Fundamentals and History of Cybernetics 1

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Topics to be covered

• Key theorists and their contributions
• The issues that have been discussed, different interpretations and how they were resolved
• Theories are answers to questions
• To understand a theory is it necessary to understand the previous theory
Origins of cybernetics

• Excitement about the utility of applied science following World War II
• The Macy Foundation conferences in New York City 1946-1953
• “Circular Causal and Feedback Mechanisms in Biological and Social Systems”
A history of cybernetics

• First order cybernetics – circular causality, engineering cybernetics
• Second order cybernetics – the role of the observer, biological cybernetics
• Social cybernetics – interaction between ideas and society, the design of intellectual (or social) movements
• Unifying epistemologies
Interpretations of cybernetics

- Alan Turing and John von Neumann, computer science, artificial intelligence, cellular automata
- Norbert Wiener, electrical engineering and control systems
- Warren McCulloch, neurophysiology, experimental epistemology
Early 1940s

- McCulloch and Pitts, “A Logical Calculus of the Ideas Immanent in Nervous Activity”
- Wiener, Rosenblueth and Bigelow, “Behavior, Purpose and Teleology”
Late 1940s

• The Macy conferences
• Wiener, *Cybernetics: or Control and Communication in Animal and Machine*
• von Neumann and Morgenstern, *Theory of Games and Economic Behavior*
• Shannon and Weaver, *The Mathematical Theory of Communication*
Early 1950s

• The last five Macy conferences, this time with published proceedings
• First commercial computers become available
Late 1950s

- CIA experiments on mind control under the name MKULTRA
- Early checkers playing programs
- At a conference at Dartmouth University cybernetics and artificial intelligence go separate ways
- Heinz von Foerster establishes Biological Computer Laboratory at U. of Illinois
Early 1960s

- Conferences on self-organizing systems
- Discussion of a “cybernetics gap” between the US and the USSR, following discussion of a “missile gap” during 1960 campaign
- American Society for Cybernetics is founded in 1964
Late 1960s

• Anti Viet Nam war movement in the US
• Campus protests
• A productive period for the Biological Computer Laboratory (BCL)
Early 1970s

• The Mansfield Amendment has the effect of cutting off funding for BCL
• Von Foerster introduces the term “second order cybernetics,” beginning an effort to create a scientific revolution
• Von Foerster moves to California
• The “ultra secret” of World War II is revealed
Late 1970s

- Conflict within the American Society for Cybernetics, a rival organization is founded
- Cyberneticians meet with general systems theorists at AAAS conferences
- Graduates of BCL move into cyberspace with help from an NSF grant for “electronic information exchange in small research communities”
Early 1980s

- Meetings between American and Soviet scientists begin on “the foundations of cybernetics and systems theory”
- Lefebvre’s theory of reflexive control begins to be discussed in US and Russia
- American Society for Cybernetics, led by BCL graduates, holds meetings emphasizing “second order cybernetics”
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Definitions of First and Second Order Cybernetics
Late 1980s

- The American Society for Cybernetics conducts tutorials on first and second order cybernetics at its conferences
- Meetings between American and Soviet scientists continue
- The American Society for Cybernetics holds its first meeting in Europe in 1987
Early 1990s

• Meetings on “theories to guide the reform of socialist societies” begin in Vienna
• The internet becomes available
• Attempts are made to change a period of “revolutionary science” into a period of “normal science”
• “Social cybernetics” begins to be distinguished from “biological cybernetics”
The cybernetics of science

NORMAL SCIENCE

The correspondence principle

Incommensurable definitions

SCIENTIFIC REVOLUTION
The Correspondence Principle

• Proposed by Niels Bohr when developing the quantum theory
• Any new theory should reduce to the old theory to which it corresponds for those cases in which the old theory is known to hold
• A new dimension is required
An Application of the Correspondence Principle
Stages in the development of cybernetics in the US

• First order cybernetics – circular causality, engineering cybernetics, 1940s to 1974
• Second order cybernetics – the role of the observer, biological cybernetics, 1974 to mid 1990s
• Social cybernetics – interaction between ideas and society, design of intellectual movements, mid 1990s
Late 1990s

- Meetings continue in Vienna every two years on the transitions in the former Soviet Union
- The year 2000 computer problem is discussed as an error in a knowledge society
- Niklas Luhmann’s writings introduce constructivism, second order cybernetics, and autopoiesis to a large audience
Early 2000s

• An increasing number of books about constructivism appear in German
• Systems scientists (ISSS) begin discussing group facilitation methods
• The internet creates a global network of universities with an increasing number of internationally co-authored papers
Eric Dent’s eight dimensions

• Circular causality vs. linear causality
• Holism vs. reductionism
• Relationships rather than entities
• Environment is important or not
• Indeterminism vs. determinism
• Self-organization vs. designed systems
• Reality is constructed or it is assumed
• Reflexivity (knowing subjects) or not
Assessment

• Different fields within systems science emphasize different dimensions

• A wide range of questions have driven research

• The key research questions are from time to time rediscovered, for example, by the Santa Fe Institute
Cybernetics itself has changed

- An early interest was to build machines that emulate human intellectual activities, Wiener’s second industrial revolution
- A later driving interest was to understand human cognition and understanding itself
- A more recent emphasis has been on social systems and the role of ideas in changing social systems
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**Three Versions of Cybernetics**
Engineering cybernetics 1

• A realist view of epistemology: knowledge is a picture of reality
• A key distinction: reality vs. scientific theories
• The puzzle to be solved: construct theories which explain observed phenomena
Engineering cybernetics 2

• What must be explained: how the world works
• A key assumption: natural processes can be explained by scientific theories
• An important consequence: scientific knowledge can be used to modify natural processes to benefit people
Biological cybernetics 1

- A biological view of epistemology: how the brain functions
- A key distinction: realism vs. constructivism
- The puzzle to be solved: include the observer within the domain of science
Biological cybernetics 2

• What must be explained: how an individual constructs a “reality”
• A key assumption: ideas about knowledge should be rooted in neurophysiology
• An important consequence: if people accept constructivism, they will be more tolerant
Social cybernetics 1

- A pragmatic view of epistemology: knowledge is constructed to achieve human purposes
- A key distinction: the biology of cognition vs. the observer as a social participant
- The puzzle to be solved: explain the relationship between the natural and the social sciences
Social cybernetics 2

• What must be explained: how people create, maintain, and change social systems through language and ideas

• A key assumption: ideas are accepted if they serve the observer’s purposes as a social participant

• An important consequence: by transforming conceptual systems (through persuasion, not coercion), we can change society
The contributions of cybernetics

- Develop a theory of circular or regulatory phenomena including goal seeking and goal formulation
- Create a theory of perception, learning, cognition, adaptation, meaning, understanding
- Include the observer within the domain of science
- Create a theory of the use of knowledge in society, reflexivity
Conclusions

• Cybernetics is transdisciplinary
• It requires some knowledge of neurophysiology, mathematics, philosophy, psychology, etc.
• Cybernetics provides a general theory of information processing and decision-making
Fundamentals and History of Cybernetics 2

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Early cybernetics

• Definitions of cybernetics
• Feedback and control
• A theory of adaptation
• Types of regulation
• The law of requisite variety
• Amplification of regulatory capability
• Self-organizing systems
Definitions of cybernetics 1

• Ampere: the science of government
• Norbert Wiener: the science of control and communication in animal and machine
• Warren McCulloch: experimental epistemology
• Stafford Beer: the science of effective organization
Definitions of cybernetics 2

• Gregory Bateson: a science of form and pattern rather than substance
• Gordon Pask: the art of manipulating defensible metaphors
• Jean Piaget: the endeavor to model the processes of cognitive adaptation in the human mind
Ashby’s definition of a system

- A set of variables selected by an observer
- Assumes the variables are related and the observer has a purpose for selecting those variables
- Multiple views of copper as a material
- Multiple views of a corporation
Variables: Vector descriptions

• Weather: temperature, pressure, humidity
• Automobile instrument panel: speed, fuel, temperature, oil pressure, generator
• Medical records: height, weight, blood pressure, blood type
• Corporation: assets, liabilities, sales, profits or losses, employees
• Stock exchange: high, low, close, volume
States

- A state is an event
- The value of a vector at a particular time defines a state
- The behavior of a system can be described as a sequence of states
Causal influence diagram

- Shows relationships among variables
- Signs on arrows
  + Two variables move in the same direction
  - Two variables move in opposite directions
- Signs on loops
  Positive: reinforcing loop
  Negative: balancing loop
FIRST ORDER CYBERNETICS

1. Regulation
2. The law of requisite variety
3. Self-organization
Trivial and nontrivial systems

- A trivial system reliably responds in the same way to a given input: a machine
- A nontrivial system can at different times give a different output to the same input
- The input triggers not just an output but also an internal change
- We like, and try to produce, trivial systems
- Nontrivial systems are hard to control
- For a trivial system new information means the system is broken
Ashby’s theory of adaptation

- A system can learn if it is able to acquire a pattern of behavior that is successful in a particular environment.
- This requires not repeating unsuccessful actions and repeating successful actions.
- A system can adapt if it can learn a new pattern of behavior after recognizing that the environment has changed and that the old pattern of behavior is not working.
Two nested feedback loops

- A system with two nested feedback loops can display adaptive behavior.
- The interior, more frequent feedback loop makes small adjustments and enables learning.
- The exterior, less frequent feedback loop restructures the system (wipes out previous learning), thus permitting new learning.
Regulation

