

# Intro to Cybernetics

"If I were to choose a patron saint for cybernetics out of the history of science, I should have to choose Leibniz."  
~ Norbert Wiener *Cybernetics* (1948)

"Since Leibniz there has perhaps been no man who has had a full command of all the intellectual activity of his day. Since that time, science has been increasingly the task of specialists, in fields which show a tendency to grow progressively narrower. A century ago there may have been no Leibniz, but there was a Gauss, a Faraday, and a Darwin. Today there are few scholars who can call themselves mathematicians or physicists or biologists without restriction."~ Norbert Wiener *Cybernetics* (1948)

# Some Problems

- Multicausality, Circularity, & Complexity

Cause and effect can be a web instead of a chain

- Reduction vs. Holism; Product vs. Process

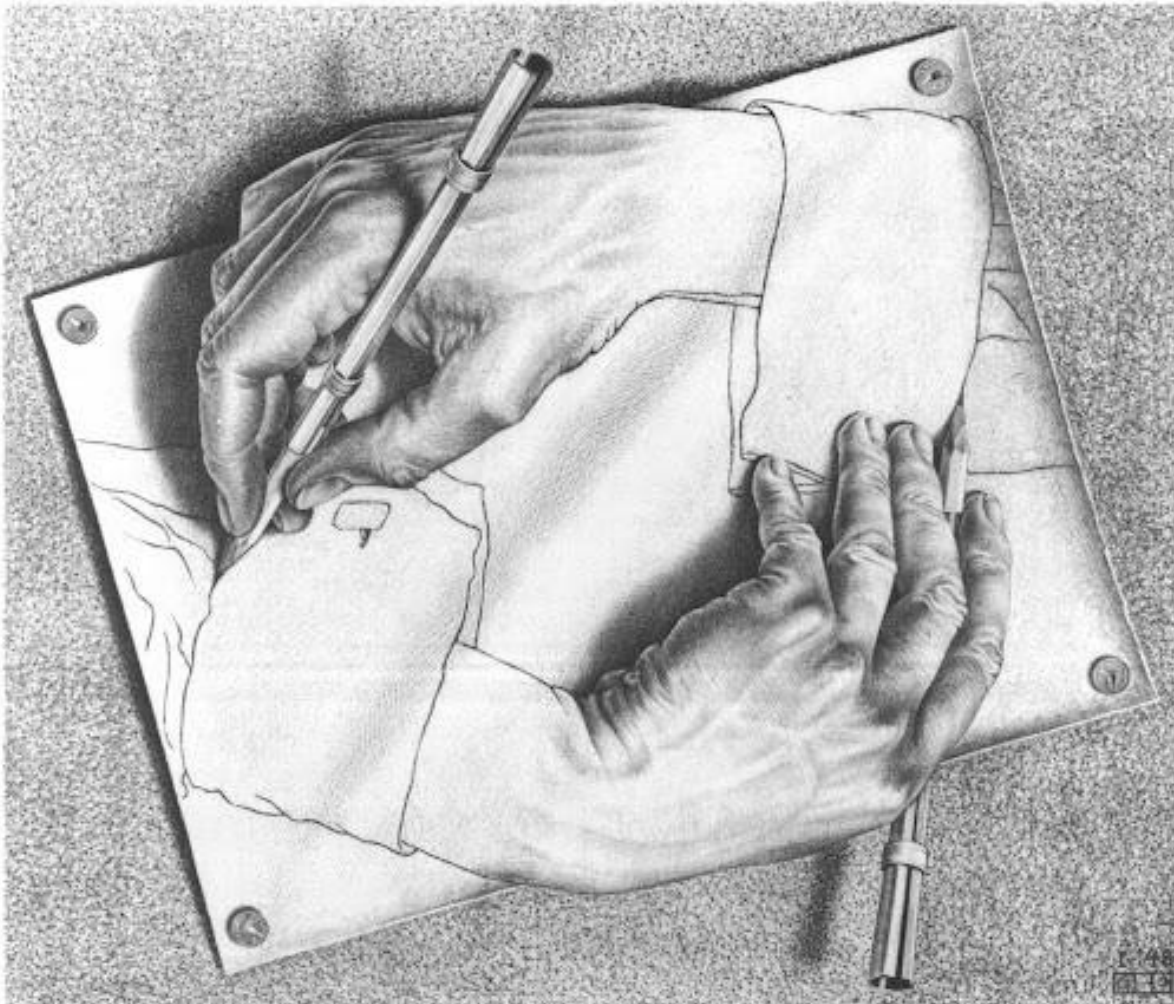
A new program was necessary to formalise and explicate a "Middle Way"

