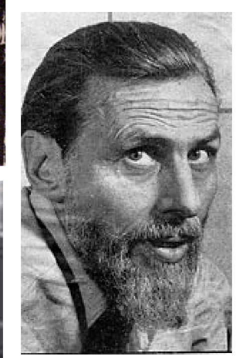
Macy Conferences: 1946-**53**

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

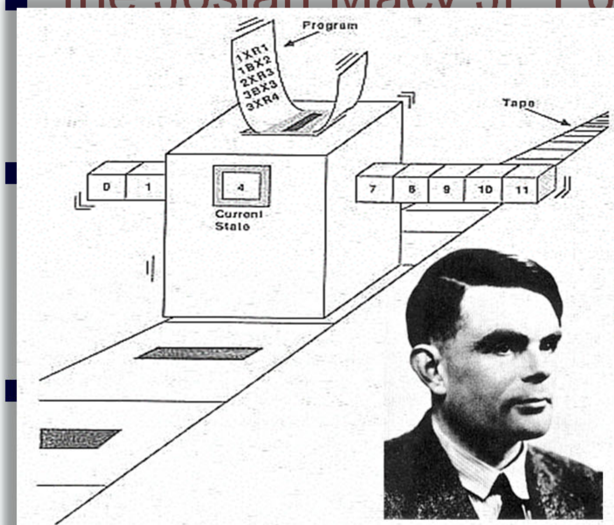


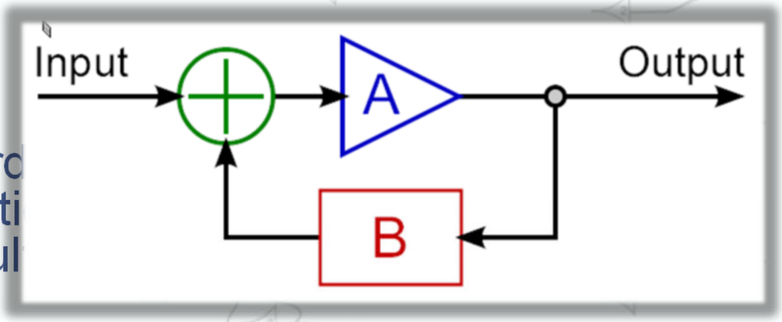




universal computers and general-purpose informatics

- 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.

- Key concepts
  - **universal computation** (Turing, Von Neumann), **information** (Shannon, Wiener), **networks** (mcCulloch), homeostasis, **feedback**, complexity, self-organization
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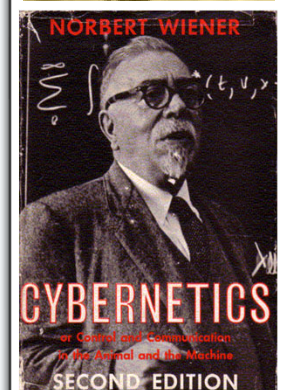