• Error-controlled regulation
  – Feedback loop
  – Thermostat

• Cause-controlled regulation
  – Disturbance, regulator, system, outcome
  – Building schools to accommodate children
The law of requisite variety

• **Information and selection**
  – “The amount of selection that can be performed is limited by the amount of information available”

• **Regulator and regulated**
  – “The variety in a regulator must be equal to or greater than the variety in the system being regulated”

• **W. Ross Ashby**
The law of requisite variety examples

- A quantitative relationship between information and selection: admitting students to a university
- The variety in the regulator must be at least as great as the variety in the system being regulated: buying a computer
- Example of selling computers to China
The Conant and Ashby theorem

• Based on the Law of Requisite Variety
• Every good regulator of a system must be a model of that system: statements linking cause and effect are needed
• Jay Forrester’s corollary: the usefulness of a mathematical simulation model should be judged in comparison not with an ideal model but rather with the mental image which would be used instead
Amplification examples

• A hydraulic lift in a gas station
• A sound amplifier
• Reading the President’s mail
Mechanical power amplification

• Simply by moving a switch an average person, indeed a child, can lift an automobile
• How is that possible?
• Electricity powers a pump that uses compressed air to move hydraulic fluid
• The fluid presses with the same force in all directions
• A large piston creates a large force
Electrical power amplification

• At a rock concert a person speaking or singing on stage can be heard by thousands of people
• How is that possible?
• Electricity flows through a series of “valves”
• Each “valve” uses a small signal to control a larger flow of electricity
Amplification of decision-making

• A grade school child who writes a letter to the President of the United States receives a reply

• How is that possible? The President is very busy

• In the White House a group of people write letters for the President

• An administrator manages the letter writers
Amplifying regulatory capability

- One-to-one regulation of variety: football, war, assumes complete hostility
- One-to-one regulation of disturbances: crime control, management by exception
- Changing the rules of the game: anti-trust regulation, preventing price fixing
- Changing the game: the change from ideological competition to sustainable development
Coping with complexity

When faced with a complex situation, there are only two choices

1. Increase the variety in the regulator: hire staff or subcontract

2. Reduce the variety in the system being regulated: reduce the variety one chooses to control
Self-organization
The historical problem

- Ashby: Can a mechanical chess player outplay its designer?
- Should an artificial intelligence device be designed, or should it learn?
- Is the task to create useful equipment or to understand cognitive processes?
- AI people chose to design equipment
- Cyberneticians chose to study learning
Conferences on self-organization

- Three conferences on self-organization were held around 1960
- The original conception was that a self-organizing system interacted with its environment
- Von Foerster opposed this conception
Three thought experiments

- Magnetic cubes in a box with ping pong balls as separators
- In first experiment all faces of all cubes have positive charges facing out
- In second experiment 3 of 6 faces of each cube have positive charges facing out
- In third experiment 5 of 6 faces of each cube have positive charges facing out
Von Foerster’s “order from noise”

• The box is open to energy. Shaking the box provides energy
• The box is closed to information. During each experiment the interaction rules among the cubes do not change
• For the first two experiments the results are not surprising and not interesting
• In the third experiment new “order” appears
Ashby’s principle of self-organization

• Any isolated, determinate, dynamic system obeying unchanging laws will develop organisms that are adapted to their environments

• Organisms and environments taken together constitute the self-organizing system
Information theory

• Shannon’s measure of uncertainty

\[ H = \frac{N \log N - n_1 \log n_1 - \ldots - n_k \log n_k}{N} \]

- \( N \) = Number of Elements
- \( k \) = number of categories
- \( n_1 \) = number of elements in the first category

• Redundancy as a measure of organization

\[ R = \frac{H \text{ (actual)}}{H \text{ (max)}} \]
Automatic Processes

• Imagine a system composed of states. Some states are stable. Some are not. The system will tend to move toward the stable equillibrial states. As it does, it selects. These selections constitute self-organization.

• Every system as it goes toward equilibrium organizes itself.
Examples of self-organization

- Competitive exclusion in a number system
- The US telegraph industry
- Behavior in families
- Amasia
- Learning, ASS
- Structure as a cause: NE blackout
A general design rule

• In order to change any system, expose it to an environment such that the interaction between the system and its environment moves the system in the direction you want it to go

• Examples
  – making steel
  – educating a child
  – incentive systems
  – government regulation
Ashby’s conception of self-organization

- It is a very general theory
- It encompasses Darwin’s theory of natural selection and learning theory
- It emphasizes the selection process rather than the generation of new variety
- It can explain “emergence” because selection at a lower level can lead to new variety at a higher level
Conventional conceptions of open and closed systems

• Open
  Receptive to new information
• Closed
  Not open to new information
  Rigid, unchanging, dogmatic
Scientific conceptions of open and closed systems

- Physics: entropy increases in thermodynamically closed systems
- Biology: living systems are open to matter/energy and information
- Management: from closed to open systems conceptualizations
- Self-organization: open to energy, closed to information (interaction rules do not change)
Review of early cybernetics

• Feedback and control
• A theory of adaptation
• Types of regulation
• The law of requisite variety
• Amplification of regulatory capability
• Conceptions of self organization
Fundamentals and History of Cybernetics 3

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Second order cybernetics
Second order cybernetics

- Definitions
- Origins in several fields
- Autopoiesis
- The philosophy of constructivism
- Practical significance
First and second order cybernetics

- Observed systems
- The purpose of a model
- Controlled systems
- Interaction among variables in a system
- Theories of social systems

- Observing systems
- The purpose of the modeler
- Autonomous sys.
- Interaction between observer and observed
- Theories of the interaction between ideas and society
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• A realist view of epistemology: knowledge is a picture of reality
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- What must be explained: how the world works
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• An important consequence: if people accept constructivism, they will be more tolerant
Fields originating 2nd order cybernetics

- Linguistics -- language limits what can be discussed
- Mathematics -- self-referential statements lead to paradox
- Neurophysiology -- observations independent of the characteristics of the observer are not physically possible
Mathematics

• Paradox, a form of inconsistency
• A set that contains itself
  – The men who are shaved by the barber
  – The men who shave themselves
  – Who shaves the barber?
• Self-referential statements and undecidability
Ramon y Cahal

- Principle of undifferentiated encoding
- What I perceive is not light or sound or touch or taste but rather “this much” at “this point” on my body
- Inside the nervous system there are only “bips” passing from neuron to neuron
- Homunculus
Autopoiesis

• The origin of the term was in biology: how to distinguish living from non-living systems
• Allopoiesis means “other production”: an assembly line
• Autopoiesis means “self production”: the biological processes that preserve life or the processes that maintain a corporation
How the nervous system works

- The blind spot
- Move your eyes within your head
- Image on your retina
- Glasses that turn the world upside down
- Listening to a speech
- Conversations at a party
- Injured war veterans
- The kitten that could not see
Objects: tokens for eigen behaviors

- What is an object? Consider a table
- I can write on it, eat off of it, crawl under it, burn it
- I know how it feels and sounds
- I have had many experiences with tables
- To these experiences I attach a label or token -- “table”
- A computer can change “table” to “Tisch” but it has had no experiences with tables
Constructivist Logic

• To learn whether our knowledge is true we would have to compare it with “reality”
• But our knowledge of the world is mediated by our senses
• Each of us constructs a “reality” based on our experiences
Constructivism

• This “reality” is reinforced or broken when communicating with others
• Knowledge, and views of the world, are negotiated
• How do we know what we think we know?
• Any statement by an observer is primarily a statement about the observer
Heinz von Foerster

- The logic of the world is the logic of descriptions of the world
- Perception is the computation of descriptions of the world
- Cognition is the computation of computation of ...
Applications of constructivism

• Therapy: from the history of an individual to assuming adaptation to an unusual environment
• Teaching: from memorizing to reinventing the world
• Artificial intelligence vs. learning automata
• Management: harmonizing different “realities”
Types of observer effects

• Sociology of knowledge
• What is observed -- elementary particles, Heisenberg uncertainty principle
• Relative velocity of observer and observed -- relativity theory
• Neurophysiology of cognition -- observations independent of the characteristics of the observer are not physically possible
In honor of von Foerster

If the world is that which I see,
And that which I see defines me,
   And for each it’s the same,
Then who is to blame,
And is this what it means to be free?
Second order cybernetics is

• An addition to science – pay attention to the observer
• An addition to the philosophy of science – observers exist in all fields, not just one field
• An effort to change society, to increase tolerance
Second order cybernetics Review

- The cybernetics of observing systems
- Definitions
- Origins in several fields
- Autopoiesis
- The philosophy of constructivism
- Practical significance
- An addition to the philosophy of science
A tutorial presented at the

World Multi-Conference on Systemics, Cybernetics, and Informatics

Orlando, Florida
July 16, 2006
Interpreting implications

• “Although people are free to construct their own realities their constructions must fit experience.” – Von Glasersfeld
• “I am claiming an ontology” – Maturana
• “People create conceptual systems which fit the purposes they are trying to achieve within a social setting” - Umpleby
An American strategy vs. a European strategy (1)

- Knowledge is based on an assessment of the situation
- Influenced by British empiricism and American pragmatism
- Question: What does American society need now?

