

# **Adaptive Systems**

## **Lecture 3.1: Early Cybernetics**

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# Contacting me

## Email

- I will normally reply within 2 working days
- [c.a.johnson@sussex.ac.uk](mailto:c.a.johnson@sussex.ac.uk)

## Canvas discussions

- Everyone can see my answers
- I will normally check these at least twice a week

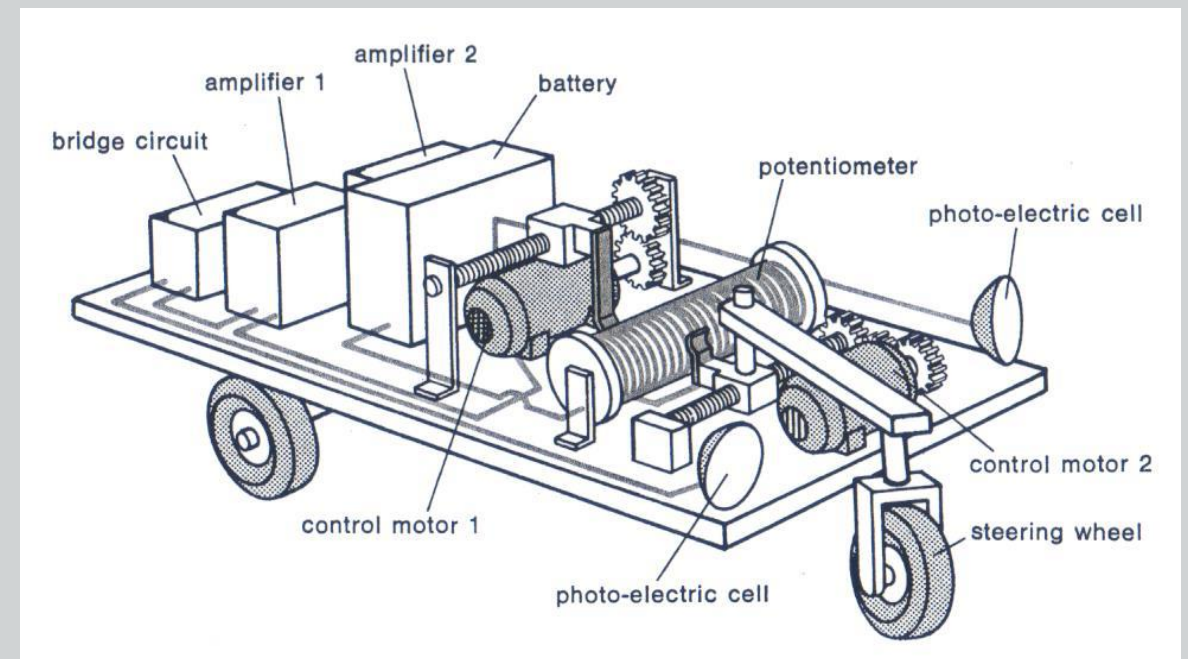
## My office hours

- TBD

# Lecture learning outcomes

## Main points:

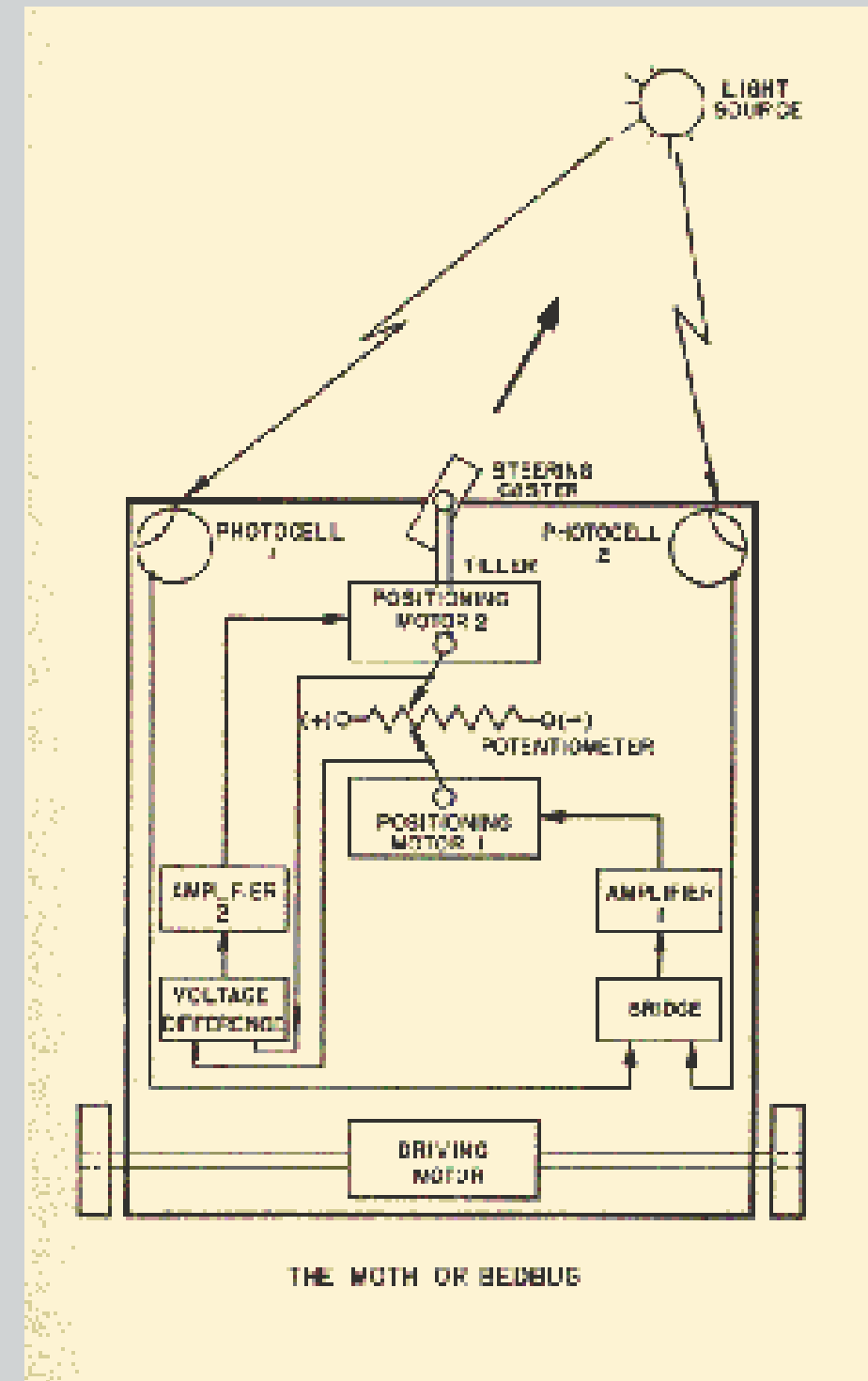
- Everything of interest to us on this module was influenced by cybernetics
- Like adaptive systems, cybernetics was cross-disciplinary from the beginning
- Feedback is everywhere, and when scientists realised this, they saw new connections between animals and machines



[1]

# Lecture outline

1. Cybernetics before cybernetics
2. The importance of feedback
3. The Macy meetings
4. Cybernetics is named
5. The cybernetic origin of artificial neural networks
6. Other cyberneticians



