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”

Author	First Order Cybernetics	Second Order Cybernetics
Von Foerster	The cybernetics of observed systems	The cybernetics of observing systems
Pask	The purpose of a model	The purpose of a modeler
Varela	Controlled systems	Autonomous systems
Umpleby	Interaction among the variables in a system	Interaction between observer and observed
Umpleby	Theories of social systems	Theories of the interaction between ideas and society

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

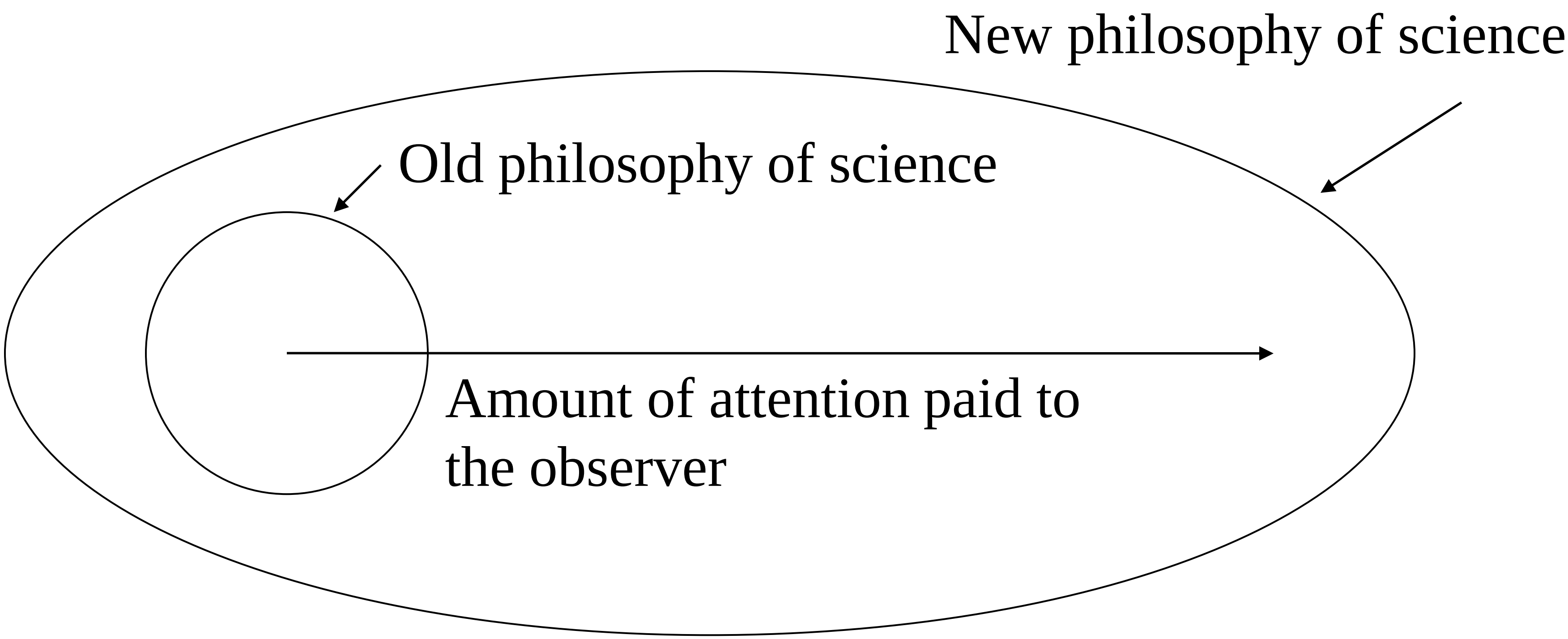
The correspondence principle

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

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

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

  N = Number of Elements

  k = number of categories

  n1 = number of elements in the first category

  H = [N log N – n1 log n1 - … -nk log nk] / N
- Redundancy as a measure of organization

  R = H (actual) / H (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

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
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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

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

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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 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

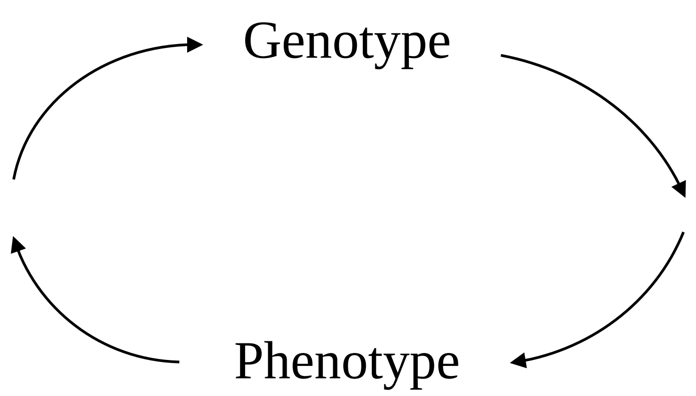
- Soros's theory is not well-known in the systems and cybernetics community
- Soros's theory is not yet widely used by economists or finance professors, despite his success as a financial manager
- Soros has a participatory, not purely descriptive, theory of social systems

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

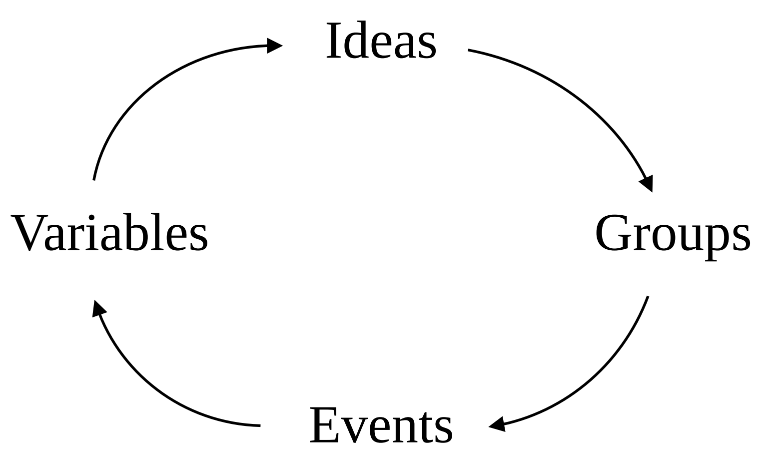
- A general theory of the evolution of systems
- Ways of describing systems



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)

The Interaction Between Ideas and Society

Ideas	Events
	1096 First Crusade
Interest in trade and in ancient learning	
	Marco Polo's trip to China
Science and technology stimulated by desire to improve trade	
	Traders accumulate wealth, nation–states develop and protect trade routes
The idea of progress, people strive to produce more than mere subsistence	
	Industrial Revolution in England
Adam Smith's *The Wealth of Nations*, 1776	
	Capital accumulation, urbanization, growing gap between rich and poor
Marx and Engles, *The Communist Manifesto*, 1848	
	Revolutions in Europe, demands for more equal distribution of wealth
Social reform movements in industrializing countries	
	World War I and the Great Depression
Keynes's theory justifying government intervention in the economy	
	World War II, World Bank and IMF established, decolonialization of the Third World
Friedman's monetary policy	
	Oil crisis in 1973 leads to abandonment of gold standard and fluctuating exchange rates
Environmental movement and futures research movement, many conferences on the "world problematique"	
	Economic progress in Asia, liberalization of communist regimes

Advantages of using all four methods

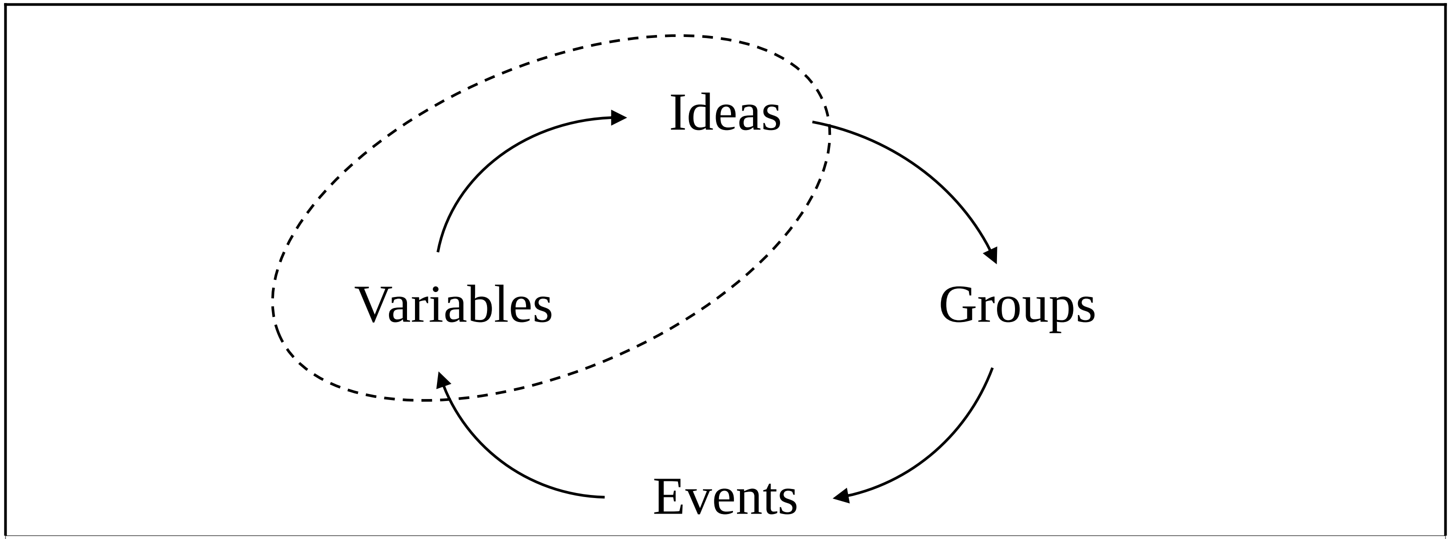
- A richer description of the social system is produced
- Important considerations are less likely to be overlooked
- The theories and methods of more than one discipline are used

Specific advantages

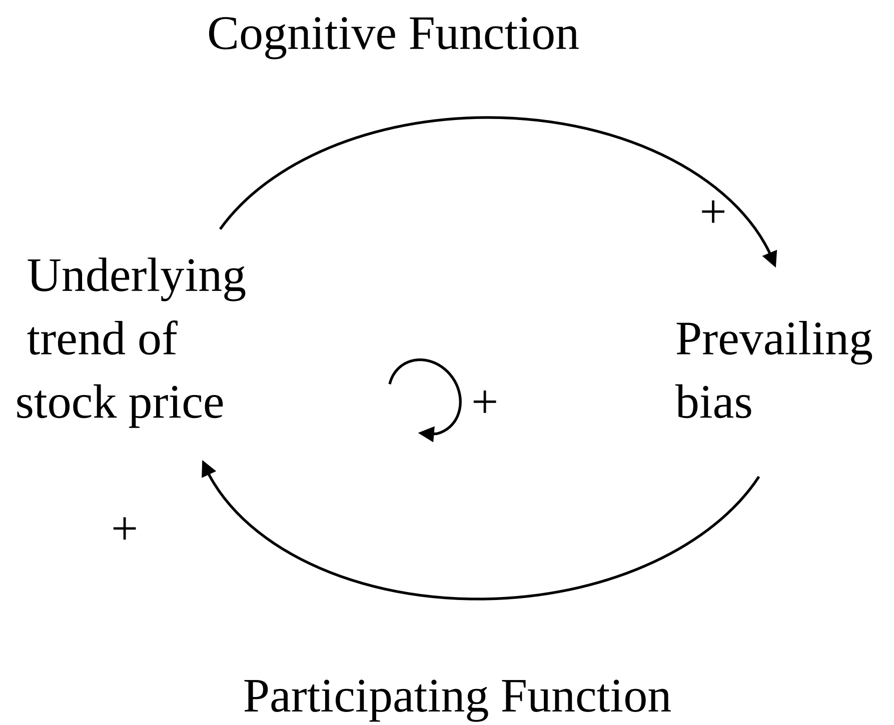
- The interests of more groups are likely to be included in the analysis
- The beliefs and values of the people involved, hence culture, are likely to be considered
- Actions to produce change (events) probably will be discussed
- The results of actions are more likely to be measured (variables)