- Knowledge is prior to action
- Influenced by German idealism
- Question: What do philosophy and science need now?
An American strategy vs. a European strategy (2)

• Answer: People should be concerned about their responsibilities as well as their rights

• Recommendation: Citizens should become more involved in public affairs

• Answer: The observer should be included within the domain of science

• Recommendation: Scientists should use a constructivist as opposed to a realist epistemology
An American strategy vs. a European strategy (3)

- Theories are imperfect descriptions of the phenomenon described.
- Action is based on social role.
- Ideas are important if they enable more effective action in the world.
- The inner world has primacy over the outer world.
- Action is based on philosophical position.
- The free realm of ideas is preferred over the necessary realm of matter.
An American strategy vs. a European strategy (4)

- The public interest is debated by the citizenry
- Arguments are addressed to educated citizens, and also academics
- Social change requires changing policies, laws, and institutions, not just ideas
- The public interest is debated primarily in a university
- Arguments are addressed to professional intellectuals
- If ideas about the nature of knowledge change, change in science and society will follow
An American strategy vs. a European strategy (5)

- Focus on certain academic disciplines -- economics, sociology, political science
- An historical experience of domination by a remote government
- The key task of society is to protect individual liberties
- Attempt to alter the conception of knowledge, regardless of discipline
- An historical experience of political chaos and disorder
- A key task of society is to control dissent
An American strategy vs. a European strategy (6)

- A high regard for practical, not theoretical, knowledge
- Tolerance is justified by respect for the individual, by empathy with others, and by the desire to ensure one’s own liberties by protecting those of others

- A high regard for philosophical thought
- Tolerance is justified by our knowledge of neurophysiology and the consequent inability of the individual to be certain of his or her beliefs
An American strategy vs. a European strategy (7)

• Intolerance is restrained by morality and law

• Tolerance and respect for others are axioms, a starting point

• Intolerance is inappropriate given the imperfect nature of our knowledge

• The appropriateness of tolerance is the conclusion of a scientific investigation; “others” are needed to confirm or challenge our beliefs
Fundamentals and History of Cybernetics 4

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Reflexivity
What is “reflexivity” and why is it important?

• Definitions
• As context, the informal fallacies
• Descriptions of three reflexive theories
  – Heinz von Foerster
  – Vladimir Lefebvre
  – George Soros
Definitions

• “reflection” – the return of light or sound waves from a surface; the action of bending or folding back; an idea or opinion made as a result of meditation

• “reflexive” -- a relation that exists between an entity and itself

• “self-reference” – such statements lead to paradox, a form of logical inconsistency
The informal fallacies

1. Fallacies of presumption which are concerned with errors in thought – circular reasoning, circular causality

2. Fallacies of relevance which raise emotional considerations – the ad hominem fallacy, including the observer

3. Fallacies of ambiguity which involve problems with language – levels of analysis, self-reference
Cybernetics and the informal fallacies

- Cybernetics violates all three informal fallacies
- It does not “sound right.” People conclude it cannot “be right”
- But the informal fallacies are just “rules of thumb”
A decision is required

• Should traditions concerning the FORM of arguments limit the SCOPE of science?
• Or, should the subject matter of science be guided by curiosity and the desire to construct explanations of phenomena?
• Cyberneticians have chosen to study certain phenomena, even if they need to use unconventional ideas and methods
Three reflexive theories

• Heinz von Foerster: Include the observer in the domain of science (1974)
• Vladimir Lefebvre: Reflect on the ethical system one is using (1982)
• George Soros: Individuals are actors as well as observers of economic and political systems (1987)
Von Foerster’s reflexive theory

• The observer should be included within the domain of science
• A theory of biology should be able to explain the existence of theories of biology
• “Reality” is a personal construct
• Individuals bear ethical responsibility not only for their actions but also for the world as they perceive it
First and second ethical systems

- If there is a conflict between means and ends, one **SHOULD** be concerned
- A bad means **SHOULD NOT** be used to achieve a good end
- This ethical system dominates in the West

- If there is a conflict between means and ends, one **SHOULD NOT** be concerned
- A bad means **CAN** be used to achieve a good end
- This ethical system was dominant in the former USSR
First and second ethical systems

- A saint is willing to compromise and has low self-esteem
- A hero is willing to compromise and has high self-esteem
- A philistin chooses confrontation and has low self-esteem
- A dissembler chooses confrontation and has high self-esteem
- A saint is willing to confront and has low self-esteem
- A hero is willing to confront and has high self-esteem
- A philistin chooses compromise and has low self-esteem
- A dissembler chooses compromise and has high self-esteem
Lefebvre’s reflexive theory

- There are two systems of ethical cognition
- People are “imprinted” with one or the other ethical system at an early age
- One’s first response is always to act in accord with the imprinted ethical system
- However, one can learn the other ethical system and act in accord with it when one realizes that the imprinted system is not working
Uses of Lefebvre’s theory

• Was used at the highest levels in both the US and the USSR during the collapse of the USSR to prevent misunderstandings
• Was NOT used during the break up of the former Yugoslavia
• People in Sarajevo said in 2004 that Lefebvre’s theory both explained why the war happened and why conflict remains
• Is currently being used in education and in psychotherapy in Russia
Soros’s reflexive theory

- Soros’s theory is compatible with second order cybernetics and other systems sciences
- Soros uses little of the language of cybernetics and systems science
- Soros’s theory provides a link between second order cybernetics and economics, finance, and political science
Reception of Soros’s work

• Soros’s theory is not well-known in the systems and cybernetics community
• Soros’s theory is not yet widely used by economists or finance professors, despite his success as a financial manager
• Soros has a participatory, not purely descriptive, theory of social systems
Soros on the philosophy of science

• Soros rejects Popper’s conception of “the unity of method,” the idea that all disciplines should use the same methods of inquiry as the natural sciences

• Soros says in social systems there are two processes – observation and participation

• The natural sciences require only observation
Two contextual ideas

• A general theory of the evolution of systems
• Ways of describing systems
Karl Mueller’s epigenetic theory
Types of societies

- Darwinian society – new variety is the result of genetic drift
- Piagetian society – organisms with complex brains have the ability to change their behavior within the lifetime of a single individual
- Polayni society – people come together to create societies that regulate behavior
- Turing society – some decision-making is delegated to programmed controllers
A model of social change using four methods for describing systems
Ways that disciplines describe social systems

- Variables – physics, economics
- Events – computer science, history
- Groups – sociology, political science
- Ideas – psychology, philosophy, cultural anthropology
- Interaction between ideas and events, a “shoelace model”
How social systems change

• Study a social system (variables) and generate a reform proposal (idea)
• Persuade and organize people to support the idea (groups)
• Produce some change, for example pass a law (event)
• Study the effects of the legislation on the social system (variables)
<table>
<thead>
<tr>
<th>Ideas</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest in trade and in ancient learning</td>
<td>1096 First Crusade</td>
</tr>
<tr>
<td>Science and technology stimulated by desire to improve trade</td>
<td>Marco Polo’s trip to China</td>
</tr>
<tr>
<td>The idea of progress, people strive to produce more than mere subsistence</td>
<td>Traders accumulate wealth, nation-states develop and protect trade routes</td>
</tr>
<tr>
<td>Adam Smith’s <em>The Wealth of Nations</em>, 1776</td>
<td>Industrial Revolution in England</td>
</tr>
<tr>
<td>Marx and Engles, <em>The Communist Manifesto</em>, 1848</td>
<td>Capital accumulation, urbanization, growing gap between rich and poor</td>
</tr>
<tr>
<td>Social reform movements in industrializing countries</td>
<td>Revolutions in Europe, demands for more equal distribution of wealth</td>
</tr>
<tr>
<td>Keynes’s theory justifying government intervention in the economy</td>
<td>World War I and the Great Depression</td>
</tr>
<tr>
<td>Friedman’s monetary policy</td>
<td>World War II., World Bank and IMF established, decolonization of the Third World</td>
</tr>
<tr>
<td>Environmental movement and futures research movement, many conferences on the “world problematique”</td>
<td>Oil crisis in 1973 leads to abandonment of gold standard and fluctuating exchange rates</td>
</tr>
<tr>
<td></td>
<td>Economic progress in Asia, liberalization of communist regimes</td>
</tr>
</tbody>
</table>
Advantages of using all four methods

- A richer description of the social system is produced
- Important considerations are less likely to be overlooked
- The theories and methods of more than one discipline are used
Specific advantages

• The interests of more groups are likely to be included in the analysis
• The beliefs and values of the people involved, hence culture, are likely to be considered
• Actions to produce change (events) probably will be discussed
• The results of actions are more likely to be measured (variables)
How reflexivity theory is different

• Classical scientific theories operate in the realm of VARIABLES and IDEAS
• Soros’s reflexivity theory describes the whole process of social change – IDEAS, GROUPS, EVENTS, VARIABLES, IDEAS
• Reflexivity is the process of shifting back and forth between description and action
A reflexive theory operates at two levels
Cognitive Function

Underlying trend of stock price +

Prevailing bias +

Participating Function

The two functions in reflexivity theory
The efficient market hypothesis

- Economists assume that markets are efficient and that information is immediately reflected in market prices
- Soros says that markets are always biased in one direction or another
- Markets can influence the events they anticipate
Equilibrium vs. reflexivity

- An increase in demand will lead to higher prices which will decrease demand.
- A drop in supply will lead to a higher price which will increase supply.
- For “momentum investors” rising price is a sign to buy, hence further increasing price.
- A falling price will lead many investors to sell, thus further reducing price.
Equilibrium theory assumes negative feedback; reflexivity theory observes positive feedback.
Examples in business and economics