- Scientists saw connections across disciplines

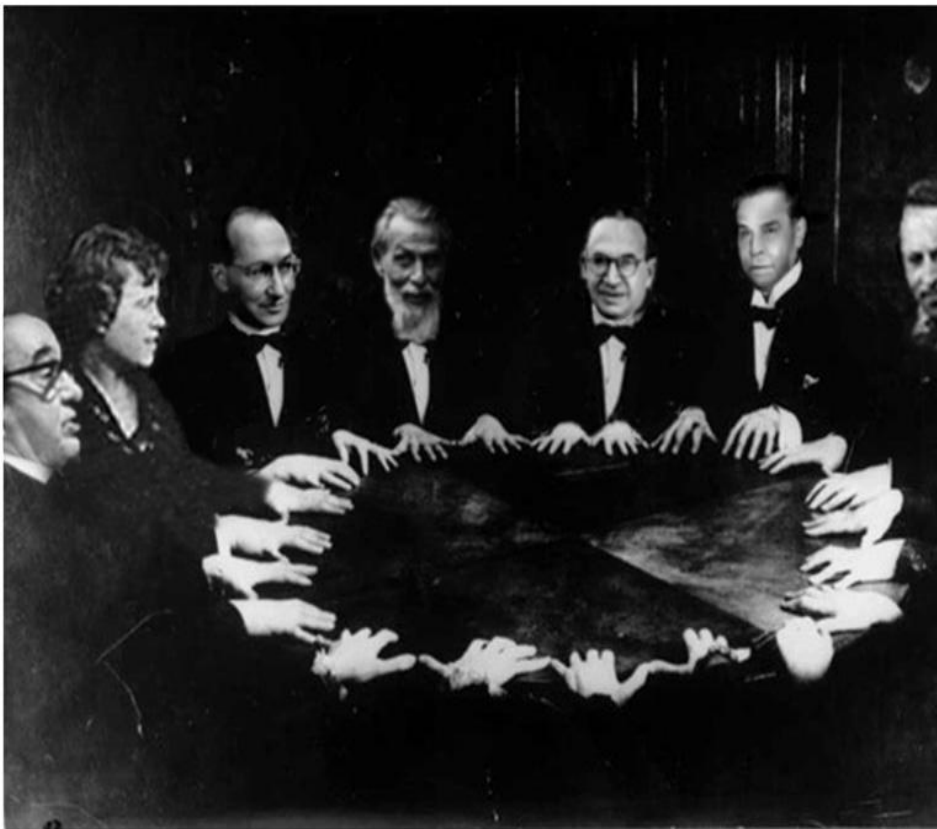
There was no common scientific language for communication & collaboration

"A man may be a topologist or an acoustician or a coleopterist. He will be filled with the jargon of his field, and will know all its literature and all its ramifications, but, more frequently than not, he will regard the next subject as something belonging to his colleague three doors down the corridor, and will consider any interest in it on his own part as an unwarrantable breach of privacy." ~ Norbert Wiener *Cybernetics* (1948)