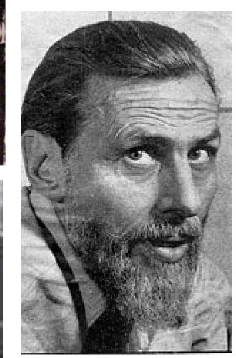

universal computers and general-purpose informatics

- the Josiah Macy Jr. Foundation Meetings
  - post-war science
    - 1946-1953
- Interdisciplinary
  - Since a large class ... ena ... causality, and mat... e, le... with a war-time te...
- Participants
  - **John Von Neuma**... **No**... **Arturo Rosenblue**... **garet Mead**, Heinz von Foerster, **War**... **ory Bateson**, Claude Shannon, ...
- Key concepts
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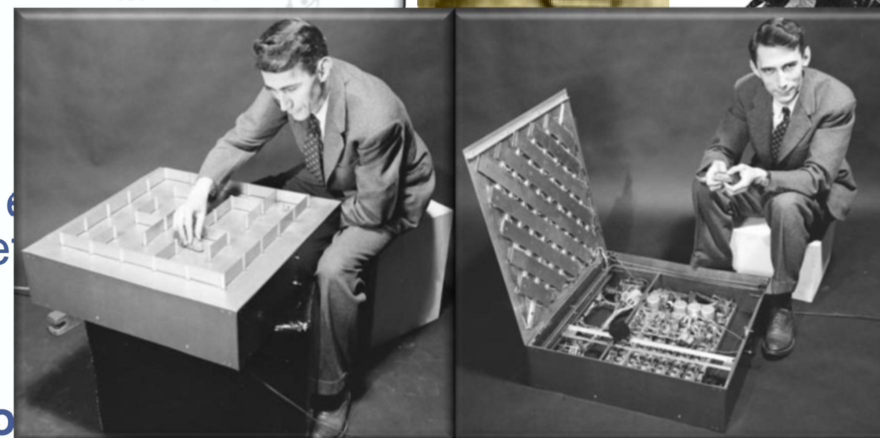

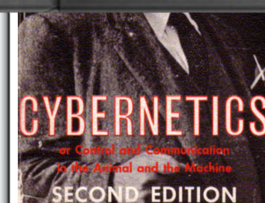

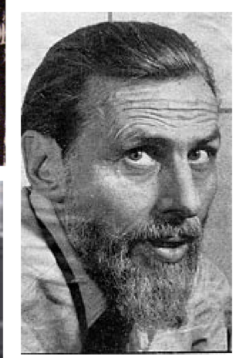

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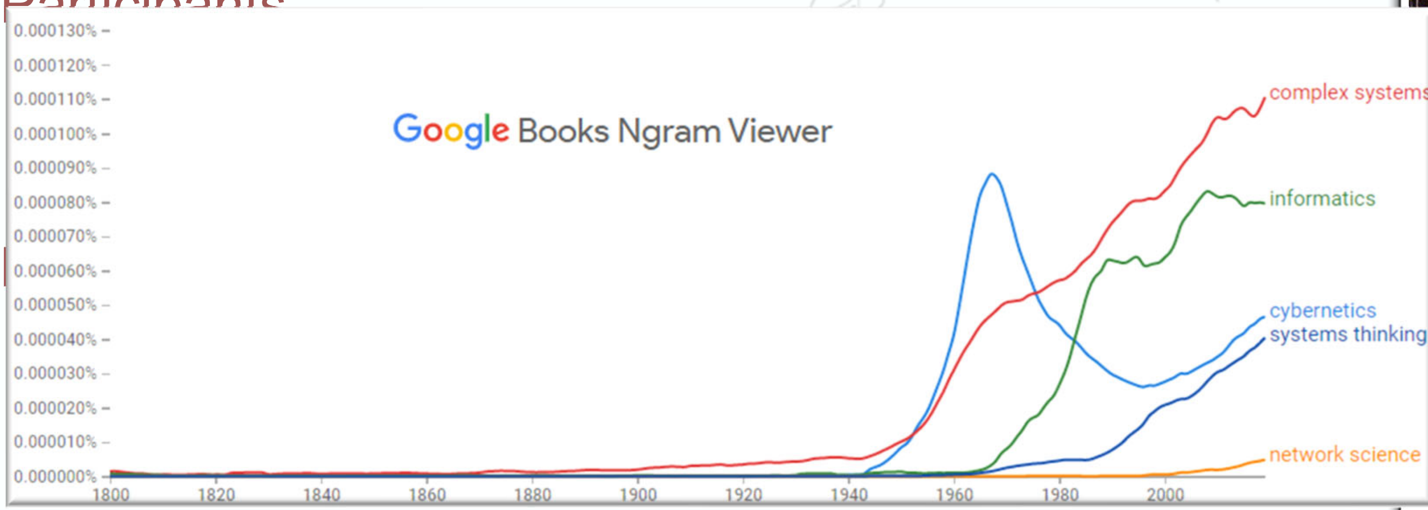