- The conglomerate boom
- Real Estate Investment Trusts (REITs)
- The venture capital boom and collapse
- The credit cycle
- The currency market
The conglomerate boom: Events

- A high tech company with a high P/E ratio begins to diversify
- It buys consumer goods companies with high dividends but low P/E ratios
- As earnings improve, the price of the conglomerate rises
- A high stock price means greater ability to borrow
The conglomerate boom (continued)

• The conglomerate borrows to buy more consumer goods companies
• Earnings per share continue to grow
• Investors eagerly buy more stock
• Eventually people realize that the character of the company has changed and a high P/E ratio is not justified
The conglomerate boom: Ideas

• Conventional view
• Rising earnings per share (EPS) mean the company has found the secret of good management

• Reflexive view
• Rising EPS is an indicator that the character of the company has changed, from high tech to consumer goods, and a high P/E ratio is no longer justified
The conglomerate boom: Groups

- Corporate managers who buy other companies
- Investors who believe in something new and foolproof
- Investors who use Reflexivity Theory
The conglomerate boom, variables
The venture capital boom
The credit cycle
Value of the $ 

Price of imports 

Inflation 

Demand for imports (due to large import component in exports) 

Domestic wages 

Price of exports 

Amount of exports 

Production 

Reflexivity in the currency market
Finance professors vs. Soros

• Most academic work in the field of finance involves building mathematical models
• Soros treats finance as a multi-person game involving human players, including himself
• Behavioral finance is a growing field, but it tends to focus on defining limits to the assumption that people are rational actors
The process of selecting a portfolio

1. Observation and experience
2. Beliefs about future performances (Soros focuses here)
3. Choice of portfolios (Markowitz focuses here)
Equilibrium vs. Reflexivity

- Information becomes immediately available to everyone
- People are rational actors
- Economic systems go quickly to equilibrium

- People act on incomplete information
- People are influenced by their biases
- Social systems display boom and bust cycles
Equilibrium vs. Reflexivity

- A theorist is outside the system observed
- Scientists should build theories using quantifiable variables
- Theories do not alter the system described
- Observers are part of the system observed
- Scientists should use a variety of descriptions of systems (e.g., ideas, groups, events, variables)
- Theories are a means to change the system described
Equilibrium vs. Reflexivity

- Complete information
- Rationality
- Equilibrium

- Incomplete info.
- Bias
- Disequilibrium
- Gaps between perception and reality
- Boom and bust cycles
Soros on political systems

• Look for gaps between perception and “reality”
• A large gap means the system is unstable
• When people realize that description and reality are far apart, legitimacy collapses
• For example, glasnost destroyed the legitimacy of the USSR Communist Party
Misperceiving the USSR

- Soviet studies experts in the West assumed the convergence theory -- The West would adopt elements of a welfare state and the USSR would liberalize
- The West did adopt some elements of welfare states
- The USSR did not liberalize, as China is now doing, at least in its economy
Soros looks for

• Rapid growth: Positive feedback systems – conglomerate boom, credit cycle, REITs, the high tech bubble

• Instability before collapse: Gaps between perception and reality – conglomerate boom, etc., claims of USSR Communist Party, overextension of US power
Soros’s contributions

• Soros’s theories expand the field of finance beyond mathematical models to anticipating the behavior of financial participants
• Soros offers an alternative to equilibrium theory as the foundation of economics
• Soros suggests a way to anticipate major political changes
• Soros’s reflexivity theory provides links between cybernetics and economics, finance, and political science
Unifying epistemologies
The cybernetics of science

NORMAL SCIENCE

The correspondence principle

Incommensurable definitions

SCIENTIFIC REVOLUTION
<table>
<thead>
<tr>
<th>Author</th>
<th>First Order Cybernetics</th>
<th>Second Order Cybernetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Von Foerster</td>
<td>The cybernetics of observed systems</td>
<td>The cybernetics of observing systems</td>
</tr>
<tr>
<td>Pask</td>
<td>The purpose of a model</td>
<td>The purpose of a modeler</td>
</tr>
<tr>
<td>Varela</td>
<td>Controlled systems</td>
<td>Autonomous systems</td>
</tr>
<tr>
<td>Umpleby</td>
<td>Interaction among the variables in a system</td>
<td>Interaction between observer and observed</td>
</tr>
<tr>
<td>Umpleby</td>
<td>Theories of social systems</td>
<td>Theories of the interaction between ideas and society</td>
</tr>
</tbody>
</table>

Definitions of First and Second Order Cybernetics
The Correspondence Principle

• Proposed by Niels Bohr when developing the quantum theory

• Any new theory should reduce to the old theory to which it corresponds for those cases in which the old theory is known to hold

• A new dimension is required
An Application of the Correspondence Principle

New philosophy of science

Old philosophy of science

Amount of attention paid to the observer
<table>
<thead>
<tr>
<th>Three Versions of Cybernetics</th>
<th>Engineering Cybernetics</th>
<th>Biological Cybernetics</th>
<th>Social Cybernetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>The view of epistemology</td>
<td>A realist view of epistemology: knowledge is a “picture” of reality</td>
<td>A biological view of epistemology: how the brain functions</td>
<td>A pragmatic view of epistemology: knowledge is constructed to achieve human purposes</td>
</tr>
<tr>
<td>A key distinction</td>
<td>Reality vs. scientific theories</td>
<td>Realism vs. Constructivism</td>
<td>The biology of cognition vs. the observer as a social participant</td>
</tr>
<tr>
<td>The puzzle to be solved</td>
<td>Construct theories which explain observed phenomena</td>
<td>Include the observer within the domain of science</td>
<td>Explain the relationship between the natural and the social sciences</td>
</tr>
<tr>
<td>What must be explained</td>
<td>How the world works</td>
<td>How an individual constructs a “reality”</td>
<td>How people create, maintain, and change social systems through language and ideas</td>
</tr>
<tr>
<td>A key assumption</td>
<td>Natural processes can be explained by scientific theories</td>
<td>Ideas about knowledge should be rooted in neurophysiology.</td>
<td>Ideas are accepted if they serve the observer’s purposes as a social participant</td>
</tr>
<tr>
<td>An important consequence</td>
<td>Scientific knowledge can be used to modify natural processes to benefit people</td>
<td>If people accept constructivism, they will be more tolerant</td>
<td>By transforming conceptual systems (through persuasion, not coercion), we can change society</td>
</tr>
</tbody>
</table>

**Three Versions of Cybernetics**
Toward a larger view

• At a dinner in Vienna in November 2005 Karl Mueller mentioned Heinz von Foerster’s 1971 article “Computing in the Semantic Domain

• Von Foerster described a triangle and labeled two sides syntactics and semantics

• Mueller wondered what the third side would be
Creating a theory of epistemologies

• I suggested “pragmatics”

• Later in thinking about the triangle it occurred to me that the three sides corresponded to three points of view in the history of cybernetics

• The triangle suggested a way to unify previously competing epistemologies
<table>
<thead>
<tr>
<th>Syntactics</th>
<th>Semantics</th>
<th>Pragmatics</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_c(W,D)$</td>
<td>$R_w(D,C)$</td>
<td>$R_d(W,C)$</td>
</tr>
</tbody>
</table>

Determined by an organism’s behavioral potential

Gives rise to concepts such as “territory,” “control,” “objects,” and “names”

Determined by an organism’s cognitive potential

Gives rise to concepts such as “volition,” “action” “conceptions,” and “propositions”

Determined by an organism’s perceptive potential

Gives rise to concepts such as “niche,” “instinct,” “reality” and “consciousness”

---

Von Foerster’s epistemological triangle
## Epistemological triangle

<table>
<thead>
<tr>
<th>World and description</th>
<th>Observer and description</th>
<th>Observer and world</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syntactics</td>
<td>Semantics</td>
<td>Pragmatics</td>
</tr>
<tr>
<td>Representation</td>
<td>Coherence concept of truth</td>
<td>Pragmatic concept of truth</td>
</tr>
<tr>
<td>concept of truth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>British Empiricism</td>
<td>German Idealism</td>
<td>American Pragmatism</td>
</tr>
<tr>
<td>Inanimate Objects</td>
<td>Knowing Subjects</td>
<td>Social Reforms</td>
</tr>
<tr>
<td>Unquestioned Objectivity</td>
<td>Constructed Objectivity</td>
<td>Contested Objectivity</td>
</tr>
<tr>
<td>Form</td>
<td>Meaning</td>
<td>What works</td>
</tr>
</tbody>
</table>
Another use of the triangle

• In 1991 I made a table comparing constructivist cybernetics, or the work of von Foerster, with that of Popper and Kuhn

• It seems to me that the three columns in that table also can be mapped onto the triangle