# Both Designed & Emergent

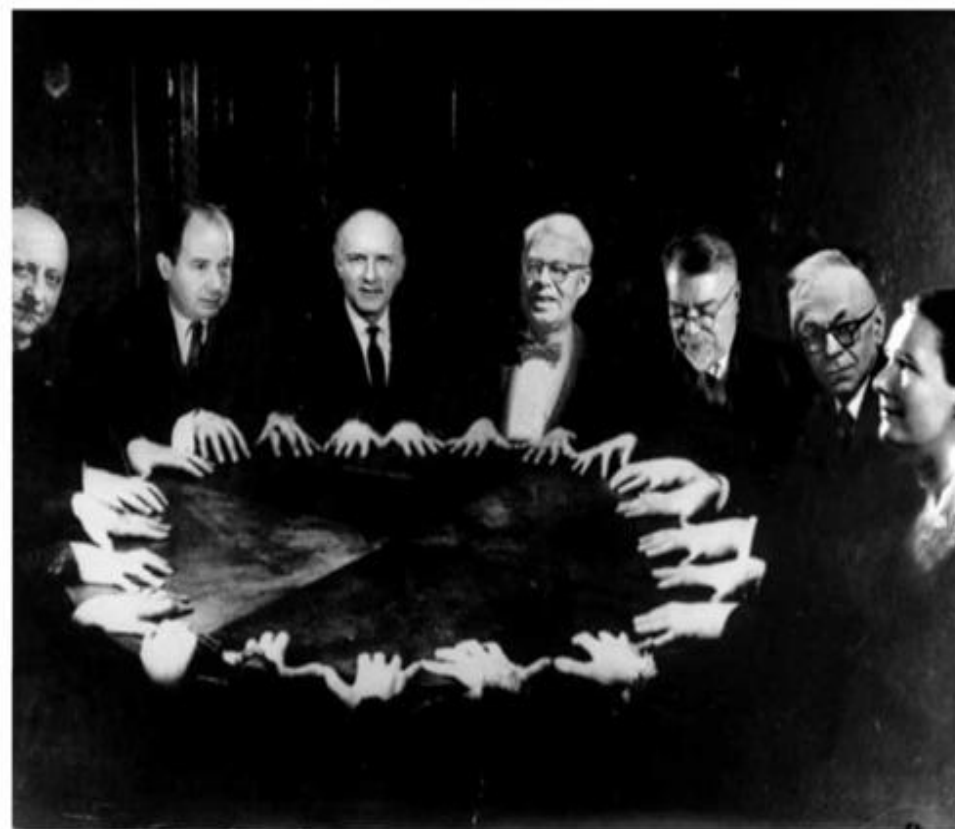


# Macy Conferences 1946-53



Cybernetic Séance - New York City, 1947

From Left to Right : Rafael Lorente De No (Neurophysiologist), Margaret Mead (Anthropologist), Kurt Lewin (Psychologist), Warren S. McCulloch (Neuropsychiatrist), Paul F. Lazarsfeld (Sociologist), Arturo Rosenblueth (Physiologist) and Gregory Bateson (Anthropologist).  
 Front (missing from view): Molly Harrower (Psychologist), Heinrich Klüver (Psychologist), Norbert Wiener (Mathematician), Lawrence K. Frank (Social Scientist), Heinz von Foerster (Electrical Engineer), John von Neumann (Mathematician) and Ralph W. Gerard (Neurophysiologist).  
 Observers (missing from view): Frank Fremont-Smith (Medical Director of the Macy Foundation), Julian Bigelow (Computer Engineer), Walter Pitts (Mathematician), George Evelyn Hutchinson (Ecologist), Leonard J. Savage (Mathematician), Henry Brosin (Psychiatrist), Theodore Schneirla (Comparative Psychologist), Hans Lukas Teuber (Psychologist), Gerhardt von Bonin (Neuroanatomist), Lawrence S. Kubie (Psychiatrist), Filmer S. C. Northrop (Philosopher), Alex Bavelas (Social Psychologist) and Donald Marquis (Psychologist).