# What did cybernetics lead to?

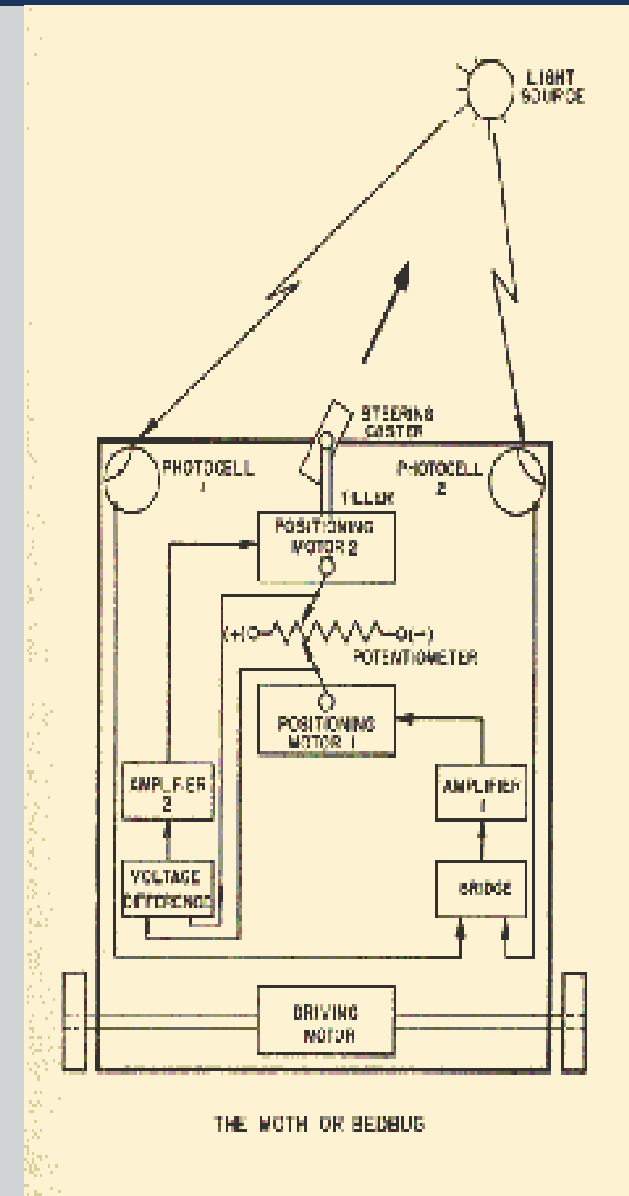
- **AI and robotics**
- **Control theory**
- **Systems thinking**
- **Management science**
- **Information theory**
- **Cellular automata**
- **Artificial life**
- **Neural networks**
- **Genetic algorithms**
- **Self-organisation**
- **Ultrastability**
- **Requisite variety**
- **Order-from-noise**
- **Autopoiesis**
- **The free energy principle**

**All of these ideas and areas of research are at least partially descended from cybernetics**

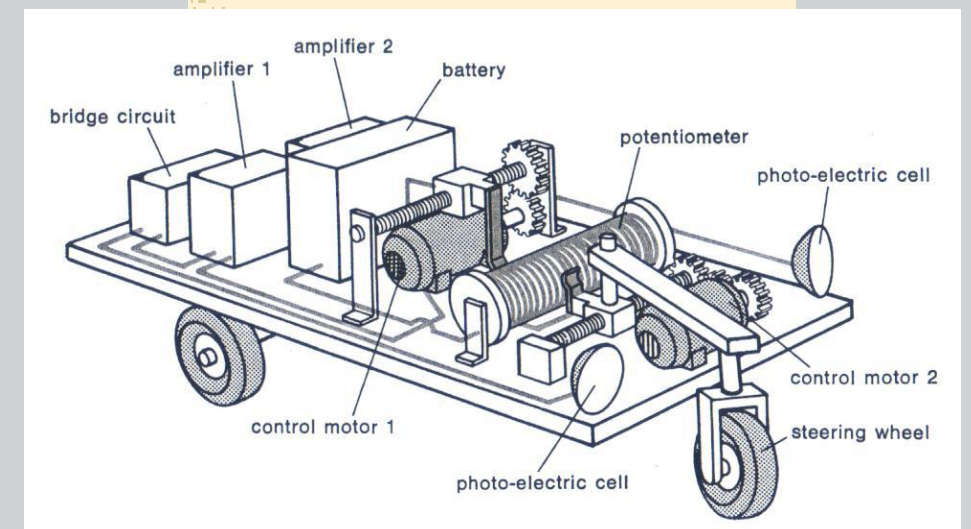
# The father of cybernetics

## Norbert Wiener

- Wanted to be a scientist
  - but he was too clumsy for practical work!
- Settled for philosophy, and *completed* his PhD at the age of 18
- Later realised that he was more interested and talented in the area of mathematics
  - but remained interested in science, as well as engineering



[2]



[1]



# Cybernetics before cybernetics

- During World War II, Wiener was very keen to play his part in the fight against the Nazis
- With the engineer Julian Bigelow, he started developing a tracking system for anti-aircraft artillery
- When they were joined by the physiologist Arturo Rosenblueth, they came to think that the kinds of **feedback** mechanisms that they were developing for gun control were also operating in the nervous systems of the guns' operators
- [Many early cyberneticians were similarly involved in the war effort]



# Cybernetics before cybernetics

- In 1942 a meeting was arranged by the Josiah Macy Jr. Foundation to discuss cerebral inhibition
- Attendees included Rosenblueth, the neuropsychiatrist Warren McCulloch, the psychologist Lawrence Kubie, the anthropologists Margaret Mead and Gregory Bateson and the sociologist Lawrence K. Frank
- Rosenblueth showed how ideas on **feedback** and **circular causality** were applicable across the normal disciplinary boundaries, and could be applied to systems of many types
- In 1943, Rosenblueth, Wiener, and Bigelow published a paper on the same subject

## BEHAVIOR, PURPOSE AND TELEOLOGY

ARTURO ROSENBLUETH, NORBERT WIENER AND JULIAN BIGELOW

This essay has two goals. The first is to define the behavioristic study of natural events and to classify behavior. The second is to stress the importance of the concept of purpose.