• This suggests that cybernetics constitutes an important third perspective in the philosophy of science
<table>
<thead>
<tr>
<th>Popper</th>
<th>von Foerster</th>
<th>Kuhn</th>
</tr>
</thead>
<tbody>
<tr>
<td>A normative view of epistemology: how</td>
<td>A biological view of epistemology: how</td>
<td>A sociological view of epistemology: how</td>
</tr>
<tr>
<td>scientists should operate</td>
<td>the brain functions</td>
<td>scientists in fact operate</td>
</tr>
<tr>
<td>Non-science vs. science</td>
<td>Realism vs. constructivism</td>
<td>Steady progress vs. revolutions</td>
</tr>
<tr>
<td>Solve the problem of induction: conjectures</td>
<td>Include the observer within the domain of</td>
<td>Explain turmoil in original records vs.</td>
</tr>
<tr>
<td>and refutations</td>
<td>science</td>
<td>smooth progress in textbooks</td>
</tr>
<tr>
<td>How science as a picture of reality is</td>
<td>How an individual constructs a “reality”</td>
<td>How paradigms are developed and then replaced</td>
</tr>
<tr>
<td>tested and grows</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How science as a picture of reality is</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tested and grows</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific knowledge exists independent of</td>
<td>Ideas about knowledge should be rooted in</td>
<td>Even data and experiments are interpreted</td>
</tr>
<tr>
<td>human beings</td>
<td>neurophysiology</td>
<td></td>
</tr>
<tr>
<td>We can know what we know and do not know</td>
<td>If people accept this view, they will be</td>
<td>Science is a community activity</td>
</tr>
<tr>
<td></td>
<td>more tolerant</td>
<td></td>
</tr>
</tbody>
</table>
Popper’s three “worlds”

- “World” can be thought of as Popper’s “world one”
- “The observer” is what Popper meant by “world two”
- “Description” can be thought of as Popper’s “world three”
Cautions

- The fact that ideas can be plausibly mapped onto a triangle carries no meaning per se.
- However, an arrangement in the form of a diagram may reveal connections or missing pieces that had not been apparent before.
- A graphical representation of ideas is simply a heuristic device.
Implications of the triangle

- A step toward a theory of epistemologies
- Shows how the three epistemologies are related
- Not “choose one” but rather “use all three”
- Shows the importance of von Foerster in comparison with Popper and Kuhn
- Shows clearly what each epistemology tends to neglect
Implications of the triangle

• Suggests that an addition is needed to the distinction between Science One and Science Two or between Mode One and Mode Two knowledge
• Second order cybernetics is redefined
• No longer a competing epistemology but rather a theory of epistemologies
Overview of cybernetics

• Stages in the development of cybernetics: engineering, biology, social systems
• Areas of application: computer science and robotics, management, family therapy, epistemology, economics and political science
• Theoretical issues: the nature of information, knowledge, adaptation, learning, self-organization, cognition, autonomy, understanding
References

ADDITIONAL REFERENCES

Fundamentals and History of Cybernetics 2

Stuart A. Umpleby
The George Washington University
Washington, DC
www.gwu.edu/~umpleby
Early cybernetics

- Definitions of cybernetics
- Feedback and control
- A theory of adaptation
- Types of regulation
- The law of requisite variety
- Amplification of regulatory capability
- Self-organizing systems
Definitions of cybernetics

• Ampere: the science of government
• Norbert Wiener: the science of control and communication in animal and machine
• Warren McCulloch: experimental epistemology
• Stafford Beer: the science of effective organization
Definitions of cybernetics 2

- Gregory Bateson: a science of form and pattern rather than substance
- Gordon Pask: the art of manipulating defensible metaphors
- Jean Piaget: the endeavor to model the processes of cognitive adaptation in the human mind
Ashby’s definition of a system

• A set of variables selected by an observer
• Assumes the variables are related and the observer has a purpose for selecting those variables
• Multiple views of copper as a material
• Multiple views of a corporation
Variables: Vector descriptions

- Weather: temperature, pressure, humidity
- Automobile instrument panel: speed, fuel, temperature, oil pressure, generator
- Medical records: height, weight, blood pressure, blood type
- Corporation: assets, liabilities, sales, profits or losses, employees
- Stock exchange: high, low, close, volume
States

• A state is an event
• The value of a vector at a particular time defines a state
• The behavior of a system can be described as a sequence of states
Causal influence diagram

• Shows relationships among variables
• Signs on arrows
  + Two variables move in the same direction
  - Two variables move in opposite directions
• Signs on loops
  Positive: reinforcing loop
  Negative: balancing loop
FIRST ORDER CYBERNETICS

1. Regulation
2. The law of requisite variety
3. Self-organization
Trivial and nontrivial systems

- A trivial system reliably responds in the same way to a given input: a machine.
- A nontrivial system can at different times give a different output to the same input.
- The input triggers not just an output but also an internal change.
- We like, and try to produce, trivial systems.
- Nontrivial systems are hard to control.
- For a trivial system new information means the system is broken.
Ashby’s theory of adaptation

• A system can learn if it is able to acquire a pattern of behavior that is successful in a particular environment
• This requires not repeating unsuccessful actions and repeating successful actions
• A system can adapt if it can learn a new pattern of behavior after recognizing that the environment has changed and that the old pattern of behavior is not working
Two nested feedback loops

- A system with two nested feedback loops can display adaptive behavior.
- The interior, more frequent feedback loop makes small adjustments and enables learning.
- The exterior, less frequent feedback loop restructures the system (wipes out previous learning), thus permitting new learning.
Regulation

• Error-controlled regulation
  – Feedback loop
  – Thermostat

• Cause-controlled regulation
  – Disturbance, regulator, system, outcome
  – Building schools to accommodate children
The law of requisite variety

• Information and selection
  – “The amount of selection that can be performed is limited by the amount of information available”

• Regulator and regulated
  – “The variety in a regulator must be equal to or greater than the variety in the system being regulated”

• W. Ross Ashby
The law of requisite variety examples

- A quantitative relationship between information and selection: admitting students to a university
- The variety in the regulator must be at least as great as the variety in the system being regulated: buying a computer
- Example of selling computers to China
The Conant and Ashby theorem

• Based on the Law of Requisite Variety
• Every good regulator of a system must be a model of that system: statements linking cause and effect are needed
• Jay Forrester’s corollary: the usefulness of a mathematical simulation model should be judged in comparison not with an ideal model but rather with the mental image which would be used instead
Amplification examples

- A hydraulic lift in a gas station
- A sound amplifier
- Reading the President’s mail
Mechanical power amplification
Mechanical power amplification

- Simply by moving a switch an average person, indeed a child, can lift an automobile
- How is that possible?
- Electricity powers a pump that uses compressed air to move hydraulic fluid
- The fluid presses with the same force in all directions
- A large piston creates a large force
Electrical power amplification
Electrical power amplification

• At a rock concert a person speaking or singing on stage can be heard by thousands of people
• How is that possible?
• Electricity flows through a series of “valves”
• Each “valve” uses a small signal to control a larger flow of electricity
Amplification of decision-making

• A grade school child who writes a letter to the President of the United States receives a reply
• How is that possible? The President is very busy
• In the White House a group of people write letters for the President
• An administrator manages the letter writers
Amplifying regulatory capability

- One-to-one regulation of variety: football, war, assumes complete hostility
- One-to-one regulation of disturbances: crime control, management by exception
- Changing the rules of the game: anti-trust regulation, preventing price fixing
- Changing the game: the change from ideological competition to sustainable development
Coping with complexity

When faced with a complex situation, there are only two choices

1. Increase the variety in the regulator: hire staff or subcontract

2. Reduce the variety in the system being regulated: reduce the variety one chooses to control
Self-organization
The historical problem

• Ashby: Can a mechanical chess player outplay its designer?
• Should an artificial intelligence device be designed, or should it learn?
• Is the task to create useful equipment or to understand cognitive processes?
• AI people chose to design equipment
• Cyberneticians chose to study learning
Conferences on self-organization

• Three conferences on self-organization were held around 1960

• The original conception was that a self-organizing system interacted with its environment

• Von Foerster opposed this conception
Three thought experiments

- Magnetic cubes in a box with ping pong balls as separators
- In first experiment all faces of all cubes have positive charges facing out
- In second experiment 3 of 6 faces of each cube have positive charges facing out
- In third experiment 5 of 6 faces of each cube have positive charges facing out
Von Foerster’s “order from noise”

- The box is open to energy. Shaking the box provides energy.
- The box is closed to information. During each experiment the interaction rules among the cubes do not change.
- For the first two experiments the results are not surprising and not interesting.
- In the third experiment new “order” appears.
Early conception

Self-organizing system

Ashby’s conception

Self-organizing system

organism
organism
organism
organism
organism
organism
organism

environment
Ashby’s principle of self-organization

• Any isolated, determinate, dynamic system obeying unchanging laws will develop organisms that are adapted to their environments

• Organisms and environments taken together constitute the self-organizing system
Measuring organization

- Redundancy
  A measure of organization
- Shannon’s information theory
  Information is that which reduces uncertainty

\[ R = 1 - \frac{H_{\text{actual}}}{H_{\text{max}}} \]

Limiting cases

- Prob. categories: each element in its own category
- Prob. categories: all elements in 1 category

where \( H_{\text{max}} = \log N \)
Information theory

• Shannon’s measure of uncertainty
  \[ H = \frac{N \log N - n_1 \log n_1 - \ldots - n_k \log n_k}{N} \]
  \( N = \text{Number of Elements} \)
  \( k = \text{number of categories} \)
  \( n_1 = \text{number of elements in the first category} \)

• Redundancy as a measure of organization
  \[ R = \frac{H \text{ (actual)}}{H \text{ (max)}} \]
Automatic Processes

• Imagine a system composed of states. Some states are stable. Some are not.
  The system will tend to move toward the stable equillibrial states.
  As it does, it selects.
  These selections constitute self-organization.