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

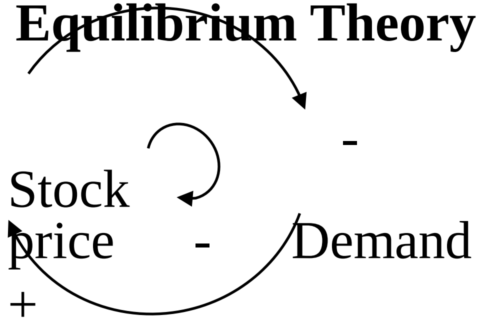
- Economists assume that markets are efficient and that information is immediately reflected in market prices
- Soros says that markets are always biased in one direction or another
- Markets can influence the events they anticipate

Equilibrium vs. reflexivity

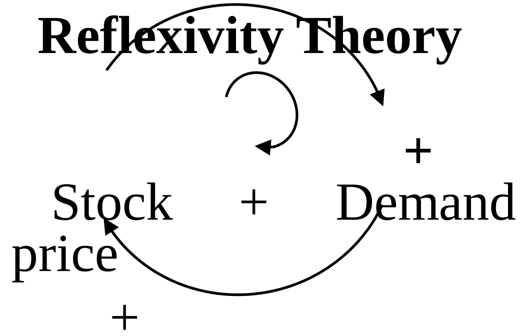
- An increase in demand will lead to higher prices which will decrease demand
- A drop in supply will lead to a higher price which will increase supply

- 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



Reflexivity Theory



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

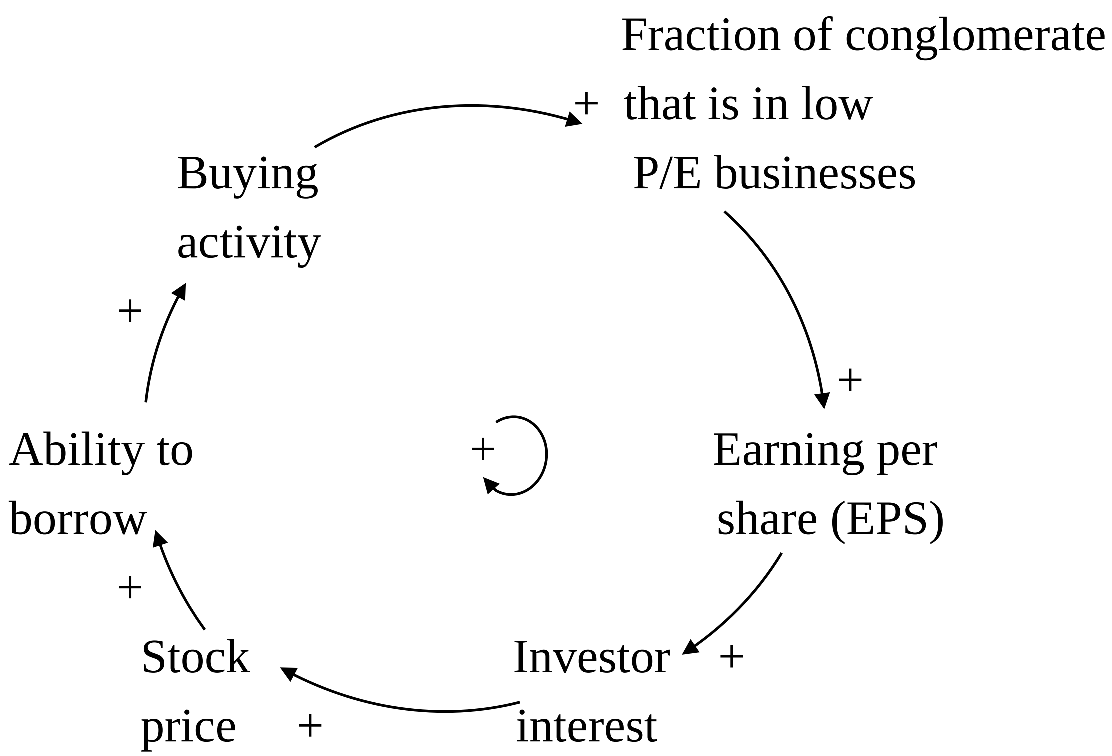
The conglomerate boom: Ideas

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

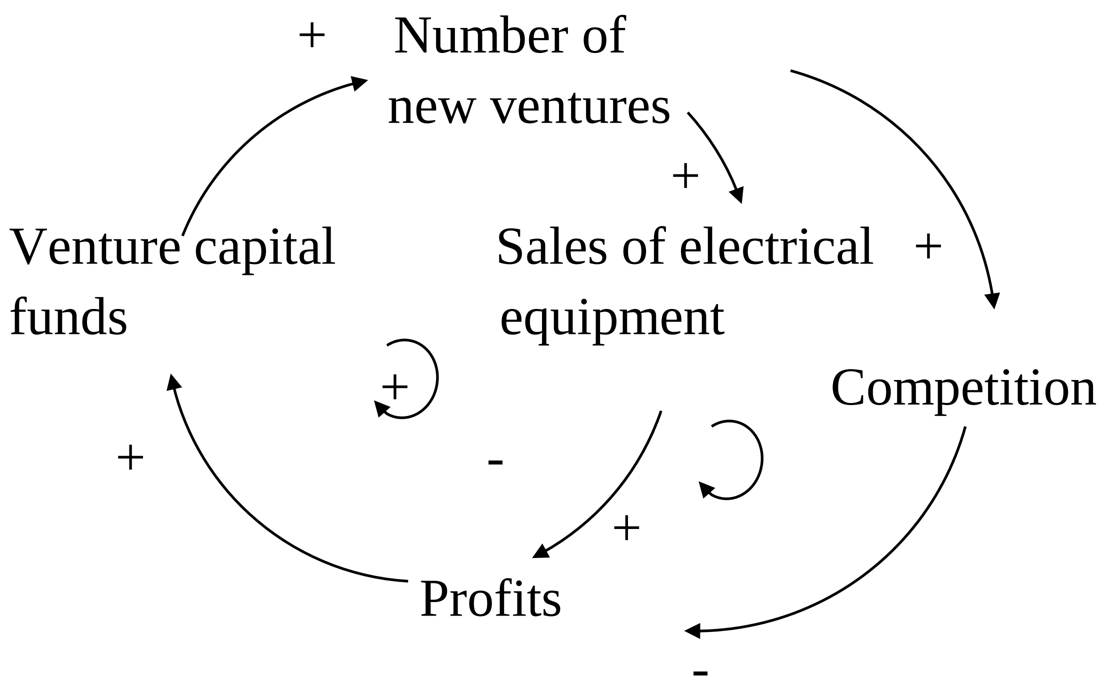
- Reflexive view
- Rising EPS is an indicator that the character of the company has changed, from high tech to consumer goods, and a high P/E ratio is no longer justified

The conglomerate boom: Groups

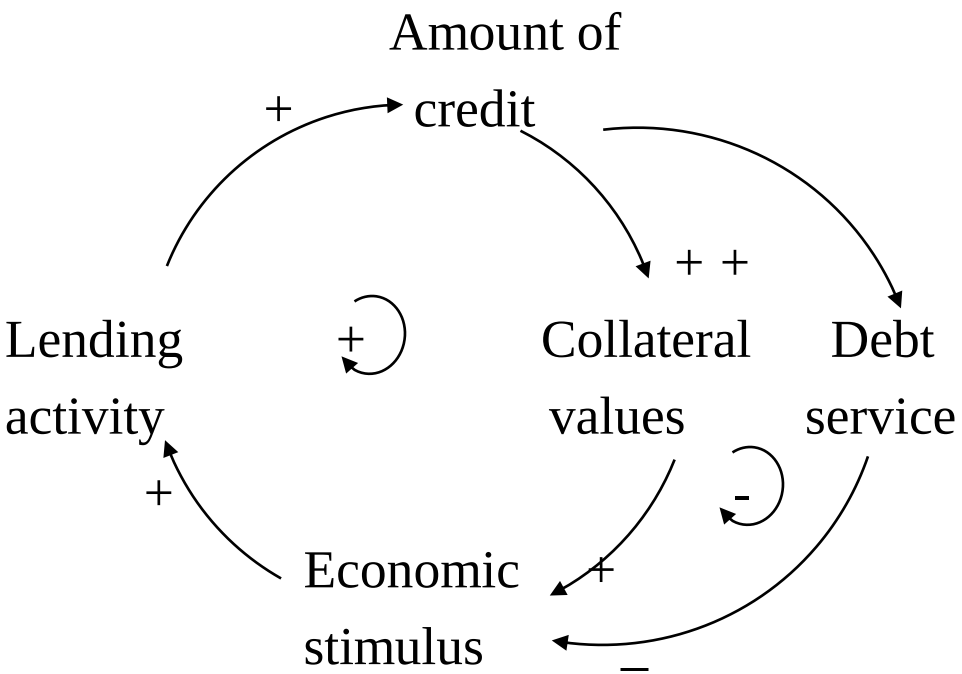
- Corporate managers who buy other companies
- Investors who believe in something new and foolproof
- Investors who use Reflexivity Theory