# Cybernetics before cybernetics

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[3]

- In this paper, Rosenblueth et al. attempted to provide a behaviouristic account of what it means for something to have a purpose
  - “All purposeful behavior may be considered to require negative feed-back”
  - meaning that “. . . a uniform behavioristic analysis is applicable to both **machines and living organisms**, regardless of the complexity of the behavior.” [3]
- The importance of **feedback**, and how widespread it is, is now unquestioned,
- But talk of **purpose** and **teleology** is controversial

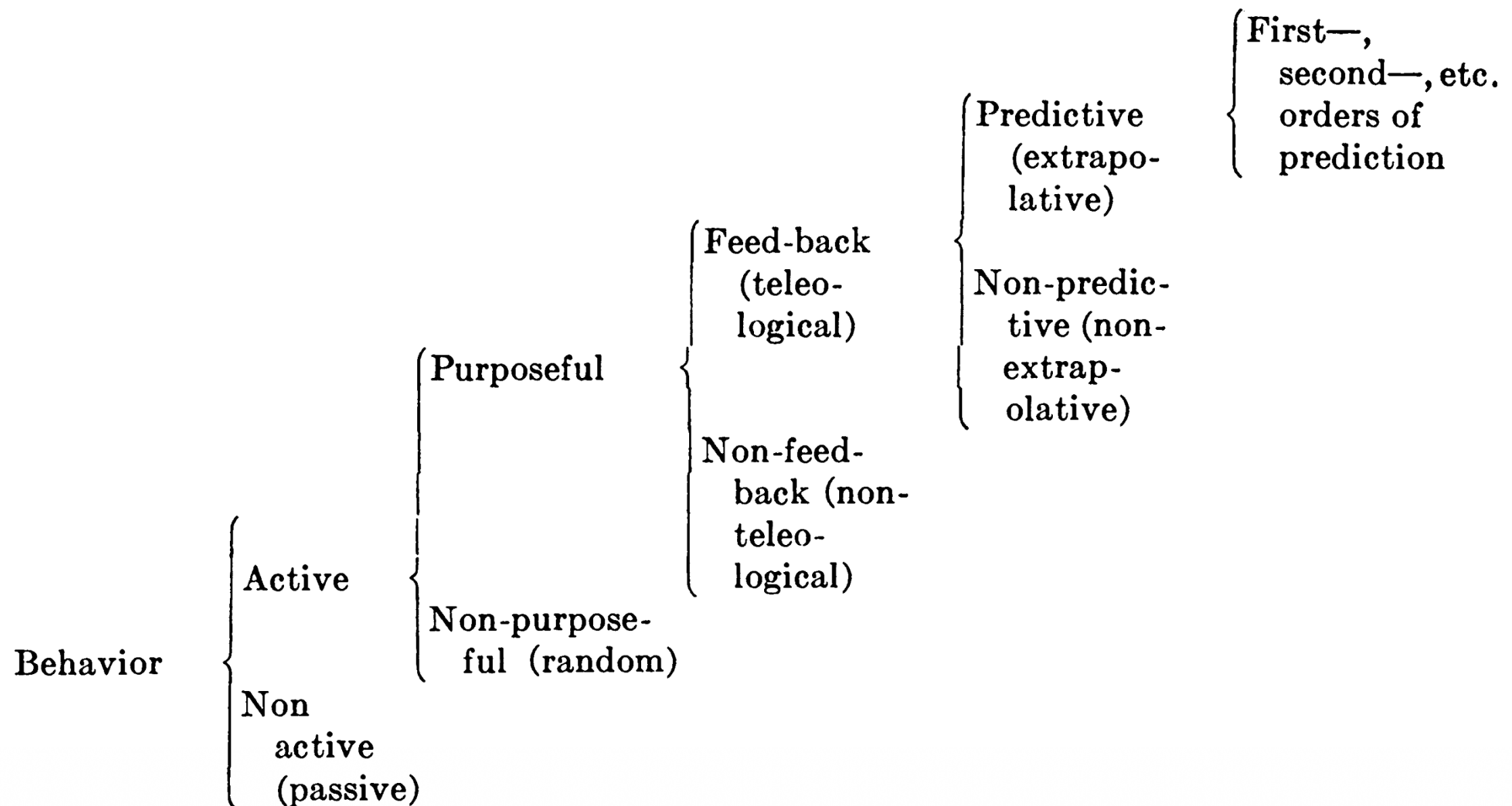
# Cybernetics before cybernetics

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[3]