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# Macy Conferences Cont.

The Macy Conferences on Cybernetics  
Gruppenfoto der TeilnehmerInnen 1953



Dritte Reihe: Peggy Kubie, Henry W. Brosin, Gregory Bateson, Frank Fremont-Smith, John R. Bowman, George E. Hutchinson, Hans-Lukas Teuber, Julian H. Bigelow, Claude E. Shannon, Walter Pitts, Heinz von Foerster

Zweite Reihe: Leonard J. Savage, Janet Freed Lynch, Gerhardt von Bonin, Lawrence S. Kubie, Lawrence K. Frank, Henry Quastler, Donald G. Marquis, Heinrich Klüver, Filmer S. C. Northrop

Erste Reihe: Theodore C. Schneirla, Yehoshua Bar-Hillel, Margaret Mead, Warren S. McCulloch, Jan Droogleever Fortuyn, Yuen Ren Chao, W. Grey Walter, Vahe E. Amassian

# What is Cybernetics?

"Control and communication in the animal and the machine."~Norbert Wiener

"Science concerned with the study of systems of any nature which are capable of receiving, storing and processing information so as to use it for control."~A. N. Kolmogorov

"A branch of mathematics dealing with problems of control, recursiveness, and information, focuses on forms and the patterns that connect."~Gregory Bateson

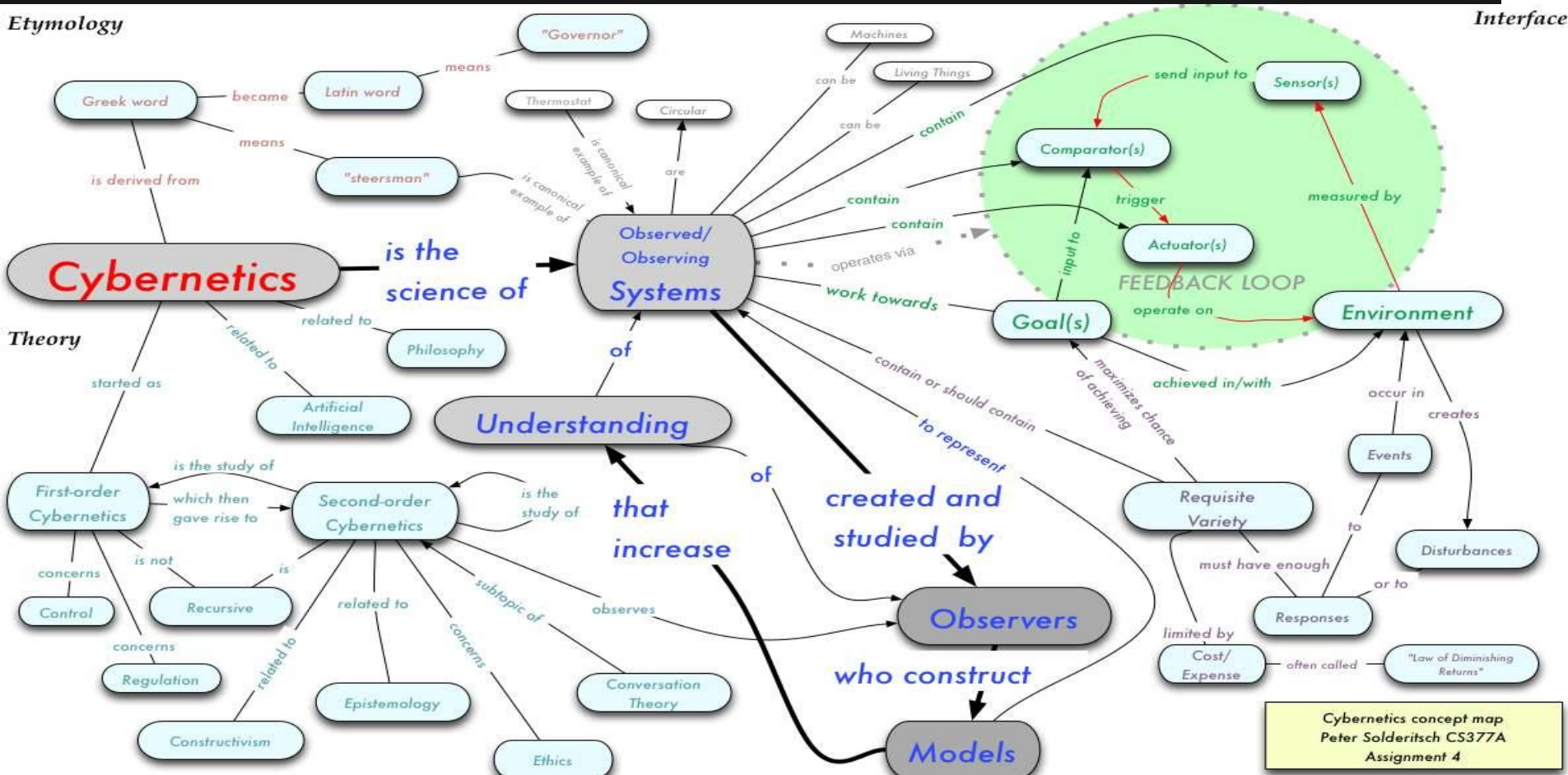
"'The art of steersmanship': deals with all forms of behavior in so far as they are regular, or determinate, or reproducible: stands to the real machine -- electronic, mechanical, neural, or economic -- much as geometry stands to real object in our terrestrial space; offers a method for the scientific treatment of the system in which complexity is outstanding and too important to be ignored."—W. Ross Ashby