• Every system as it goes toward equilibrium organizes itself.
Examples of self-organization

• Competitive exclusion in a number system
• The US telegraph industry
• Behavior in families
• Amasia
• Learning, ASS
• Structure as a cause: NE blackout
## Competitive Exclusion in an Number System

### Number Of

<table>
<thead>
<tr>
<th>Time</th>
<th>Competing Numbers</th>
<th>Evens</th>
<th>Odds</th>
<th>Zeros</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 7 6 4 9 5 3 2 0 8</td>
<td>5</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>7 2 4 6 5 5 6 0 0 8</td>
<td>7</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4 8 4 0 5 0 0 0 0 6</td>
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<td>1</td>
<td>5</td>
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<tr>
<td>4</td>
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<td>0</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>4 0 0 0 0 0 0 0 0 8</td>
<td>10</td>
<td>0</td>
<td>8</td>
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<tr>
<td>6</td>
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<td>9</td>
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<td>7</td>
<td>0 0 0 0 0 0 0 0 0 0</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>

### Partition

<table>
<thead>
<tr>
<th>Time</th>
<th>Partition</th>
<th>H</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N: n,n,, . . . , n</td>
<td>3.3219</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>10: 1,1,1,1,1,1,1,1,1,1</td>
<td>2.7219</td>
<td>.1806</td>
</tr>
<tr>
<td>3</td>
<td>10: 5,2,1,1,1</td>
<td>1.9610</td>
<td>.4097</td>
</tr>
<tr>
<td>4</td>
<td>10: 7,2,1</td>
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## Redundancy in the U.S. Telegraph Industry 1845-1900

<table>
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<th>YEAR</th>
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<td>1900</td>
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<td>146:</td>
<td>146</td>
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Redundancy in the U.S. Telegraph Industry 1845-1900

- The chart illustrates the trend of redundancy in the U.S. Telegraph Industry from 1845 to 1900.
- There is an overall increase in redundancy over the period, with significant growth from the 1870s to the 1890s.
- Key periods of growth include the late 1860s to early 1870s and the late 1880s to early 1890s.

**Key Points**
- **1845**: Initial stage with minimal redundancy.
- **1850**: Stability with slight increase.
- **1855**: Growth begins, redundancy starts to rise.
- **1860**: Steady increase; redundancy nearly doubles.
- **1865**: Consistent growth rate; redundancy more than doubles.
- **1870**: Significant increase; redundancy nearly quadruples.
- **1875**: Continues to rise but at a slower rate.
- **1880**: Further increase; redundancy nearly quintuples.
- **1885**: Steady growth; redundancy six times higher than in 1845.
- **1890**: Growth plateaus; redundancy about seven times higher than in 1845.
- **1900**: Near peak; redundancy eight times higher than in 1845.
A general design rule

• In order to change any system, expose it to an environment such that the interaction between the system and its environment moves the system in the direction you want it to go

• Examples
  – making steel
  – educating a child
  – incentive systems
  – government regulation
Ashby’s conception of self-organization

- It is a very general theory
- It encompasses Darwin’s theory of natural selection and learning theory
- It emphasizes the selection process rather than the generation of new variety
- It can explain “emergence” because selection at a lower level can lead to new variety at a higher level
Conventional conceptions of open and closed systems

- **Open**
  - Receptive to new information

- **Closed**
  - Not open to new information
  - Rigid, unchanging, dogmatic
Scientific conceptions of open and closed systems

- Physics: entropy increases in thermodynamically closed systems
- Biology: living systems are open to matter/energy and information
- Management: from closed to open systems conceptualizations
- Self-organization: open to energy, closed to information (interaction rules do not change)
Review of early cybernetics

- Feedback and control
- A theory of adaptation
- Types of regulation
- The law of requisite variety
- Amplification of regulatory capability
- Conceptions of self organization
A tutorial presented at the

World Multi-Conference on Systemics, Cybernetics, and Informatics

Orlando, Florida
July 16, 2006
Fundamentals and History of Cybernetics 3

Stuart A. Umpleby
The George Washington University
Washington, DC
www.gwu.edu/~umpleby
Second order cybernetics
Second order cybernetics

• Definitions
• Origins in several fields
• Autopoiesis
• The philosophy of constructivism
• Practical significance
First and second order cybernetics

- Observed systems
- The purpose of a model
- Controlled systems
- Interaction among variables in a system
- Theories of social systems
- Observing systems
- The purpose of the modeler
- Autonomous sys.
- Interaction between observer and observed
- Theories of the interaction between ideas and society
First order cybernetics 1

• A realist view of epistemology: knowledge is a picture of reality
• A key distinction: reality vs. scientific theories
• The puzzle to be solved: construct theories which explain observed phenomena
First order cybernetics 2

• What must be explained: how the world works
• A key assumption: natural processes can be explained by scientific theories
• An important consequence: scientific knowledge can be used to modify natural processes to benefit people
Second order cybernetics 1

• A biological view of epistemology: how the brain functions
• A key distinction: realism vs. constructivism
• The puzzle to be solved: include the observer within the domain of science
Second order cybernetics 2

• What must be explained: how an individual constructs a “reality”
• A key assumption: ideas about knowledge should be rooted in neurophysiology
• An important consequence: if people accept constructivism, they will be more tolerant
Fields originating 2nd order cybernetics

- Linguistics -- language limits what can be discussed
- Mathematics -- self-referential statements lead to paradox
- Neurophysiology -- observations independent of the characteristics of the observer are not physically possible
Mathematics

• Paradox, a form of inconsistency
• A set that contains itself
  – The men who are shaved by the barber
  – The men who shave themselves
  – Who shaves the barber?
• Self-referential statements and undecidability
Ramon y Cahal

• Principle of undifferentiated encoding
• What I perceive is not light or sound or touch or taste but rather “this much” at “this point” on my body
• Inside the nervous system there are only “bips” passing from neuron to neuron
• Homunculus
Autopoiesis

• The origin of the term was in biology: how to distinguish living from non-living systems

• Allopoiesis means “other production”: an assembly line

• Autopoiesis means “self production”: the biological processes that preserve life or the processes that maintain a corporation
How the nervous system works

• The blind spot
• Move your eyes within your head
• Image on your retina
• Glasses that turn the world upside down
• Listening to a speech
• Conversations at a party
• Injured war veterans
• The kitten that could not see
The blind spot experiment
Images on the retina are inverted
Injured war veteran
Objects: tokens for eigen behaviors

• What is an object? Consider a table
• I can write on it, eat off of it, crawl under it, burn it
• I know how it feels and sounds
• I have had many experiences with tables
• To these experiences I attach a label or token -- “table”
• A computer can change “table” to “Tisch” but it has had no experiences with tables
Constructivist Logic

- To learn whether our knowledge is true we would have to compare it with “reality”
- But our knowledge of the world is mediated by our senses
- Each of us constructs a “reality” based on our experiences
Constructivism

- This “reality” is reinforced or broken when communicating with others
- Knowledge, and views of the world, are negotiated
- How do we know what we think we know?
- Any statement by an observer is primarily a statement about the observer
Heinz von Foerster

- The logic of the world is the logic of descriptions of the world
- Perception is the computation of descriptions of the world
- Cognition is the computation of computation of ...
Applications of constructivism

• Therapy: from the history of an individual to assuming adaptation to an unusual environment
• Teaching: from memorizing to reinventing the world
• Artificial intelligence vs. learning automata
• Management: harmonizing different “realities”
Types of observer effects

- Sociology of knowledge
- What is observed -- elementary particles, Heisenberg uncertainty principle
- Relative velocity of observer and observed -- relativity theory
- Neurophysiology of cognition – observations independent of the characteristics of the observer are not physically possible
In honor of von Foerster

If the world is that which I see,
And that which I see defines me,
And for each it’s the same,
Then who is to blame,
And is this what it means to be free?
Second order cybernetics is

• An addition to science – pay attention to the observer

• An addition to the philosophy of science – observers exist in all fields, not just one field

• An effort to change society, to increase tolerance
Second order cybernetics Review

- The cybernetics of observing systems
- Definitions
- Origins in several fields
- Autopoiesis
- The philosophy of constructivism
- Practical significance
- An addition to the philosophy of science
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Interpreting implications

• “Although people are free to construct their own realities their constructions must fit experience.” – Von Glasersfeld
• “I am claiming an ontology” – Maturana
• “People create conceptual systems which fit the purposes they are trying to achieve within a social setting” - Umpleby
An American strategy vs. a European strategy (1)

- Knowledge is based on an assessment of the situation
- Influenced by British empiricism and American pragmatism
- Question: What does American society need now?

- Knowledge is prior to action
- Influenced by German idealism
- Question: What do philosophy and science need now?
An American strategy vs. a European strategy (2)

• Answer: People should be concerned about their responsibilities as well as their rights

• Recommendation: Citizens should become more involved in public affairs

• Answer: The observer should be included within the domain of science

• Recommendation: Scientists should use a constructivist as opposed to a realist epistemology
An American strategy vs. a European strategy (3)

- Theories are imperfect descriptions of the phenomenon described
- Action is based on social role
- Ideas are important if they enable more effective action in the world
- The inner world has primacy over the outer world
- Action is based on philosophical position
- The free realm of ideas is preferred over the necessary realm of matter
An American strategy vs. a European strategy (4)

• The public interest is debated by the citizenry

• Arguments are addressed to educated citizens, and also academics

• Social change requires changing policies, laws, and institutions, not just ideas

• The public interest is debated primarily in a university

• Arguments are addressed to professional intellectuals

• If ideas about the nature of knowledge change, change in science and society will follow
An American strategy vs. a European strategy (5)

- Focus on certain academic disciplines -- economics, sociology, political science
- An historical experience of domination by a remote government
- The key task of society is to protect individual liberties
- Attempt to alter the conception of knowledge, regardless of discipline
- An historical experience of political chaos and disorder
- A key task of society is to control dissent
An American strategy vs. a European strategy (6)

- A high regard for practical, not theoretical, knowledge
- Tolerance is justified by respect for the individual, by empathy with others, and by the desire to ensure one’s own liberties by protecting those of others

- A high regard for philosophical thought
- Tolerance is justified by our knowledge of neurophysiology and the consequent inability of the individual to be certain of his or her beliefs
An American strategy vs. a European strategy (7)

- Intolerance is restrained by morality and law
- Tolerance and respect for others are axioms, a starting point
- Intolerance is inappropriate given the imperfect nature of our knowledge
- The appropriateness of tolerance is the conclusion of a scientific investigation; “others” are needed to confirm or challenge our beliefs
Fundamentals and History of Cybernetics 4

Stuart A. Umpleby
The George Washington University
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www.gwu.edu/~umpleby
Reflexivity
Observation

Self-awareness
Reflexivity in a social system
What is “reflexivity” and why is it important?