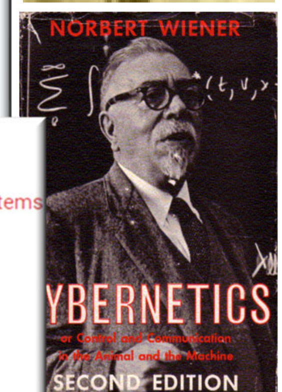

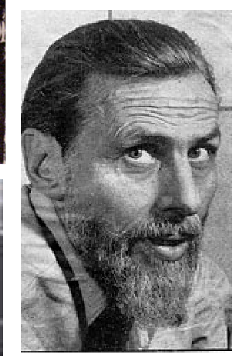

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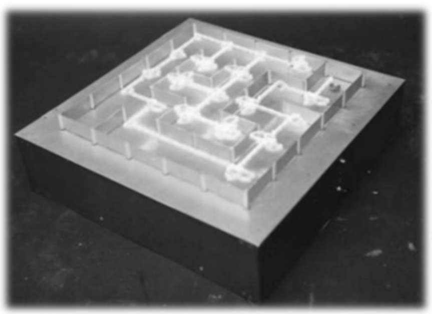
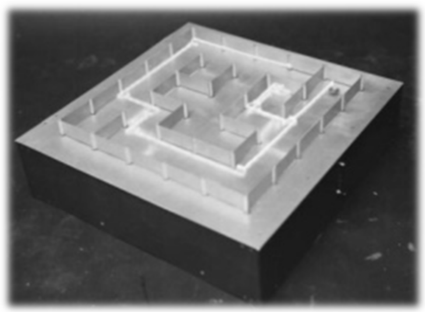
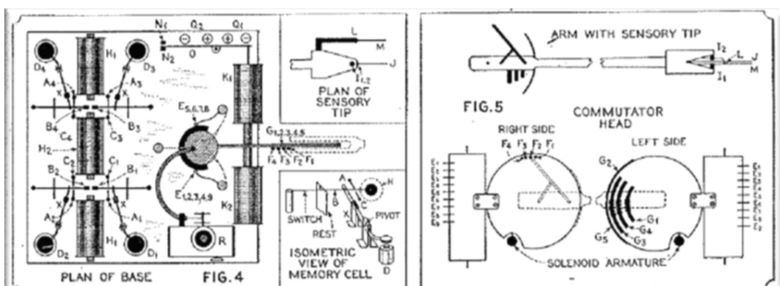
controlling information to achieve life-like behavior

- 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

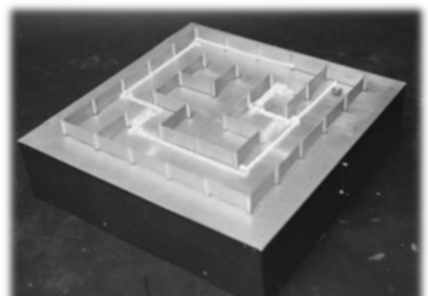




controlling information to achieve life-like behavior

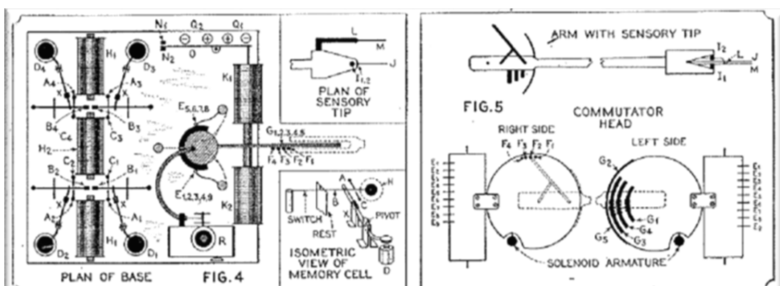


Details of the various parts of the "memory cells" and actuating mechanisms



Shannon's mouse

controlling information to achieve life-like behavior



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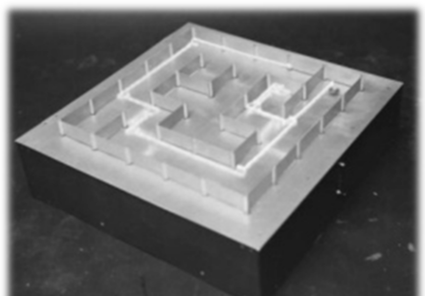