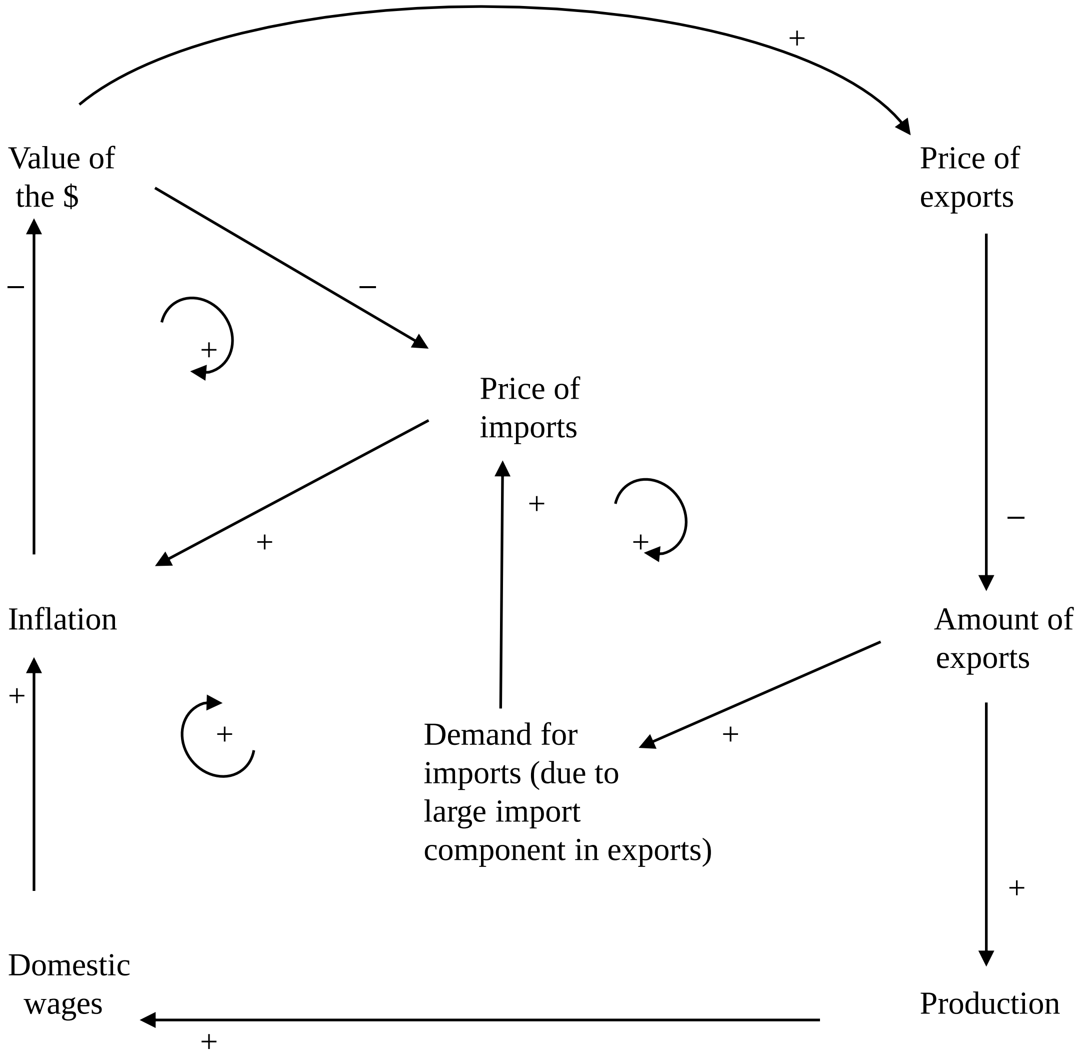
The conglomerate boom, variables



The venture capital boom



The credit cycle



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

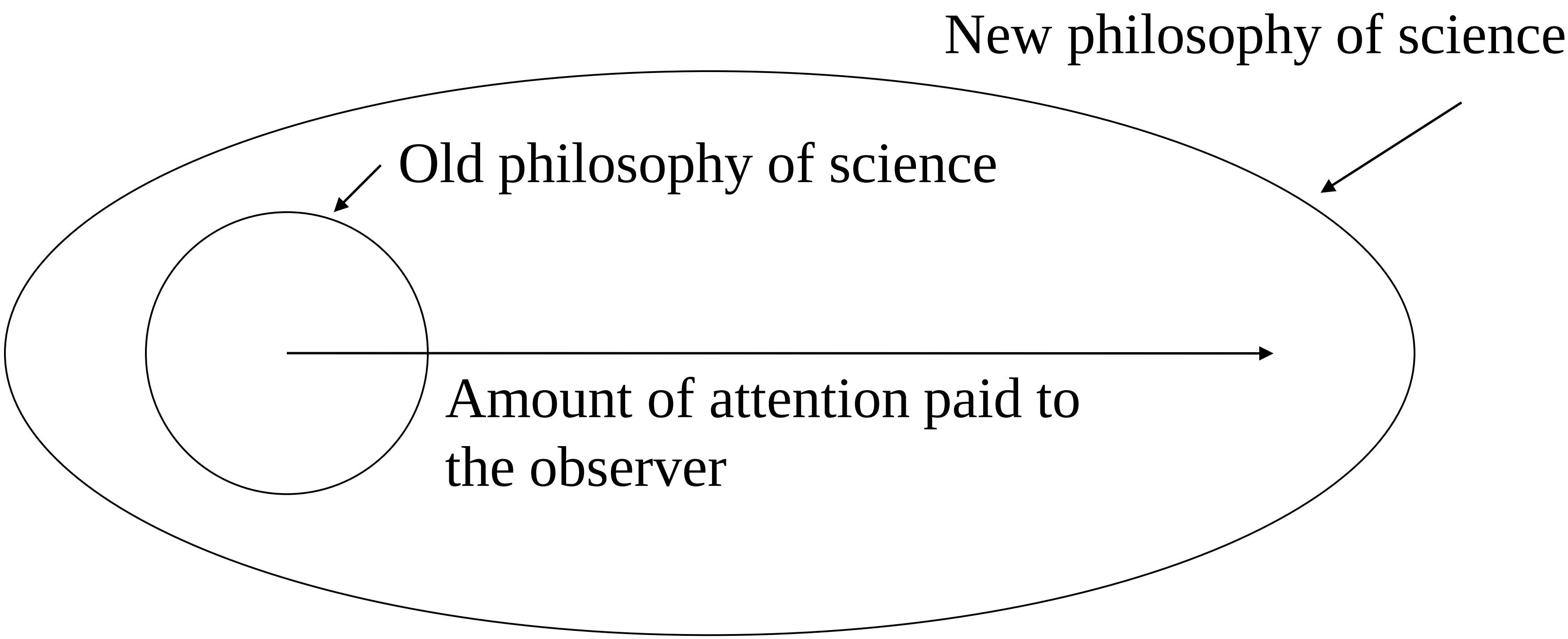
SCIENTIFIC REVOLUTION

Author	First Order Cybernetics	Second Order Cybernetics
Von Foerster	The cybernetics of observed systems	The cybernetics of observing systems
Pask	The purpose of a model	The purpose of a modeler
Varela	Controlled systems	Autonomous systems
Umpleby	Interaction among the variables in a system	Interaction between observer and observed
Umpleby	Theories of social systems	Theories of the interaction between ideas and society

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

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

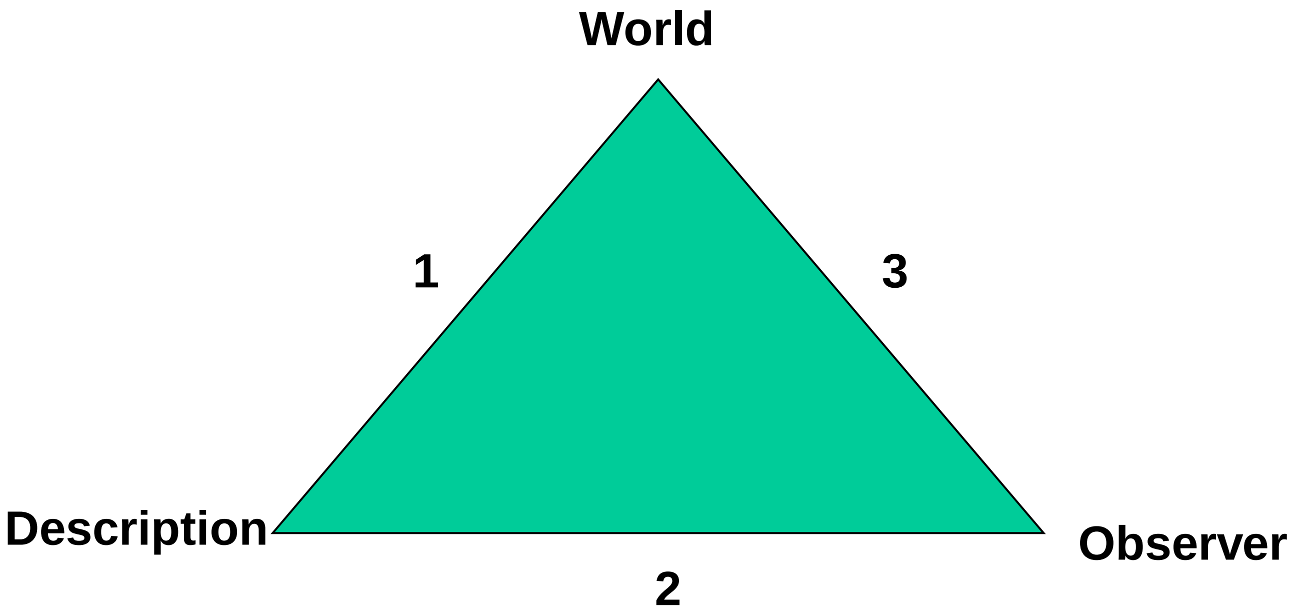
Three Versions of Cybernetics

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


World
1
3
Description
Observer
2

Syntactics	Semantics	***Pragmatics***
Rc(W,D)	Rw(D,C)	Rd(W,C)
Determined by an organism’s behavioral potential	Determined by an organism’s cognitive potential	Determined by an organism’s perceptive potential
Gives rise to concepts such as “territory,” “control,” “objects,” and “names”	Gives rise to concepts such as “volition,” “action” “conceptions,” and “propositions”	Gives rise to concepts such as “niche,” “instinct,” “reality” and “consciousness”

Von Foerster’s epistemological triangle

Epistemological triangle

World and description	Observer and description	Observer and world
Syntactics	Semantics	Pragmatics
Representation concept of truth	Coherence concept of truth	Pragmatic concept of truth
British Empiricism	German Idealism	American Pragmatism
Inanimate Objects	Knowing Subjects	Social Reforms
Unquestioned Objectivity	Constructed Objectivity	Contested Objectivity
Form	Meaning	What works

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

Popper	**von Foerster**	**Kuhn**
A normative view of epistemology: how scientists should operate	A biological view of epistemology: how the brain functions	A sociological view of epistemology: how scientists in fact operate
Non-science vs. science	Realism vs. constructivism	Steady progress vs. revolutions
Solve the problem of induction: conjectures and refutations	Include the observer within the domain of science	Explain turmoil in original records vs. smooth progress in textbooks
How science as a picture of reality is tested and grows	How an individual constructs a "reality"	How paradigms are developed and then replaced
Scientific knowledge exists independent of human beings	Ideas about knowledge should be rooted in neurophysiology	Even data and experiments are interpreted
We can know what we know and do not know	If people accept this view, they will be more tolerant	Science is a community activity

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

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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