"The art of effective organization."~Stafford Beer

"The science and art of understanding."~Humberto Maturana

"The art and science of manipulating defensible metaphors."~Gordon Pask

# What is Cybernetics really?



"Use the word `cybernetics', Norbert, because nobody knows what it means. This will always put you at an advantage in arguments." ~Claude Shannon



# Influencers & Influenced

- Technology

Information Theory; Systems Engineering

- Biology

Teleology, GST; BioInformatics

- Psychology

Neuroscience; BPS & Family Systems, CBT

- Sociology/Anthropology

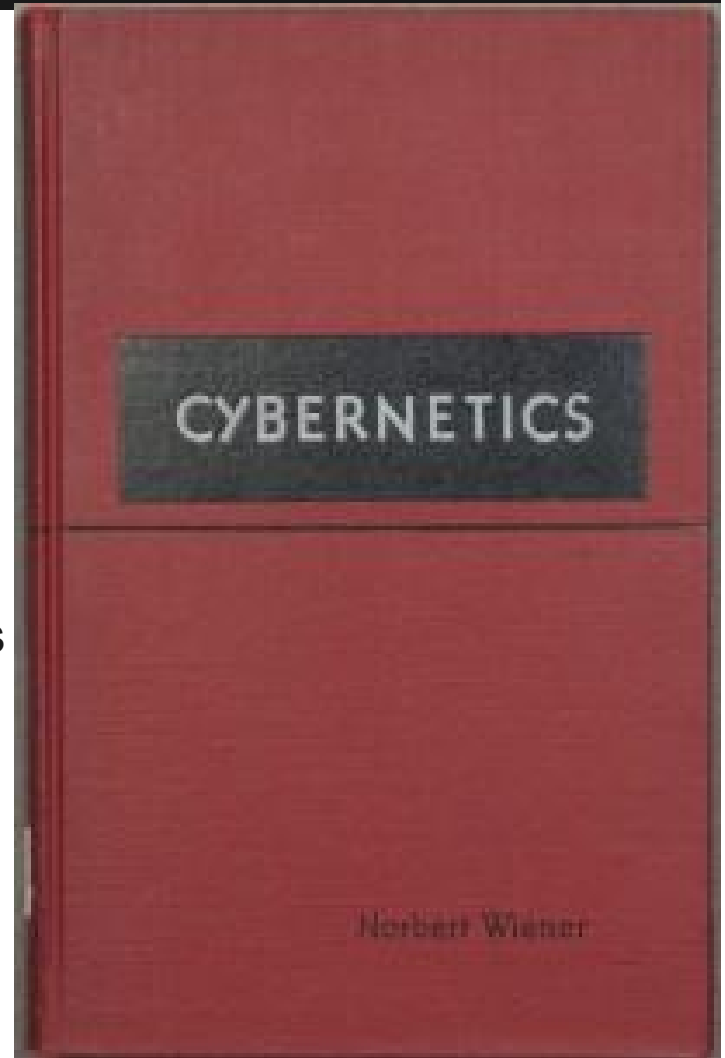
Organization Science; Social Network Analysis