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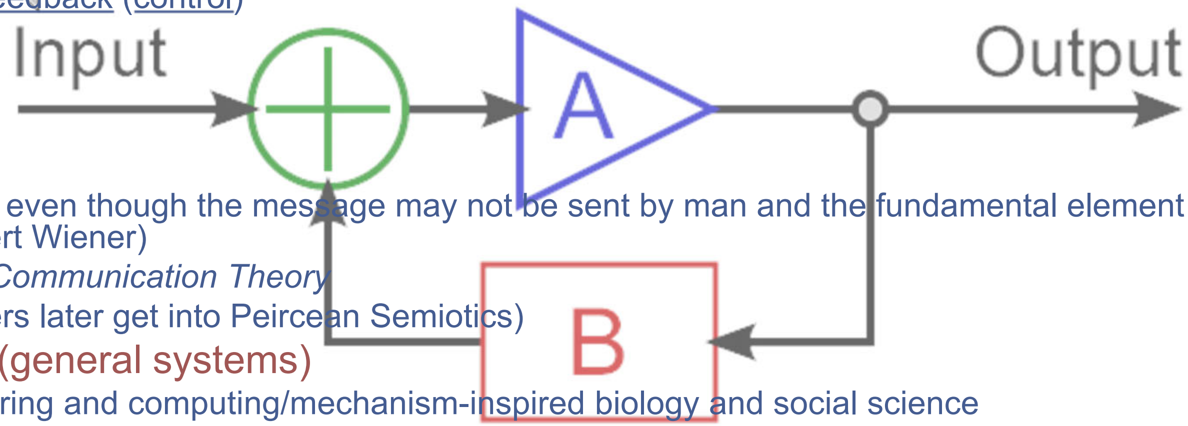
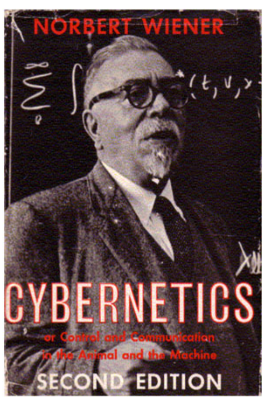
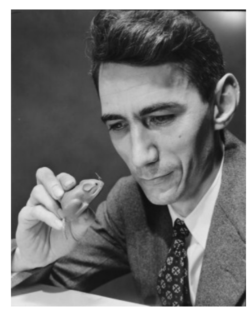
at the Macy meetings

- 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







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at the Macy meetings

- Norbert Wiener and Arturo Rosenblueth
  - Goal-directed behavior and negative feedback (contr
  - Homeostasis and circular causality
    - In machines and biology
- Automata Theory (Von Neumann)
- Communication and Information
  - The fundamental idea is the message, even though t… 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

Input

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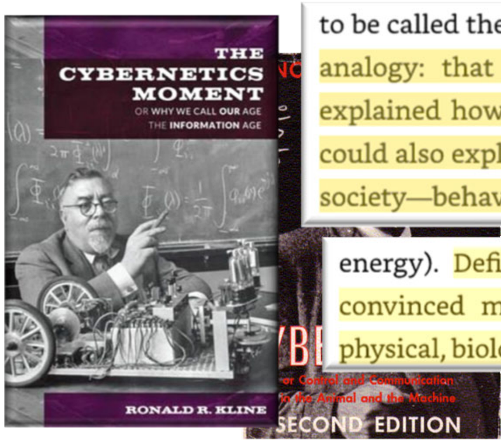
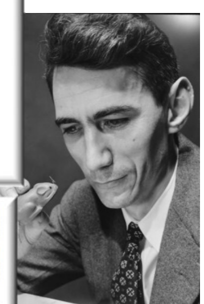
and, sometimes, for creating the theory of information based on this concept. The attributions "Shannon-Wiener" or "Wiener-Shannon" are common in these accounts.[8] John von Neumann, who knew both men, disputed this pedigree by noting that a physicist, Leo Szilard, had equated information with entropy 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