• Definitions
• As context, the informal fallacies
• Descriptions of three reflexive theories
  – Heinz von Foerster
  – Vladimir Lefebvre
  – George Soros
Definitions

• “reflection” – the return of light or sound waves from a surface; the action of bending or folding back; an idea or opinion made as a result of meditation

• “reflexive” -- a relation that exists between an entity and itself

• “self-reference” – such statements lead to paradox, a form of logical inconsistency
The informal fallacies

1. Fallacies of presumption which are concerned with errors in thought – circular reasoning, circular causality

2. Fallacies of relevance which raise emotional considerations – the ad hominem fallacy, including the observer

3. Fallacies of ambiguity which involve problems with language – levels of analysis, self-reference
Cybernetics and the informal fallacies

- Cybernetics violates all three informal fallacies
- It does not “sound right.” People conclude it cannot “be right”
- But the informal fallacies are just “rules of thumb”
A decision is required

• Should traditions concerning the FORM of arguments limit the SCOPE of science?
• Or, should the subject matter of science be guided by curiosity and the desire to construct explanations of phenomena?
• Cyberneticians have chosen to study certain phenomena, even if they need to use unconventional ideas and methods
Three reflexive theories

• Heinz von Foerster: Include the observer in the domain of science (1974)
• Vladimir Lefebvre: Reflect on the ethical system one is using (1982)
• George Soros: Individuals are actors as well as observers of economic and political systems (1987)
Von Foerster’s reflexive theory

• The observer should be included within the domain of science
• A theory of biology should be able to explain the existence of theories of biology
• “Reality” is a personal construct
• Individuals bear ethical responsibility not only for their actions but also for the world as they perceive it
First and second ethical systems

• If there is a conflict between means and ends, one SHOULD be concerned
• A bad means should NOT be used to achieve a good end
• This ethical system dominates in the West

• If there is a conflict between means and ends, one SHOULD NOT be concerned
• A bad means CAN be used to achieve a good end
• This ethical system was dominant in the former USSR
First and second ethical systems

- A saint is willing to compromise and has low self-esteem
- A hero is willing to compromise and has high self-esteem
- A philistine chooses confrontation and has low self-esteem
- A dissembler chooses confrontation and has high self-esteem
- A saint is willing to confront and has low self-esteem
- A hero is willing to confront and has high self-esteem
- A philistine chooses compromise and has low self-esteem
- A dissembler chooses compromise and has high self-esteem
Lefebvre’s reflexive theory

• There are two systems of ethical cognition
• People are “imprinted” with one or the other ethical system at an early age
• One’s first response is always to act in accord with the imprinted ethical system
• However, one can learn the other ethical system and act in accord with it when one realizes that the imprinted system is not working
Uses of Lefebvre’s theory

• Was used at the highest levels in both the US and the USSR during the collapse of the USSR to prevent misunderstandings
• Was NOT used during the break up of the former Yugoslavia
• People in Sarajevo said in 2004 that Lefebvre’s theory both explained why the war happened and why conflict remains
• Is currently being used in education and in psychotherapy in Russia
Soros’s reflexive theory

• Soros’s theory is compatible with second order cybernetics and other systems sciences
• Soros uses little of the language of cybernetics and systems science
• Soros’s theory provides a link between second order cybernetics and economics, finance, and political science
Reception of Soros’s work

• Soros’s theory is not well-known in the systems and cybernetics community
• Soros’s theory is not yet widely used by economists or finance professors, despite his success as a financial manager
• Soros has a participatory, not purely descriptive, theory of social systems
Soros on the philosophy of science

- Soros rejects Popper’s conception of “the unity of method,” the idea that all disciplines should use the same methods of inquiry as the natural sciences.
- Soros says in social systems there are two processes – observation and participation.
- The natural sciences require only observation.
Two contextual ideas

• A general theory of the evolution of systems
• Ways of describing systems
Karl Mueller’s epigenetic theory
Types of societies

• Darwinian society – new variety is the result of genetic drift

• Piagetian society – organisms with complex brains have the ability to change their behavior within the lifetime of a single individual

• Polayni society – people come together to create societies that regulate behavior

• Turing society – some decision-making is delegated to programmed controllers
A model of social change using four methods for describing systems
Ways that disciplines describe social systems

• Variables – physics, economics
• Events – computer science, history
• Groups – sociology, political science
• Ideas – psychology, philosophy, cultural anthropology
• Interaction between ideas and events, a “shoelace model”
How social systems change

• Study a social system (variables) and generate a reform proposal (idea)
• Persuade and organize people to support the idea (groups)
• Produce some change, for example pass a law (event)
• Study the effects of the legislation on the social system (variables)
<table>
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<tr>
<th>Ideas</th>
<th>Events</th>
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<tbody>
<tr>
<td>Interest in trade and in ancient learning</td>
<td>1096 First Crusade</td>
</tr>
<tr>
<td>Science and technology stimulated by desire to improve trade</td>
<td>Marco Polo’s trip to China</td>
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<tr>
<td>The idea of progress, people strive to produce more than mere subsistence</td>
<td>Traders accumulate wealth, nation-states develop and protect trade routes</td>
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<tr>
<td>Adam Smith’s <em>The Wealth of Nations</em>, 1776</td>
<td>Industrial Revolution in England</td>
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<tr>
<td>Marx and Engles, <em>The Communist Manifesto</em>, 1848</td>
<td>Capital accumulation, urbanization, growing gap between rich and poor</td>
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<td>Social reform movements in industrializing countries</td>
<td>Revolutions in Europe, demands for more equal distribution of wealth</td>
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<tr>
<td>Keynes’s theory justifying government intervention in the economy</td>
<td>World War I and the Great Depression</td>
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<tr>
<td>Friedman’s monetary policy</td>
<td>World War II., World Bank and IMF established, decolonization of the Third World</td>
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<td>Environmental movement and futures research movement, many conferences on the “world problematique”</td>
<td>Oil crisis in 1973 leads to abandonment of gold standard and fluctuating exchange rates</td>
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<td>Economic progress in Asia, liberalization of communist regimes</td>
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</table>
Advantages of using all four methods

• A richer description of the social system is produced
• Important considerations are less likely to be overlooked
• The theories and methods of more than one discipline are used
Specific advantages

• The interests of more groups are likely to be included in the analysis
• The beliefs and values of the people involved, hence culture, are likely to be considered
• Actions to produce change (events) probably will be discussed
• The results of actions are more likely to be measured (variables)
How reflexivity theory is different

• Classical scientific theories operate in the realm of VARIABLES and IDEAS

• Soros’s reflexivity theory describes the whole process of social change – IDEAS, GROUPS, EVENTS, VARIABLES, IDEAS

• Reflexivity is the process of shifting back and forth between description and action
A reflexive theory operates at two levels
The two functions in reflexivity theory
The efficient market hypothesis

- Economists assume that markets are efficient and that information is immediately reflected in market prices.
- Soros says that markets are always biased in one direction or another.
- Markets can influence the events they anticipate.
Equilibrium vs. reflexivity

• An increase in demand will lead to higher prices which will decrease demand
• A drop in supply will lead to a higher price which will increase supply
• For “momentum investors” rising price is a sign to buy, hence further increasing price
• A falling price will lead many investors to sell, thus further reducing price
Equilibrium theory assumes negative feedback; reflexivity theory observes positive feedback.
Examples in business and economics

• The conglomerate boom
• Real Estate Investment Trusts (REITs)
• The venture capital boom and collapse
• The credit cycle
• The currency market
The conglomerate boom: Events

- A high tech company with a high P/E ratio begins to diversify
- It buys consumer goods companies with high dividends but low P/E ratios
- As earnings improve, the price of the conglomerate rises
- A high stock price means greater ability to borrow
The conglomerate boom (continued)

• The conglomerate borrows to buy more consumer goods companies
• Earnings per share continue to grow
• Investors eagerly buy more stock
• Eventually people realize that the character of the company has changed and a high P/E ratio is not justified
The conglomerate boom: Ideas

- Conventional view
- Rising earnings per share (EPS) mean the company has found the secret of good management

- Reflexive view
- Rising EPS is an indicator that the character of the company has changed, from high tech to consumer goods, and a high P/E ratio is no longer justified
The conglomerate boom: Groups

- Corporate managers who buy other companies
- Investors who believe in something new and foolproof
- Investors who use Reflexivity Theory
The conglomerate boom, variables
The venture capital boom
The credit cycle
Value of the $  