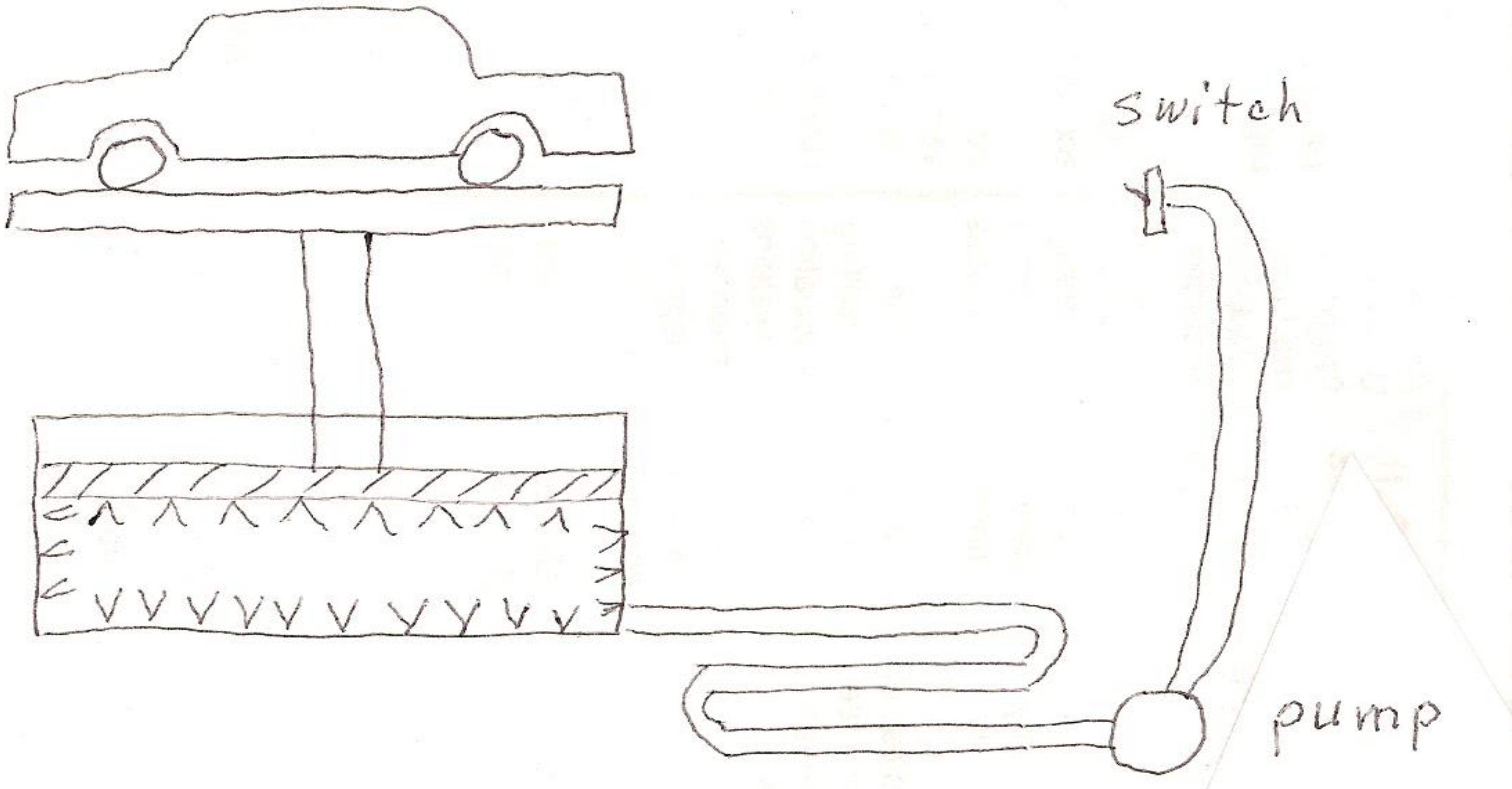
The Conant and Ashby theorem

- 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

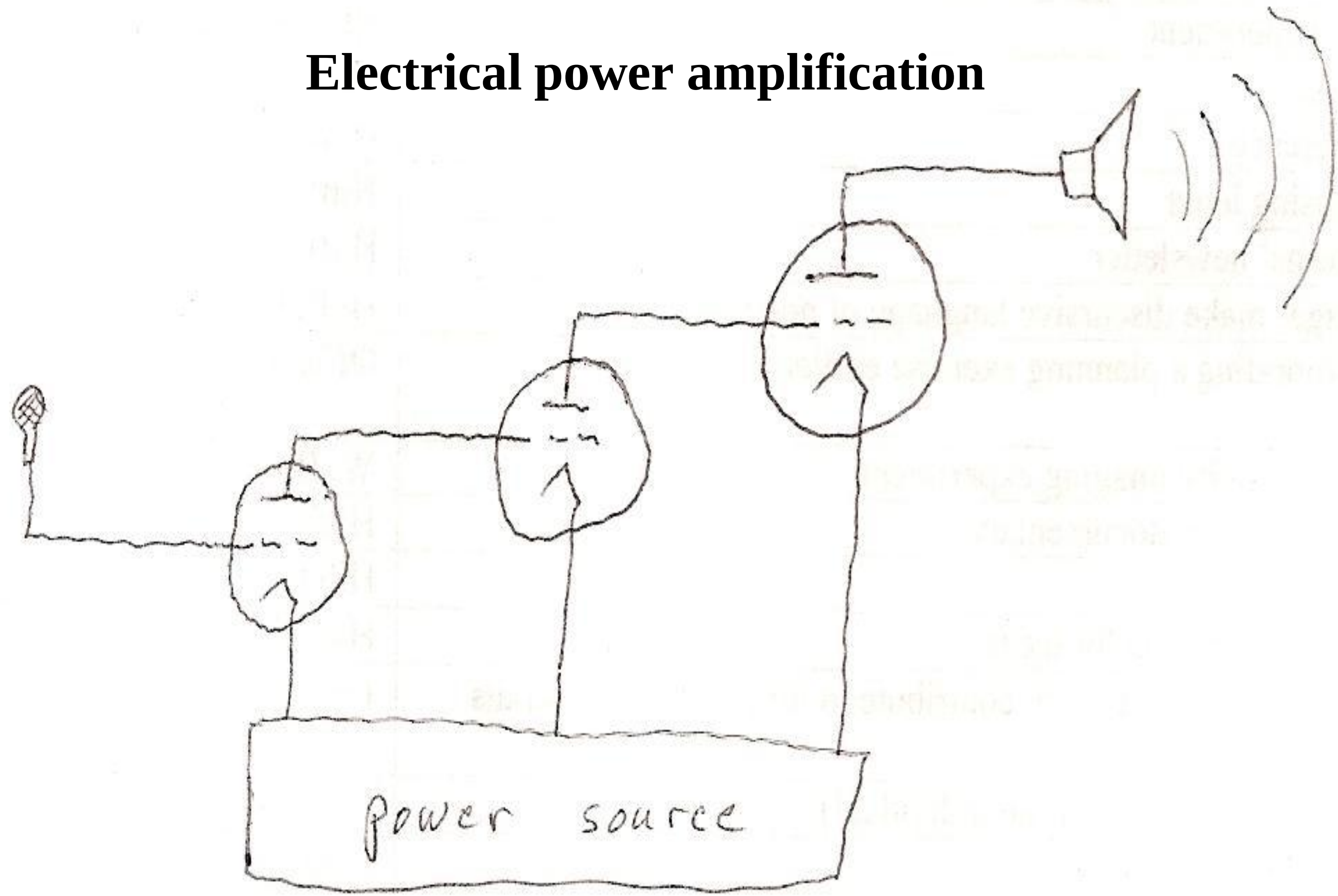
Mechanical power amplification



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

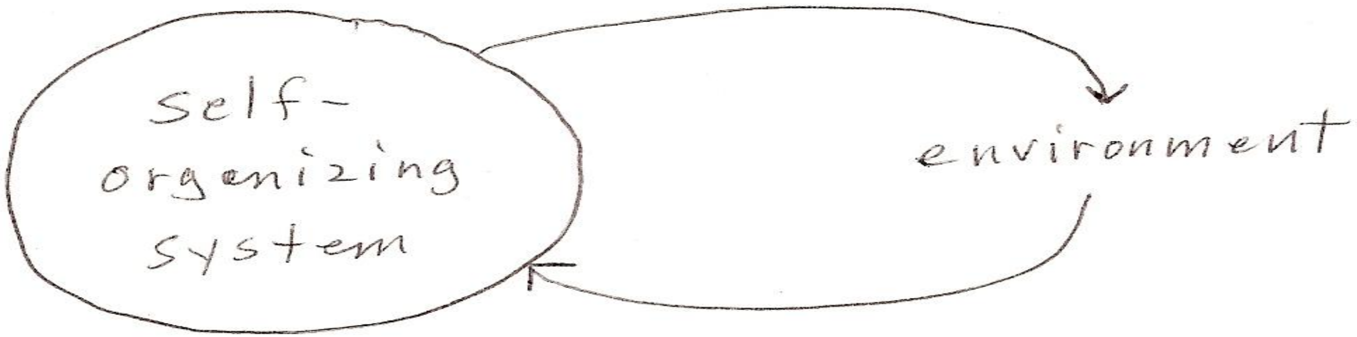
Three thought experiments

- 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

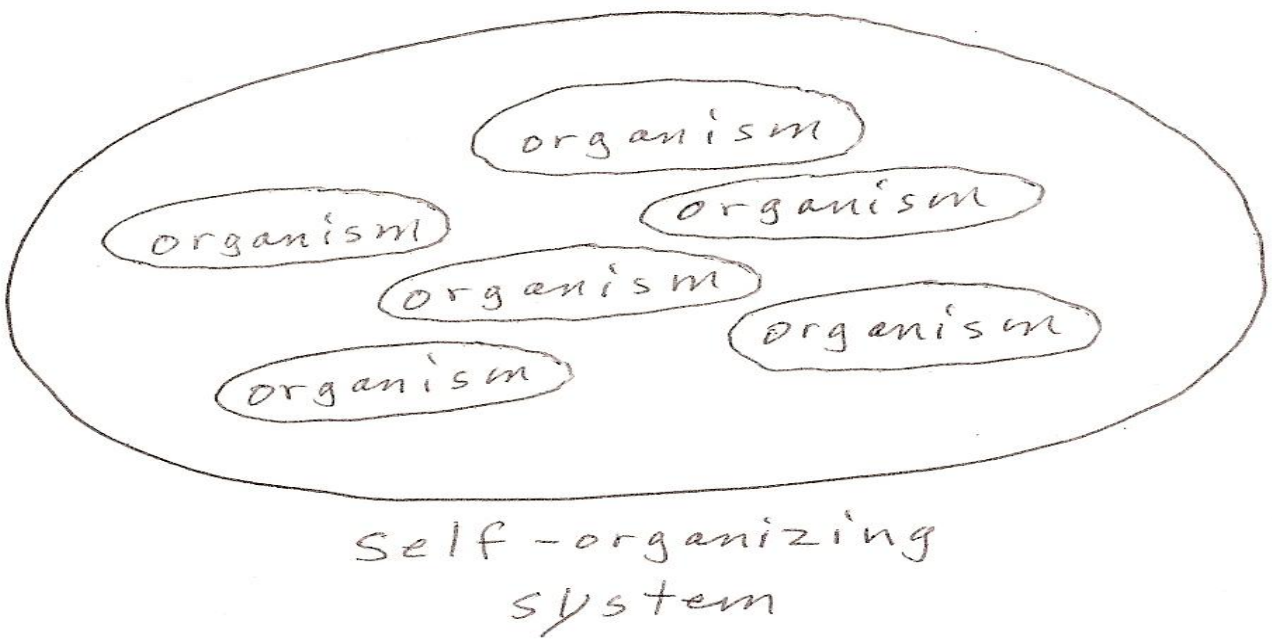
Von Foerster’s “order from noise”

- 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



Ashby's conception



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

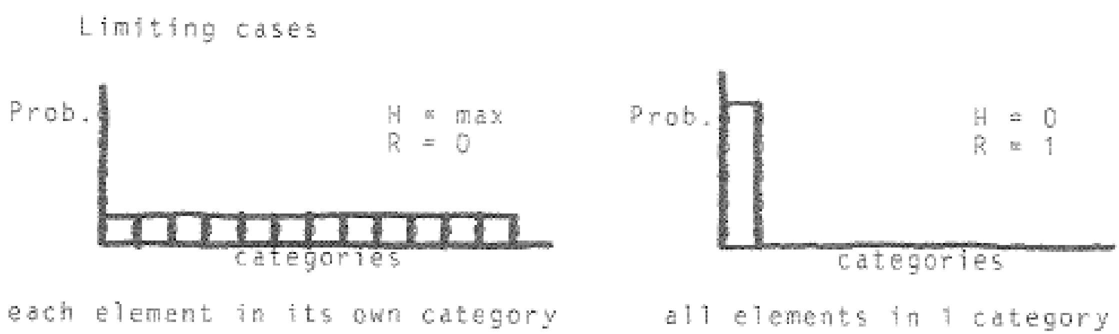
- Redundancy

  A measure of organization

- Shannon's information theory

  Information is that which reduces uncertainty

R = 1 - (Hactual / Hmax) where H max = log N



Information theory

- Shannon's measure of uncertainty

  N = Number of Elements

  k = number of categories

  n1 = number of elements in the first category

  H = [N log N – n1 log n1 - … -nk log nk] / N
- Redundancy as a measure of organization