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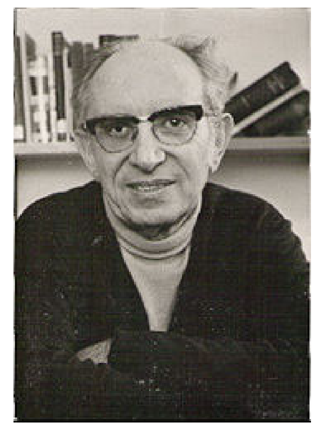
at the Macy meetings

- 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".



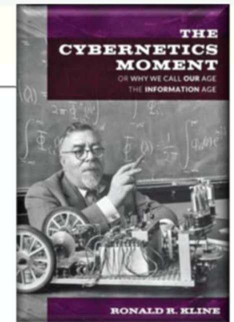
other key concepts

at the Macy meetings

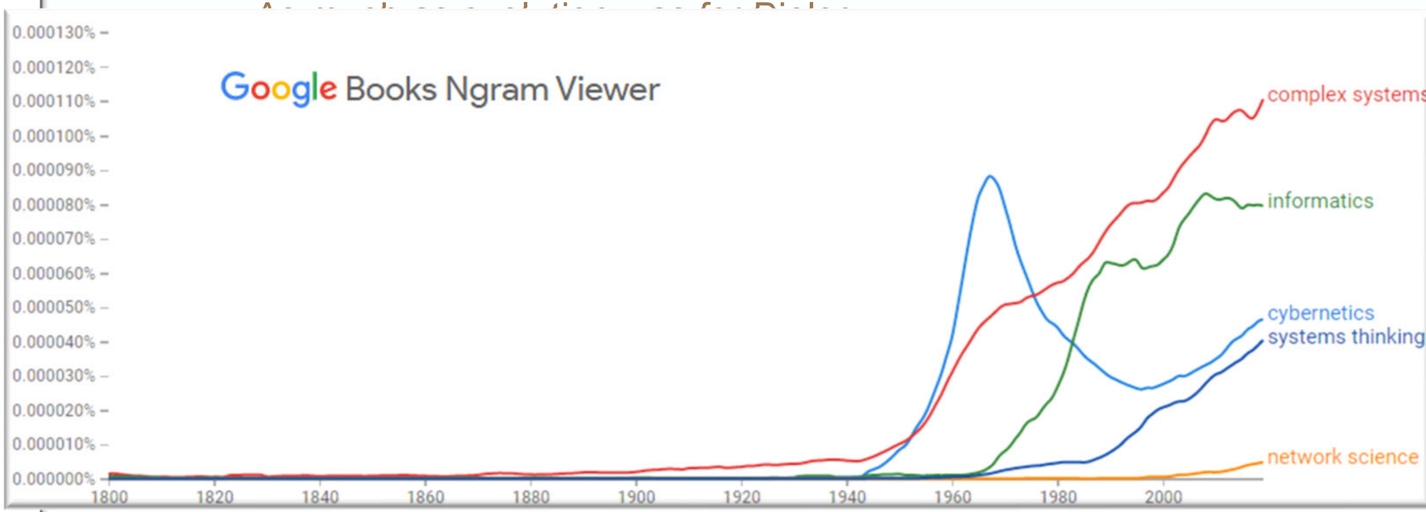
- Gregory Bateson and Margaret Mead

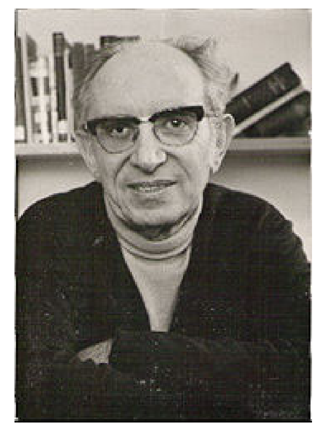
thrived when the cybernetics moment ended. In adopting the language and concepts of cybernetics and information theory, scientists turned the metaphor of information into the matter-of-fact description of what is processed, stored, and retrieved in physical, biological, and social systems. Engineers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

- Can a computer learn to learn?