Price of exports  

Inflation  

Price of imports  

Demand for imports (due to large import component in exports)  

Domestic wages  

Production  

Reflexivity in the currency market
Finance professors vs. Soros

• Most academic work in the field of finance involves building mathematical models.
• Soros treats finance as a multi-person game involving human players, including himself.
• Behavioral finance is a growing field, but it tends to focus on defining limits to the assumption that people are rational actors.
The process of selecting a portfolio

1. Observation and experience
2. Beliefs about future performances (Soros focuses here)
3. Choice of portfolios (Markowitz focuses here)
Equilibrium vs. Reflexivity

- Information becomes immediately available to everyone
- People are rational actors
- Economic systems go quickly to equilibrium
- People act on incomplete information
- People are influenced by their biases
- Social systems display boom and bust cycles
Equilibrium vs. Reflexivity

- A theorist is outside the system observed
- Scientists should build theories using quantifiable variables
- Theories do not alter the system described

- Observers are part of the system observed
- Scientists should use a variety of descriptions of systems (e.g., ideas, groups, events, variables)
- Theories are a means to change the system described
Equilibrium vs. Reflexivity

- Complete information
- Rationality
- Equilibrium

- Incomplete info.
- Bias
- Disequilibrium
- Gaps between perception and reality
- Boom and bust cycles
Soros on political systems

• Look for gaps between perception and “reality”
• A large gap means the system is unstable
• When people realize that description and reality are far apart, legitimacy collapses
• For example, glasnost destroyed the legitimacy of the USSR Communist Party
Misperceiving the USSR

- Soviet studies experts in the West assumed the convergence theory -- The West would adopt elements of a welfare state and the USSR would liberalize
- The West did adopt some elements of welfare states
- The USSR did not liberalize, as China is now doing, at least in its economy
Soros looks for

• Rapid growth: Positive feedback systems – conglomerate boom, credit cycle, REITs, the high tech bubble

• Instability before collapse: Gaps between perception and reality – conglomerate boom, etc., claims of USSR Communist Party, overextension of US power
Soros’s contributions

• Soros’s theories expand the field of finance beyond mathematical models to anticipating the behavior of financial participants
• Soros offers an alternative to equilibrium theory as the foundation of economics
• Soros suggests a way to anticipate major political changes
• Soros’s reflexivity theory provides links between cybernetics and economics, finance, and political science
Unifying epistemologies
The cybernetics of science

NORMAL SCIENCE

The correspondence principle

Incommensurable definitions

SCIENTIFIC REVOLUTION
<table>
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<tr>
<th>Author</th>
<th>First Order Cybernetics</th>
<th>Second Order Cybernetics</th>
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</thead>
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<td>The purpose of a model</td>
<td>The purpose of a modeler</td>
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<td>Varela</td>
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<td>Autonomous systems</td>
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<td>Theories of social systems</td>
<td>Theories of the interaction between ideas and society</td>
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**Definitions of First and Second Order Cybernetics**
The Correspondence Principle

• Proposed by Niels Bohr when developing the quantum theory
• Any new theory should reduce to the old theory to which it corresponds for those cases in which the old theory is known to hold
• A new dimension is required
An Application of the Correspondence Principle
<table>
<thead>
<tr>
<th>The view of epistemology</th>
<th>A realist view of epistemology: knowledge is a “picture” of reality</th>
<th>A biological view of epistemology: how the brain functions</th>
<th>A pragmatic view of epistemology: knowledge is constructed to achieve human purposes</th>
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<td>Realism vs. Constructivism</td>
<td>The biology of cognition vs. the observer as a social participant</td>
</tr>
<tr>
<td>The puzzle to be solved</td>
<td>Construct theories which explain observed phenomena</td>
<td>Include the observer within the domain of science</td>
<td>Explain the relationship between the natural and the social sciences</td>
</tr>
<tr>
<td>What must be explained</td>
<td>How the world works</td>
<td>How an individual constructs a “reality”</td>
<td>How people create, maintain, and change social systems through language and ideas</td>
</tr>
<tr>
<td>A key assumption</td>
<td>Natural processes can be explained by scientific theories</td>
<td>Ideas about knowledge should be rooted in neurophysiology.</td>
<td>Ideas are accepted if they serve the observer’s purposes as a social participant</td>
</tr>
<tr>
<td>An important consequence</td>
<td>Scientific knowledge can be used to modify natural processes to benefit people</td>
<td>If people accept constructivism, they will be more tolerant</td>
<td>By transforming conceptual systems (through persuasion, not coercion), we can change society</td>
</tr>
</tbody>
</table>

**Three Versions of Cybernetics**

- **Engineering Cybernetics**
- **Biological Cybernetics**
- **Social Cybernetics**
Toward a larger view

• At a dinner in Vienna in November 2005 Karl Mueller mentioned Heinz von Foerster’s 1971 article “Computing in the Semantic Domain
• Von Foerster described a triangle and labeled two sides syntactics and semantics
• Mueller wondered what the third side would be
Creating a theory of epistemologies

• I suggested “pragmatics”

• Later in thinking about the triangle it occurred to me that the three sides corresponded to three points of view in the history of cybernetics

• The triangle suggested a way to unify previously competing epistemologies
<table>
<thead>
<tr>
<th>Syntactics</th>
<th>Semantics</th>
<th>Pragmatics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rc(W,D)</td>
<td>Rw(D,C)</td>
<td>Rd(W,C)</td>
</tr>
<tr>
<td>Determined by an organism’s behavioral potential</td>
<td>Determined by an organism’s cognitive potential</td>
<td>Determined by an organism’s perceptive potential</td>
</tr>
<tr>
<td>Gives rise to concepts such as “territory,” “control,” “objects,” and “names”</td>
<td>Gives rise to concepts such as “volition,” “action” “conceptions,” and “propositions”</td>
<td>Gives rise to concepts such as “niche,” “instinct,” “reality” and “consciousness”</td>
</tr>
</tbody>
</table>

**Von Foerster’s epistemological triangle**
# Epistemological triangle

<table>
<thead>
<tr>
<th>World and description</th>
<th>Observer and description</th>
<th>Observer and world</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Syntactics</strong></td>
<td><strong>Semantics</strong></td>
<td><strong>Pragmatics</strong></td>
</tr>
<tr>
<td><strong>Representation concept of truth</strong></td>
<td><strong>Coherence concept of truth</strong></td>
<td><strong>Pragmatic concept of truth</strong></td>
</tr>
<tr>
<td><strong>British Empiricism</strong></td>
<td><strong>German Idealism</strong></td>
<td><strong>American Pragmatism</strong></td>
</tr>
<tr>
<td><strong>Inanimate Objects</strong></td>
<td><strong>Knowing Subjects</strong></td>
<td><strong>Social Reforms</strong></td>
</tr>
<tr>
<td><strong>Unquestioned Objectivity</strong></td>
<td><strong>Constructed Objectivity</strong></td>
<td><strong>Contested Objectivity</strong></td>
</tr>
<tr>
<td><strong>Form</strong></td>
<td><strong>Meaning</strong></td>
<td><strong>What works</strong></td>
</tr>
</tbody>
</table>
Another use of the triangle

• In 1991 I made a table comparing constructivist cybernetics, or the work of von Foerster, with that of Popper and Kuhn
• It seems to me that the three columns in that table also can be mapped onto the triangle
• This suggests that cybernetics constitutes an important third perspective in the philosophy of science
<table>
<thead>
<tr>
<th>Popper</th>
<th>von Foerster</th>
<th>Kuhn</th>
</tr>
</thead>
<tbody>
<tr>
<td>A normative view of epistemology: how scientists should operate in fact operate</td>
<td>A biological view of epistemology: how the brain functions</td>
<td>A scientists</td>
</tr>
<tr>
<td>Non-science vs. science progress vs.</td>
<td>Realism vs. constructivism</td>
<td>Steady revolutions</td>
</tr>
<tr>
<td>Solve the problem of turmoil in induction: conjectures within the domain of original science and refutations in textbooks</td>
<td>Include the observer smooth science</td>
<td>Explain progress</td>
</tr>
</tbody>
</table>
Popper’s three “worlds”

• “World” can be thought of as Popper’s “world one”
• “The observer” is what Popper meant by “world two”
• “Description” can be thought of as Popper’s “world three”
Cautions

• The fact that ideas can be plausibly mapped onto a triangle carries no meaning per se
• However, an arrangement in the form of a diagram may reveal connections or missing pieces that had not been apparent before
• A graphical representation of ideas is simply a heuristic device
Implications of the triangle

- A step toward a theory of epistemologies
- Shows how the three epistemologies are related
- Not “choose one” but rather “use all three”
- Shows the importance of von Foerster in comparison with Popper and Kuhn
- Shows clearly what each epistemology tends to neglect
Implications of the triangle

• Suggests that an addition is needed to the distinction between Science One and Science Two or between Mode One and Mode Two knowledge

• Second order cybernetics is redefined

• No longer a competing epistemology but rather a theory of epistemologies
Overview of cybernetics

• Stages in the development of cybernetics: engineering, biology, social systems
• Areas of application: computer science and robotics, management, family therapy, epistemology, economics and political science
• Theoretical issues: the nature of information, knowledge, adaptation, learning, self-organization, cognition, autonomy, understanding
References

ADDITIONAL REFERENCES

A tutorial presented at the

World Multi-Conference on Systemics, Cybernetics, and Informatics

Orlando, Florida

July 16, 2006