  R = H (actual) / H (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

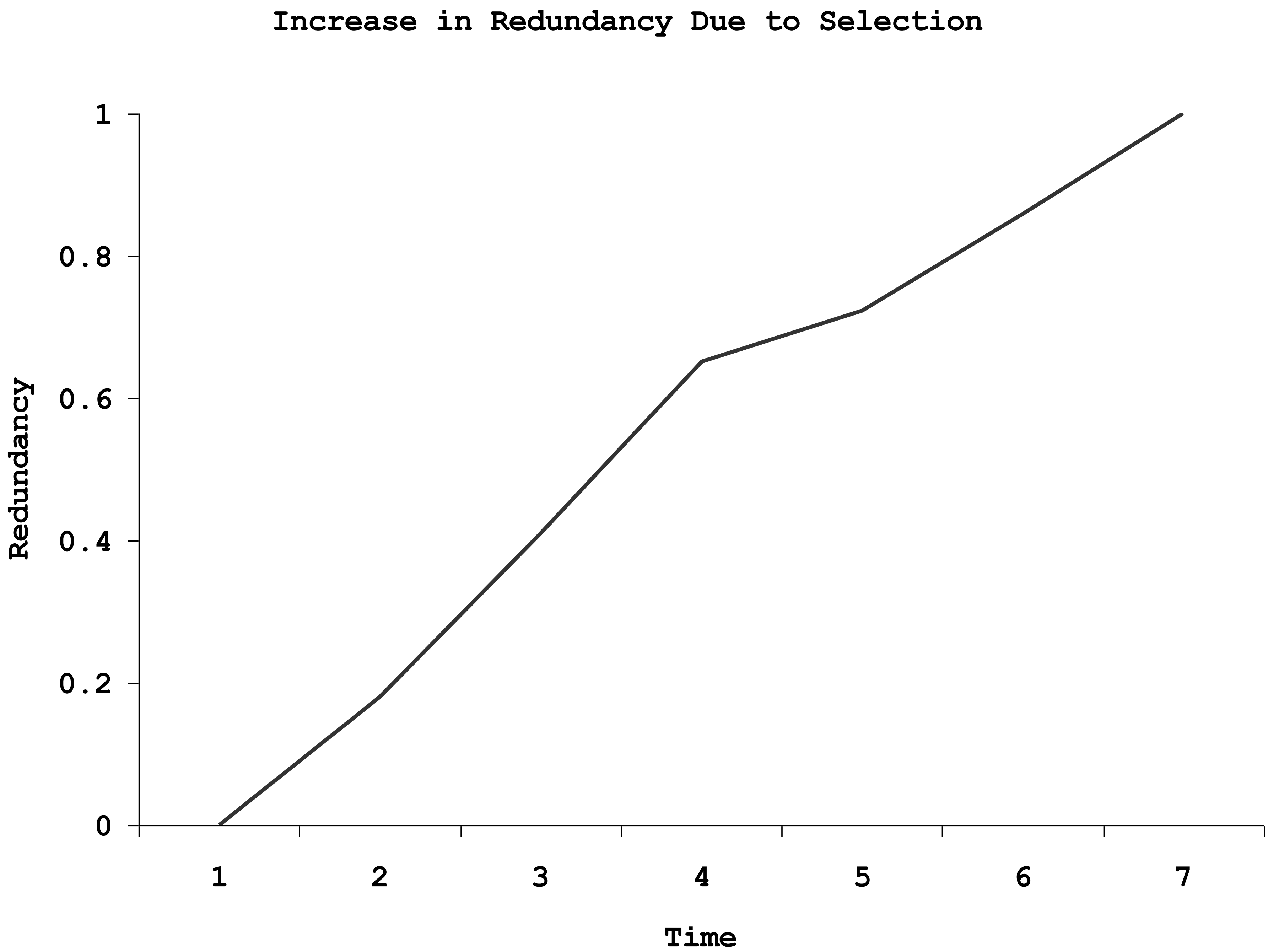
Examples of self-organization

- 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

Time	Competing Numbers										Number Of Evens	Number Of Odds	Number Of Zeros
1	1	7	6	4	9	5	3	2	0	8	5	5	1
2	7	2	4	6	5	5	6	0	0	8	7	3	2
3	4	8	4	0	5	0	0	0	0	6	9	1	5
4	2	2	0	0	0	0	0	0	0	4	10	0	7
5	4	0	0	0	0	0	0	0	0	8	10	0	8
6	0	0	0	0	0	0	0	0	0	2	10	0	9
7	0	0	0	0	0	0	0	0	0	0	10	0	10

Time	Partition		H	R
	N:	n,n,, . . . , n		
1	10:	1,1,1,1,1,1,1,1,1,1	3.3219	0
2	10:	2,2,2,1,1,1,1	2.7219	.1806
3	10:	5,2,1,1,1	1.9610	.4097
4	10:	7,2,1	1.1568	.6518
5	10:	8,1,1	.9219	.7225
6	10:	9,1	.4690	.8588
7	10:	10	0	1


Increase in Redundancy Due to Selection
Redundancy
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
Time

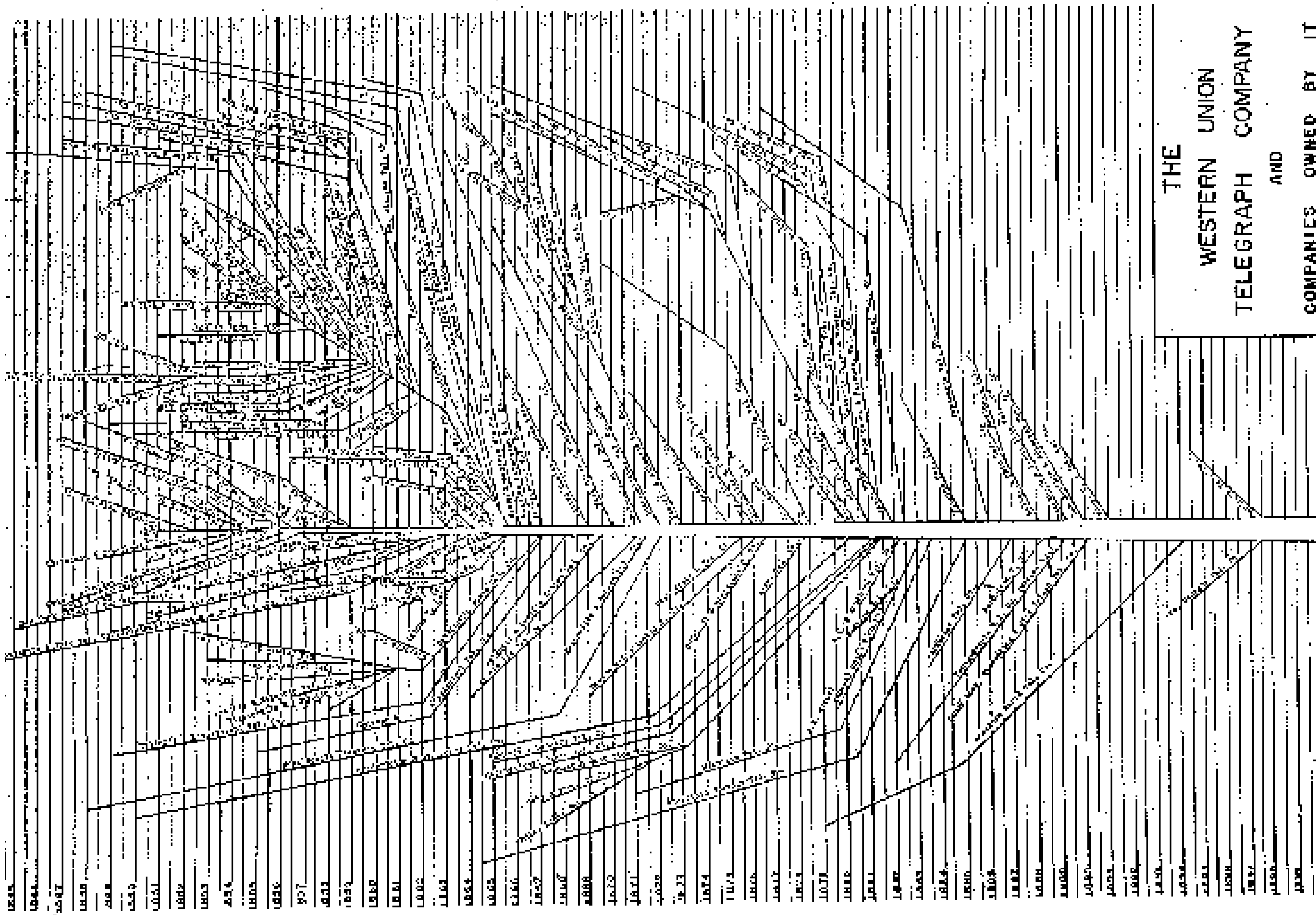


Figure 11. (From Robert L. Thompson, Wiring a Continent: The History of the Telegraph Industry in the U.S. 1832-1866, New York: Arno, 1947)