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

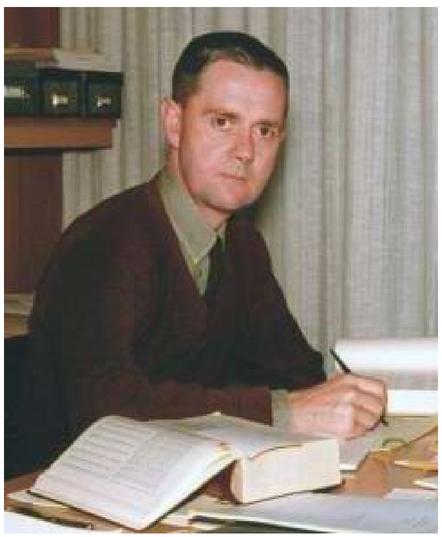




Tuyntsfq%Wjfinsl?% Heims, S.G. [1991]. *The Cybernetics Group*. MIT Press. Chapters: 11 and 12.

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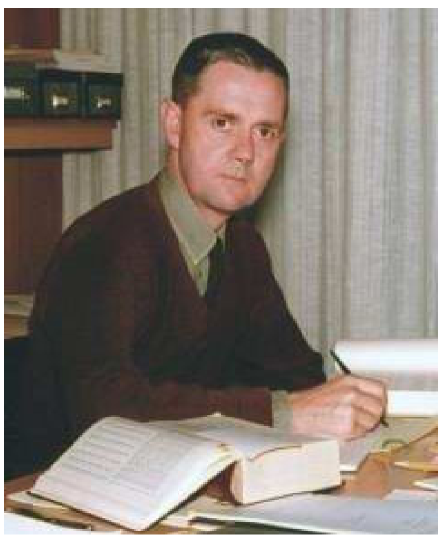
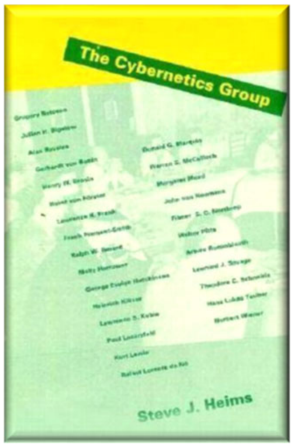
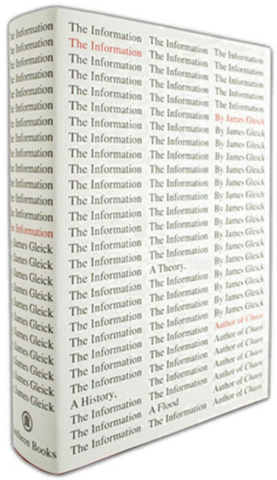
Notes: Back row (from the left): Harold Shipton, John Bates, William Hick, John Pringle, Donald Sholl, John Westcott, and Donald Mackay; middle row: Giles Brindley (guest), Turner McLardy, Ross Ashby, Thomas Gold, and Albert Uttley; front row: Alan Turing, Gurney Sutton (guest), William Rushton, George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



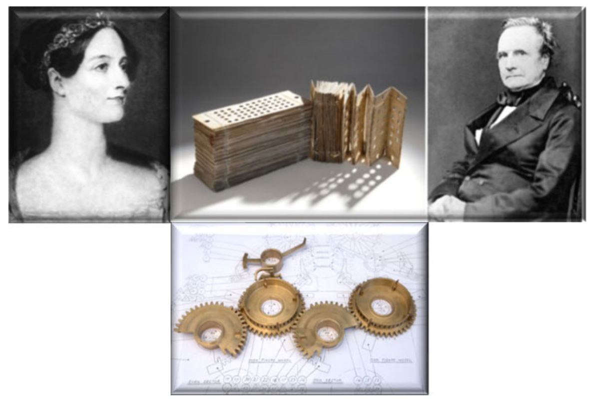
information as its own thing, functional equivalence of mechanisms, and modelling