- Anthropology

Cultural Evolution; Ecological Anthropology

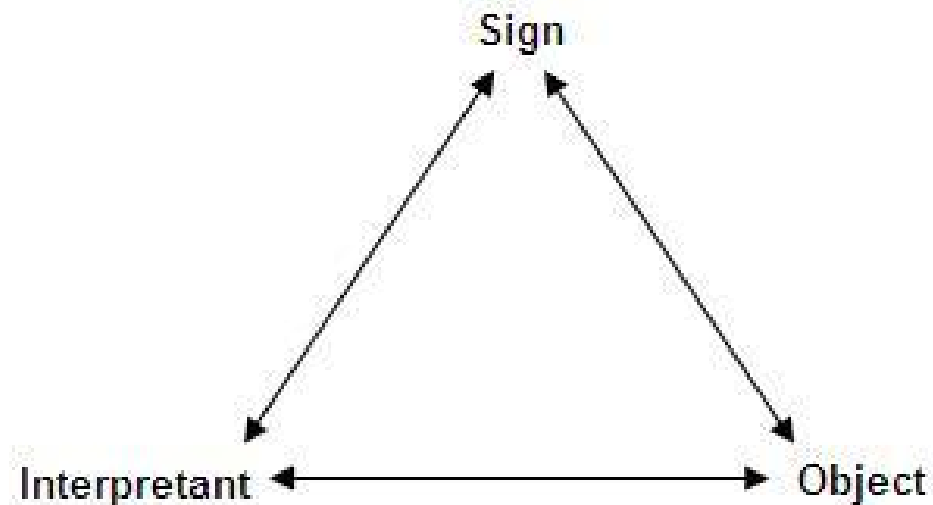
- Philosophy

Logic, Mathematics; Constructivism



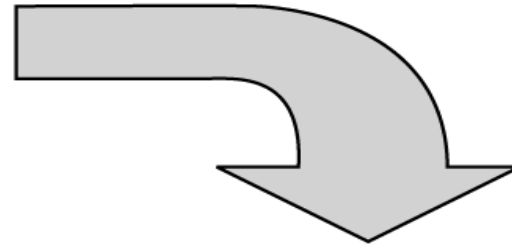
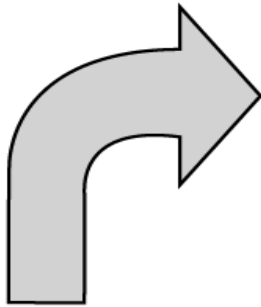
# Classical Cyberneticists

- **John Von Neumann**
  - Game Theory, Cellular Automata, Ergodicity, Quantum Mechanics, Computation
- **Norbert Wiener**
  - Cybernetics, Stochastics, Dynamics, Ergodicity, Feedback
- **W. Ross Ashby**
  - Intelligence, Requisite Variety, Selection, Regulation
- **Gregory Bateson**
  - Epistemology, Systems Theory
- **Alan Turing**
  - Computation, Chemical Morphogenesis
- **Claude Shannon**
  - Information Theory, Theoretical Genetics
- **Warren McCulloch**
  - Neural Networks
- **Walter Pitts**
  - Neural Networks
- **Talcott Parsons**
  - Action Theory
- **Margaret Mead**
  - Cultural Systems
- **Kenneth Boulding**
  - Management Science