Redundancy in the U.S. Telegraph Industry 1845-1900

YEAR	# OF CO'S.	(k)	PARTITION	UNCERTAINTY	REDUNDANCY
1845	4	4:	1,1,1,1,	2.	0
1850	23	23:	1, . . . ,1	4.5237	0
			35		.0905
1855	39	48:	6,3,2,2,1,. .,1	5.0795	.3088
			30		
1860	36	71:	15,15,5,2,2,2,1,. .,1	4.2509	.5524
			19		
1865	23	90:	35,25,6,5,1,. .,1	2.9058	.7500
			18		
1870	20	107:	82,7,1,. .,1	1.6857	.7968
			14		
1875	17	117:	95,5,3,1,. .,1	1.3960	.7885
			11		
1880	16	132:	104,6,4,4,3,1,. .,1	1.4905	.9562
1885	6	137:	132,1,1,1,1,1	.3107	.97502
1890	4	144:	141,1,1,1	.1791	
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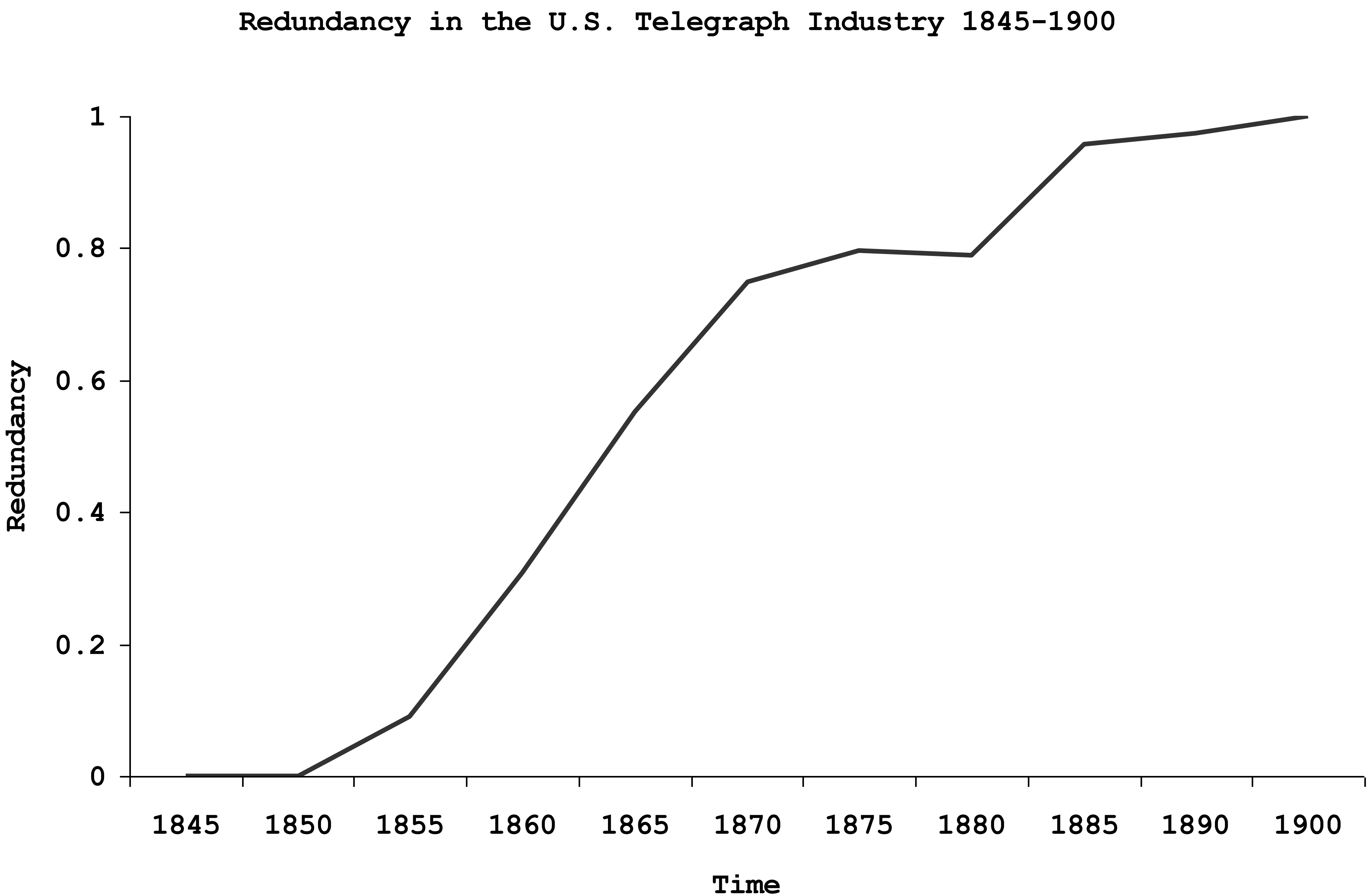
Redundancy in the U.S. Telegraph Industry 1845-1900
Redundancy
1
0.8
0.6
0.4
0.2
0
1845
1850
1855
1860
1865
1870
1875
1880
1885
1890
1900
Time

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

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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

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

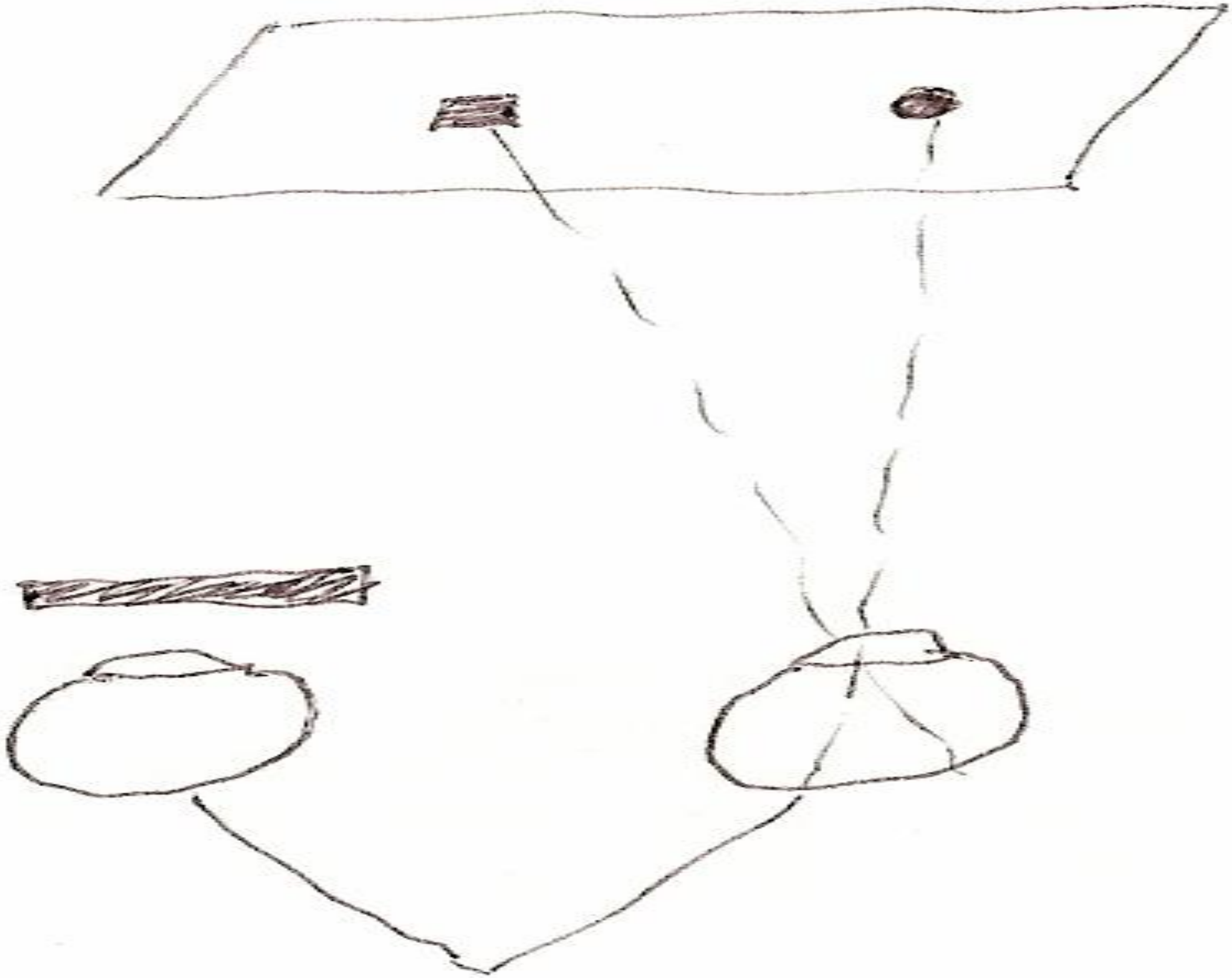
Autopoiesis

- 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

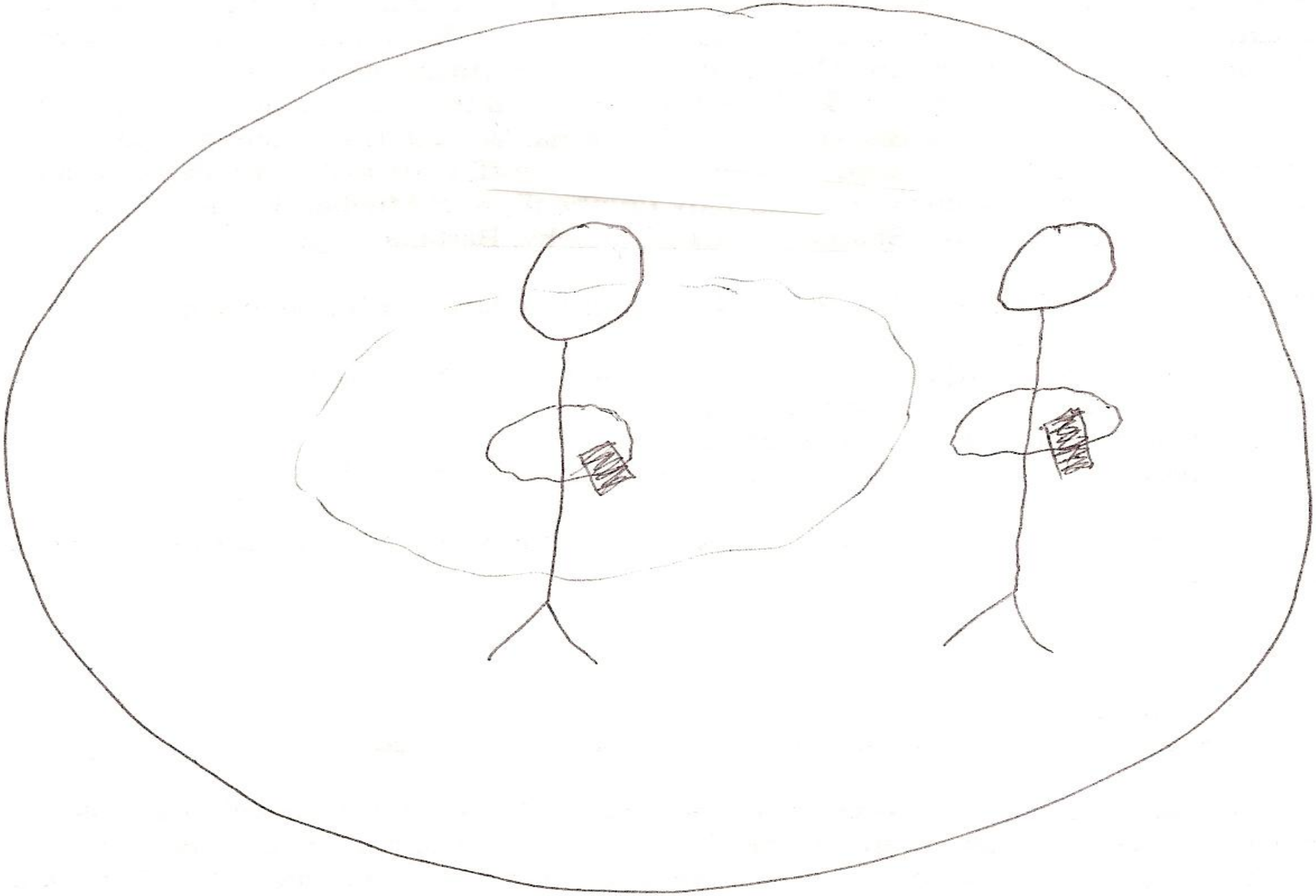
- The blind spot
- Move your eyes within your head
- Image on your retina
- Glasses that turn the world upside down
- Listening to a speech
- Conversations at a party
- Injured war veterans
- The kitten that could not see