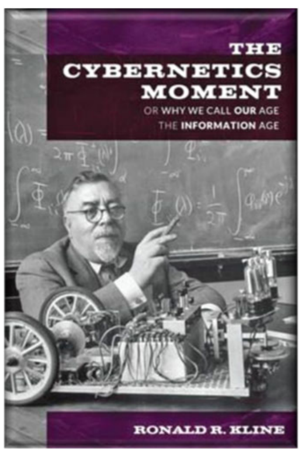


Heims, S.G. [1991]. *The Cybernetics Group*. MIT Press.

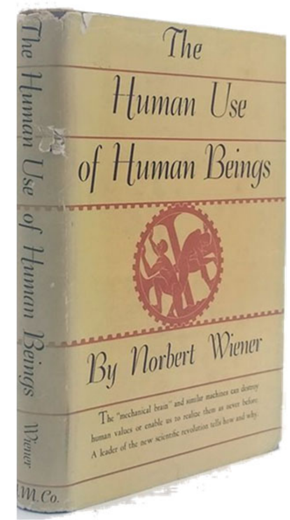


Gleick, J. [2011]. *The Information: A History, a Theory, a Flood*. Random House.





“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,



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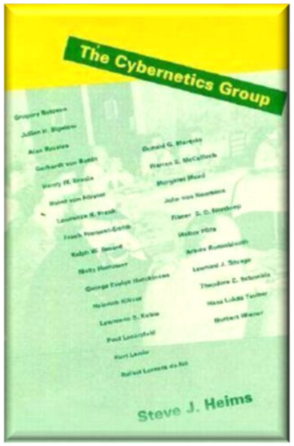
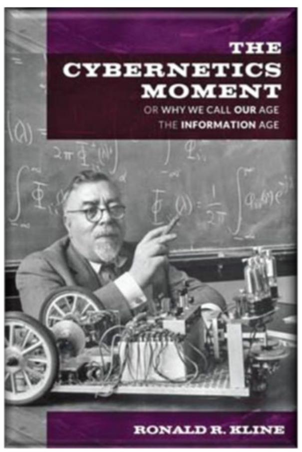
information as its own thing, functional equivalence of mechanisms, and modelling





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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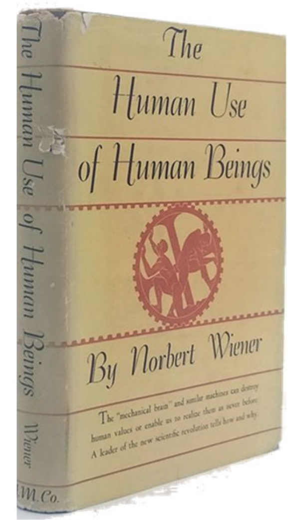

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readings

- Class Book
  - Klir, G.J. [2001]. *Facets of systems science*. Springer.
- Papers and other materials
  - Reading and Discussion Group 2
    - Savannah Sidoti, Akshay Gangadhar, et al
      - Brenner, Sydney. [2012]. "History of Science. The Revolution in the Life Sciences". *Science* **338** (6113): 1427-8.
      - Brenner, Sydney. [2012]. "Turing centenary: Life's code script. *Nature* **482** (7386) (February 22): 461-461.
      - Cobb, Matthew. [2013]. "1953: When Genes Became 'Information'." *Cell* **153** (3): 503-506.
        - Optional: Searls, David B. [2010]. "The Roots of Bioinformatics". *PLoS Computational Biology* **6**(6): e1000809.
      - Weaver, W. [1948]. "Science and Complexity". *American Scientist*, **36**(4): 536-44. Also available in Klir, G.J. [2001]. *Facets of systems Science*. Springer, pp: 533-540.