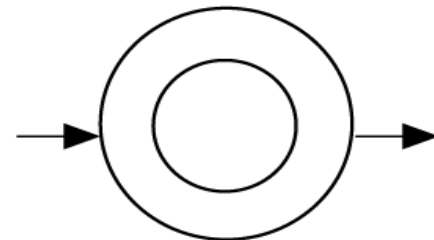


<Peirce's triad of semiotics>

# Second Order Cybernetics

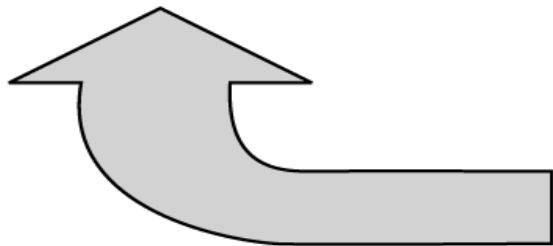


First order study of observed systems distinguishes systems that are energetically open and organisationally closed (autopoietic)



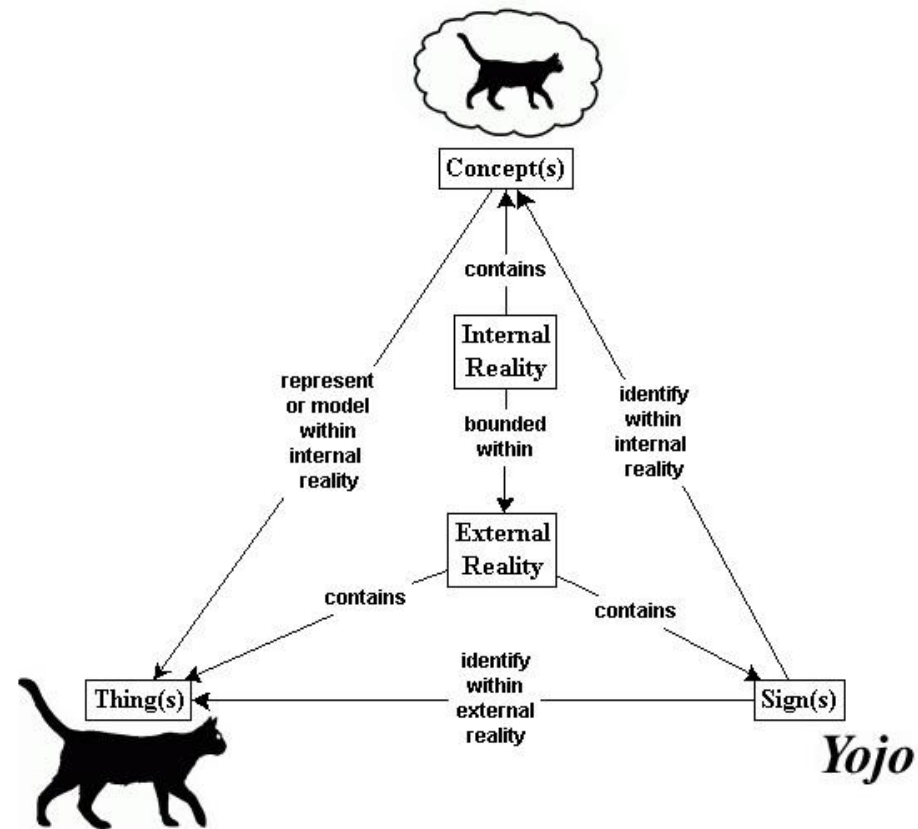
Evolution and ontogenetic development of systems that observe and converse