The blind spot experiment

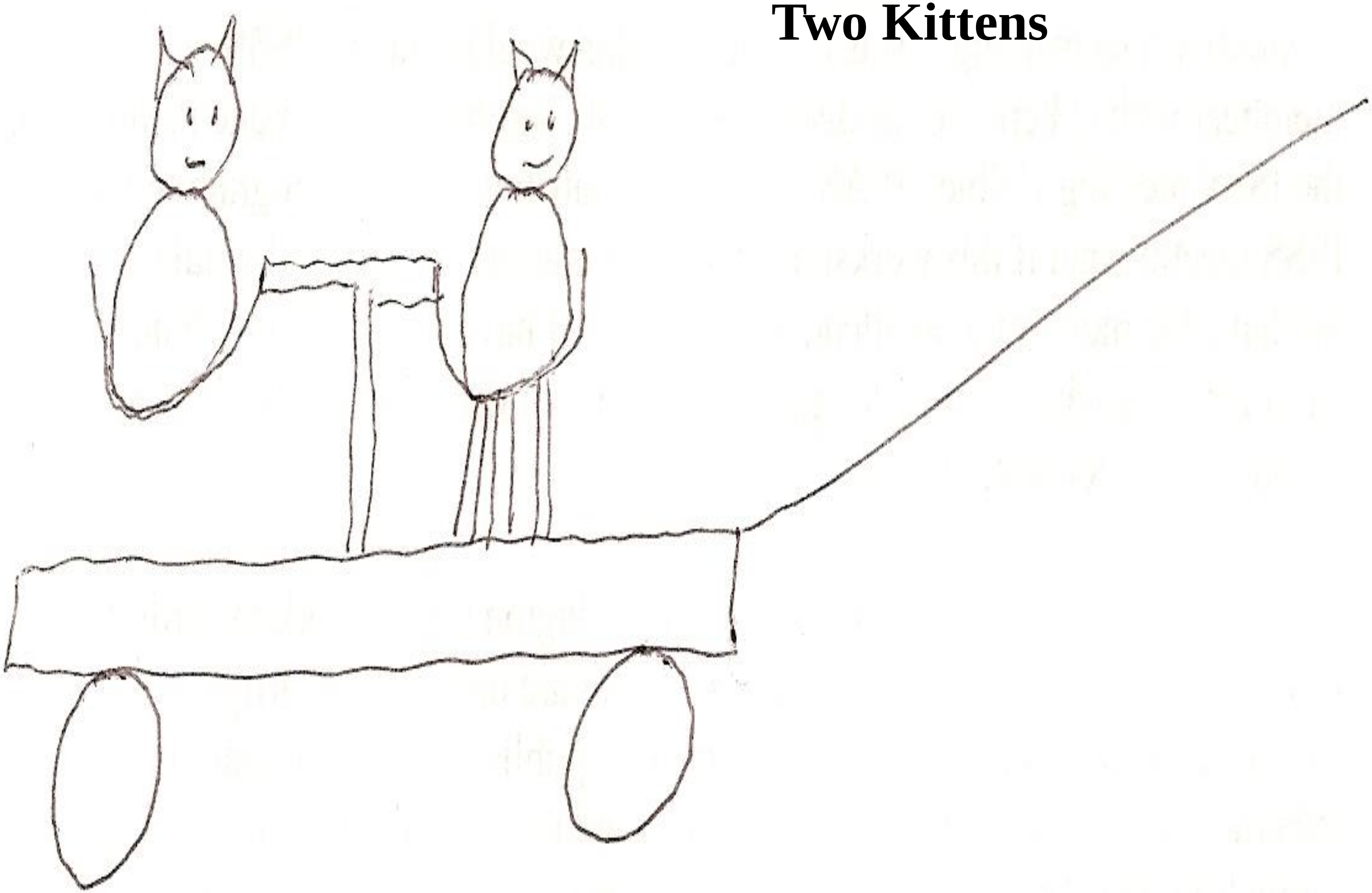


Images on the retina are inverted

Injured war veteran



Two Kittens



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

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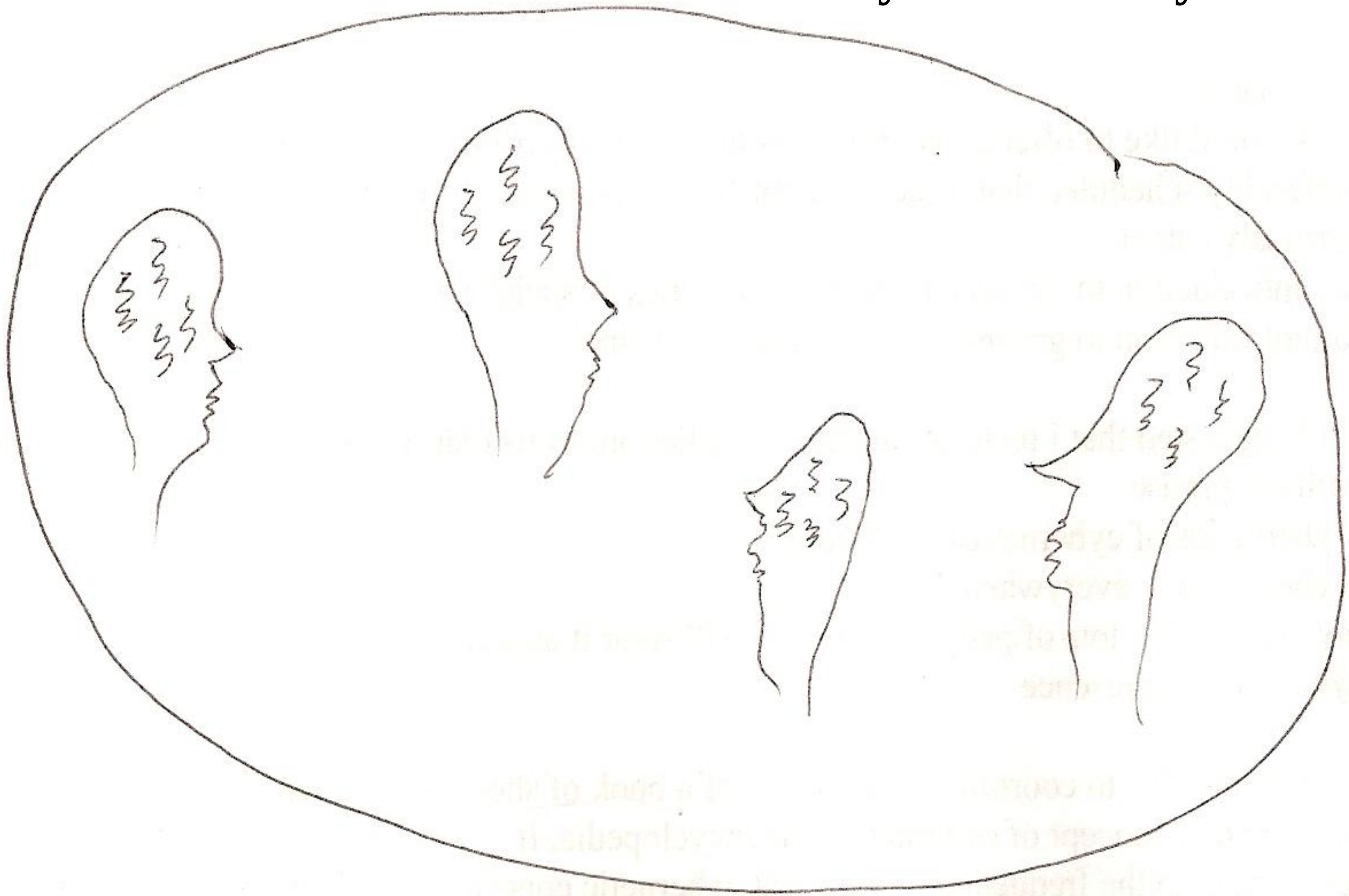
Reflexivity

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

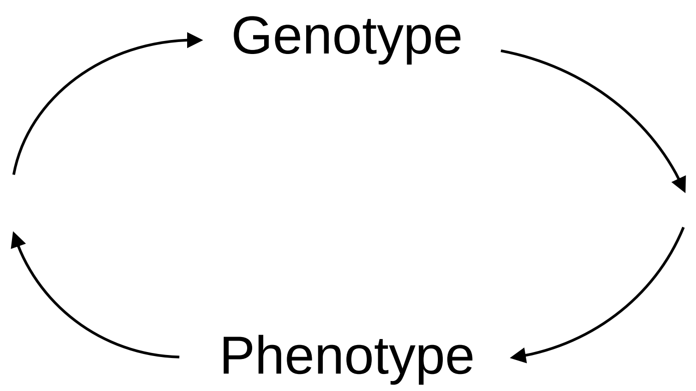
- Soros's theory is not well-known in the systems and cybernetics community
- Soros's theory is not yet widely used by economists or finance professors, despite his success as a financial manager
- Soros has a participatory, not purely descriptive, theory of social systems

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

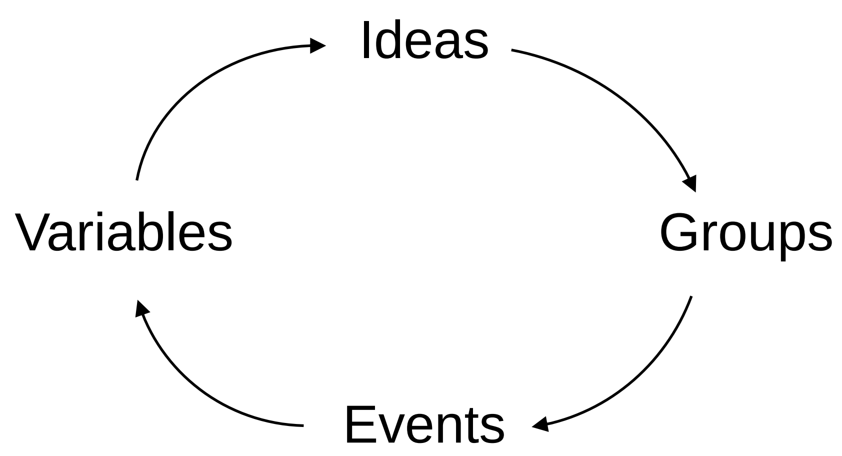
- A general theory of the evolution of systems
- Ways of describing systems



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)

The Interaction Between Ideas and Society

Ideas	Events
	1096 First Crusade
Interest in trade and in ancient learning	
	Marco Polo's trip to China
Science and technology stimulated by desire to improve trade	
	Traders accumulate wealth, nation–states develop and protect trade routes
The idea of progress, people strive to produce more than mere subsistence	
	Industrial Revolution in England
Adam Smith's *The Wealth of Nations*, 1776	
	Capital accumulation, urbanization, growing gap between rich and poor
Marx and Engles, *The Communist Manifesto*, 1848	
	Revolutions in Europe, demands for more equal distribution of wealth
Social reform movements in industrializing countries	
	World War I and the Great Depression
Keynes's theory justifying government intervention in the economy	
	World War II, World Bank and IMF established, decolonialization of the Third World
Friedman's monetary policy	
	Oil crisis in 1973 leads to abandonment of gold standard and fluctuating exchange rates
Environmental movement and futures research movement, many conferences on the "world problematique"	
	Economic progress in Asia, liberalization of communist regimes

Advantages of using all four methods

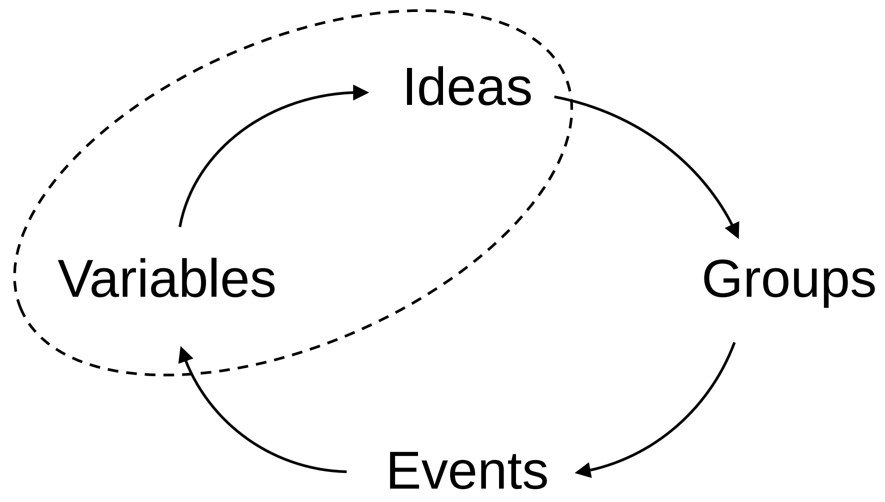
- A richer description of the social system is produced
- Important considerations are less likely to be overlooked
- The theories and methods of more than one discipline are used