# The Macy conferences

- After the war the Macy Foundation supported a series of ten meetings from 1946 to 1953
- Brought together different currents of research in mathematics (Wiener, von Neumann), neuroscience (Rosenbleuth, McCulloch), anthropology (Bateson, Mead), engineering (Shannon), psychology, etc.
- These meetings played a central role in starting the cybernetic movement
- Founding event: Macy's meeting on "the **feedback mechanisms** and **circular causal systems** in biology and the social sciences", NYC, March, 1946

# Cybernetics is named

- In 1948, Wiener published a book called “**Cybernetics**, or, **Control** and **Communication** in the **Animal and the Machine**” [5]
- From then on, the name “cybernetics” was applied to the broad range of **cross-disciplinary** research that was emerging from the Macy conferences
- This is why Wiener is often referred to as the father of cybernetics - as well as being an influential figure in the movement, he gave cybernetics its name
- The name “cybernetics” is derived from the greek word *kybernētēs*, which means ‘steersman’ or ‘pilot’
  - this directly connects the name to **feedback**, which steering is *usually* based on

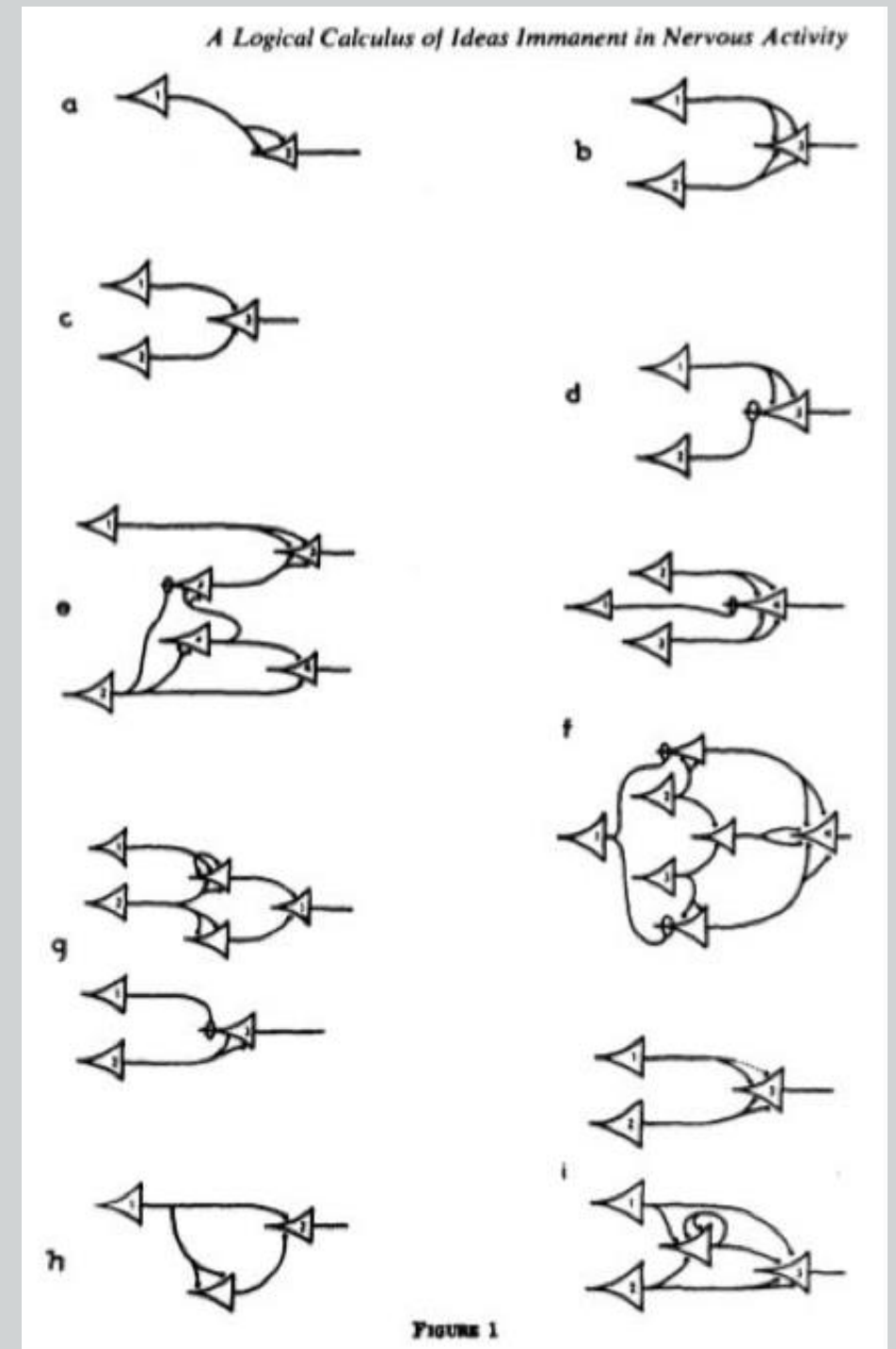
# Neural networks

- Warren McCulloch (a regular at the Macy meetings) and Walter Pitts founded the study of neural networks

## A LOGICAL CALCULUS OF THE IDEAS IMMANENT IN NERVOUS ACTIVITY

WARREN S. MCCULLOCH and WALTER H. PITTS

Because of the "all-or-none" character of nervous activity, neural events and the relations among them can be treated by means of propositional logic. It is found that the behavior of every net can be described in these terms, with the addition of more complicated logical means for nets containing circles; and that for any logical expression satisfying certain conditions, one can find a net behaving in the fashion it describes. It is shown that many particular choices among possible neurophysiological assumptions are equivalent, in the sense that for every net behaving under one assumption, there exists another net which behaves under the other and gives the same results, although perhaps not in the same time. Various applications of the calculus are discussed.