Second order study of observing systems: the observer explains himself to himself



# New Cyberneticists

- Heinz von Foerster
- *Constructivism, Population Dynamics, Engineering*
- Gordon Pask
- *Complementarity, Concurrence, Interaction of Actors*
- Donald Campbell
- *Cultural Evolution, Methodology, Selection*
- Anatol Rapoport
- *Social Network Analysis, Symbiosis, Application*
- Humberto Maturana
- *Autopoiesis, Cognitive Science, Constructivism*
- Francisco Varela
- *Neuroscience, Meditation*
- Henri Atlan
- *Cellular Biophysics, Medical Imaging*
- Stafford Beer
- *Organizational and Management Science*
- James Grier Miller
- *Living Systems Theory*
- Valentin Turchin
- *Meta Systems Transition Theory*
- Howard T. Odom
- *Ecosystemics*



# Spotlight: W. Ross Ashby

## Psychiatrist, Mathematician, Cyberneticist

B.A.1924; M.B. & B.Ch. 1928; M.A., M.D. 1935 (Cambridge); F.R.C.Psych 1971

1930-36, Clinical Psychiatrist, London County Council.

1936-47, Research Pathologist, St. Andrews Hospital, Northampton

1945-47, (Military Service) Major, Royal Army Medical Corps

1947-59, Director of Research, Barnwood House Hospital, Gloucester, England

1959-60, Director, Burden Neurological, Institute, Bristol.

1961-70, Professor, Depts of Biophysics and Electrical Engineering, University of Illinois

1970-... Professor Emeritus, University of Illinois.



*Law of Requisite Variety* : A system has good Control if and only if the dependent variables remain the same even when the independent variables or the State Function have changed. In a real system this implies that the State Function is a composition of two functions, such that the second is the inverse of (the possible changes of) the first:

$y = F(G(x))$  where:  $F$  = controller system's function of state;  $G$  = controlled system's function of state;  $x$  = inputs;  $y$  = outputs

See: Shannons' 10th Theorem; Newton's 3rd Law; Chatelier's principle <http://pcp.vub.ac.be/Books/AshbyReqVar.pdf>

*Every Good Regulator Theorem*: The design of a complex regulator often includes the making of a model of the system to be regulated. The making of such a model has hitherto been regarded as optional, as merely one of many possible ways. In this paper a theorem is presented which shows, under very broad conditions, that any regulator that is maximally both successful and simple must be isomorphic with the system being regulated. (The exact assumptions are given.) Making a model is thus necessary. The theorem has the interesting corollary that the living brain, so far as it is to be successful and efficient as a regulator for survival, must proceed, in learning, by the formation of a model (or models) of its environment.

See: Achieving control, dynamic equilibrium; and/or Nyquist Stability [http://pespmc1.vub.ac.be/Books/Conant\\_Ashby.pdf](http://pespmc1.vub.ac.be/Books/Conant_Ashby.pdf)

Principles of the Self-Organizing Dynamic System (1947); Design for a Brain (1952); Introduction to Cybernetics (1958)



# Concluding Remarks

- Feedback between Theory, Data & Practice

*The Scientist, The Engineer, and the Engineered in Processing of Dichotomies*

- Not a Science, an Approach & Program

*The designed & emergent dynamic broadens knowledge generation*

- Arguably the most successful Program ever

*Computation, Engineering, Learning, Neuroscience, Ecology, Philosophy*

- Likely the Best Bridge to the Social Sciences

*Engineering a meta-language and meta-laws isomorphic to Logic with utility*

"It is a common observation that our present culture lacks integration: there is an enormous diversity of "systems of thought" (disciplines, theories, ideologies, religions, ...), but they are mostly incoherent, if not inconsistent, and when confronted with a situation where more than one system might apply, there is no guidance for choosing the most adequate one." ~ Francis Heylighen, *Principia Cybernetica*