# Other cyberneticians

- There is much more to the story of cybernetics. Other interesting cyberneticians (cyberneticists) include:
  - William Ross Ashby
  - William Grey Walter
  - Stafford Beer
  - Gordon Pask
  - Heinz von Foerster
  - Humberto Maturana
  - Francisco Varela
  - Valentino Braitenberg
- Also, some key figures from the same period and similar research areas who aren't generally known as cyberneticians:
  - Alan Turing
  - John von Neumann
  - Claude Shannon
  - Ludwig von Bertalanffy

# Summary

## Main points:

- **Everything of interest to us on this module was influenced by cybernetics**
- **Like adaptive systems, cybernetics was cross-disciplinary from the beginning (it will become more clear how adaptive systems is descended from cybernetics in later lectures)**
- **Feedback is everywhere, and when scientists realised this, they saw new connections between animals and machines, and came to believe that the behaviours of both could be studied and analysed in the same way.**

# Bibliography

## Recommended articles and books

- [3] Arturo Rosenblueth, Norbert Wiener, and Julian Bigelow. Behavior, purpose and teleology. *Philosophy of Science*, 10(1):18–24, 1943.
- [4] Warren S. McCulloch and Walter Pitts. A logical calculus of the ideas immanent in nervous activity. *The bulletin of mathematical biophysics*, 5(4):115–133, Dec 1943
- [5] N Wiener. *Cybernetics, or Control and Communication in the Animal and the Machine*. M.I.T. P., 1 ed.. edition, 1948.

# Bibliography

## Relevant websites

[1]

<http://cyberneticzoo.com/cyberneticanimals/1949-wieners-moth-wiener-wiesner-singleton/>

[2]

<https://www.technologyreview.com/2011/06/21/193920/the-original-absent-minded-professor/>

# Bibliography

## Other websites (sources of pictures)

[6] [https://en.wikipedia.org/wiki/SCR-584\\_radar#/media/File:Exterior view of SCR-584.jpg](https://en.wikipedia.org/wiki/SCR-584_radar#/media/File:Exterior view of SCR-584.jpg)

[7] [https://en.wikipedia.org/wiki/QF\\_3.7-inch\\_AA\\_gun#/media/File:Hyde Park Anti-aircraft guns H 993.jpg](https://en.wikipedia.org/wiki/QF_3.7-inch_AA_gun#/media/File:Hyde_Park_Anti-aircraft_guns_H_993.jpg)

## Other cited articles and books

**None this time.**