Specific advantages

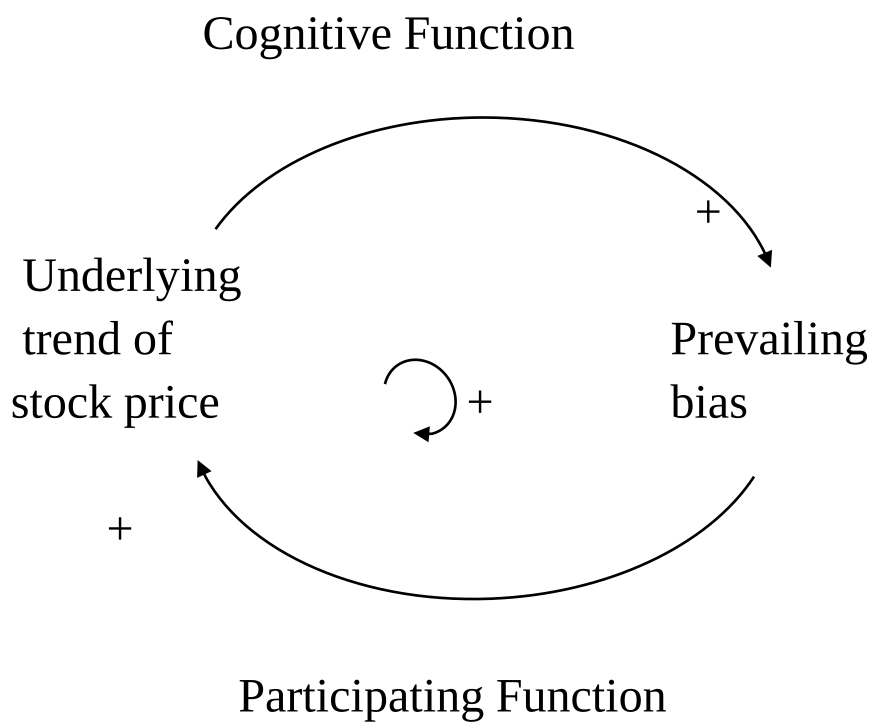
- The interests of more groups are likely to be included in the analysis
- The beliefs and values of the people involved, hence culture, are likely to be considered
- Actions to produce change (events) probably will be discussed
- The results of actions are more likely to be measured (variables)

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

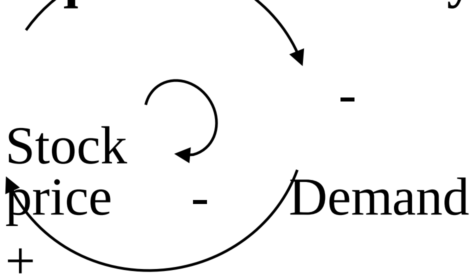
- Economists assume that markets are efficient and that information is immediately reflected in market prices
- Soros says that markets are always biased in one direction or another
- Markets can influence the events they anticipate

Equilibrium vs. reflexivity

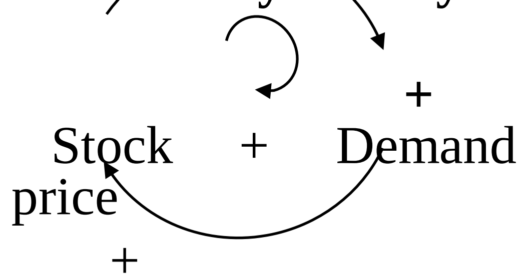
- An increase in demand will lead to higher prices which will decrease demand
- A drop in supply will lead to a higher price which will increase supply

- 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



Reflexivity Theory



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

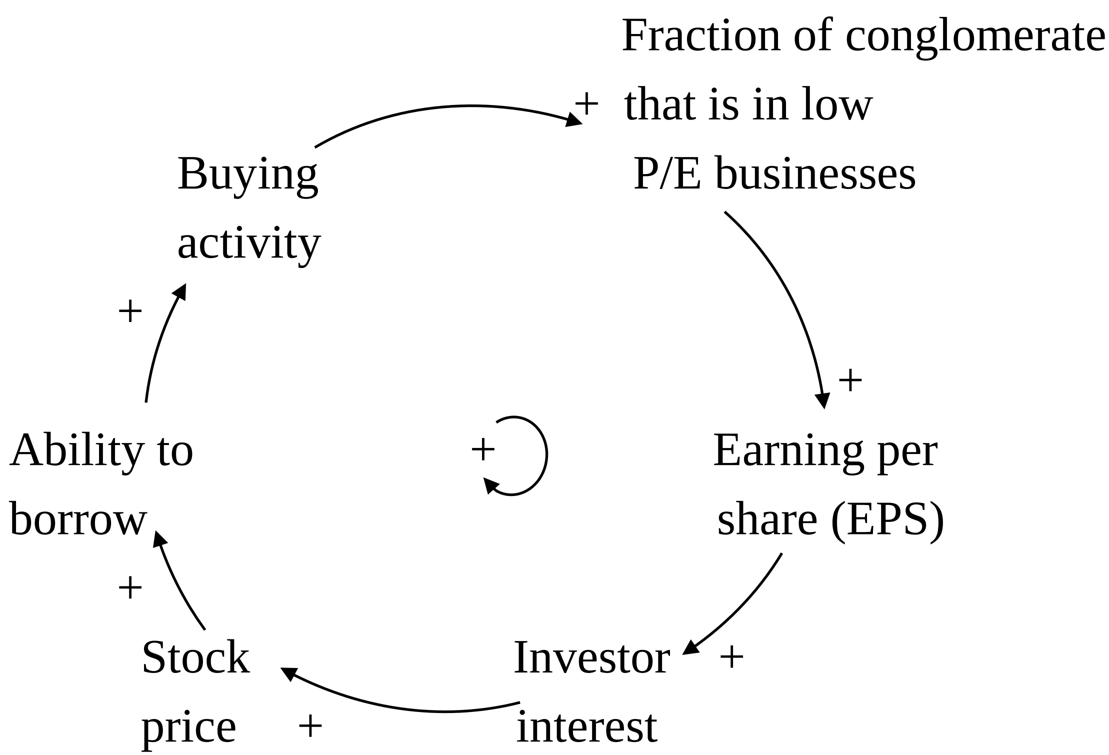
The conglomerate boom: Ideas

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

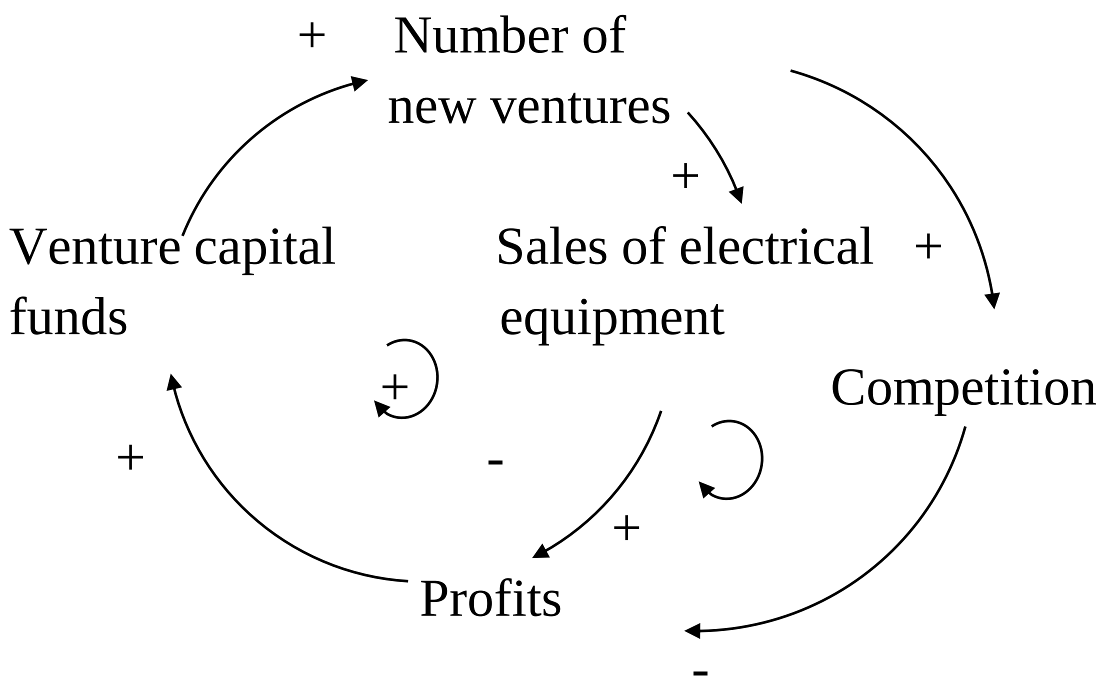
- Reflexive view
- Rising EPS is an indicator that the character of the company has changed, from high tech to consumer goods, and a high P/E ratio is no longer justified

The conglomerate boom: Groups

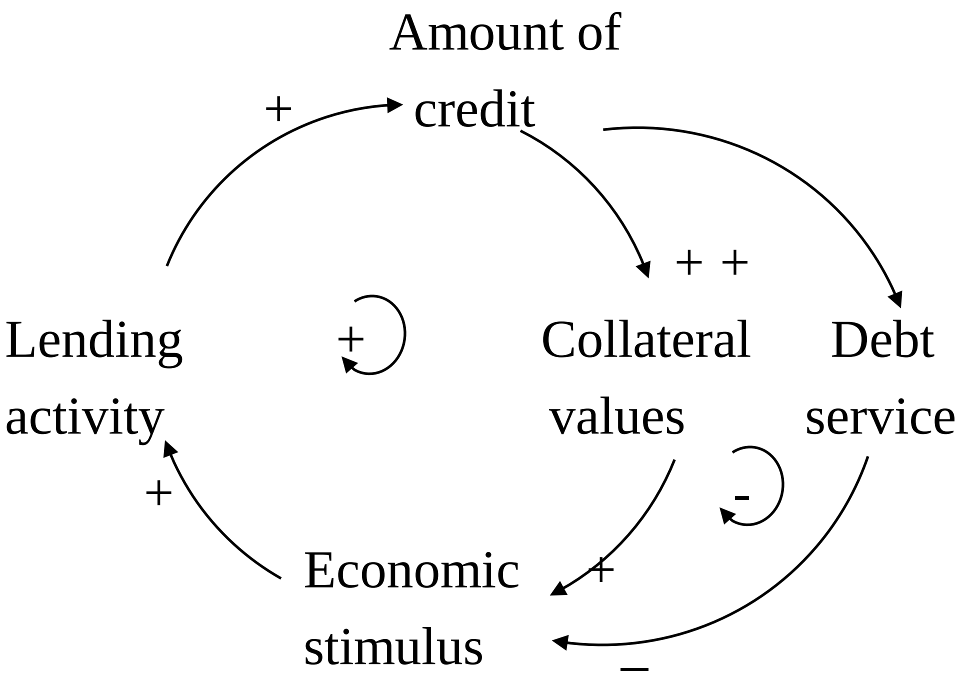
- Corporate managers who buy other companies
- Investors who believe in something new and foolproof
- Investors who use Reflexivity Theory



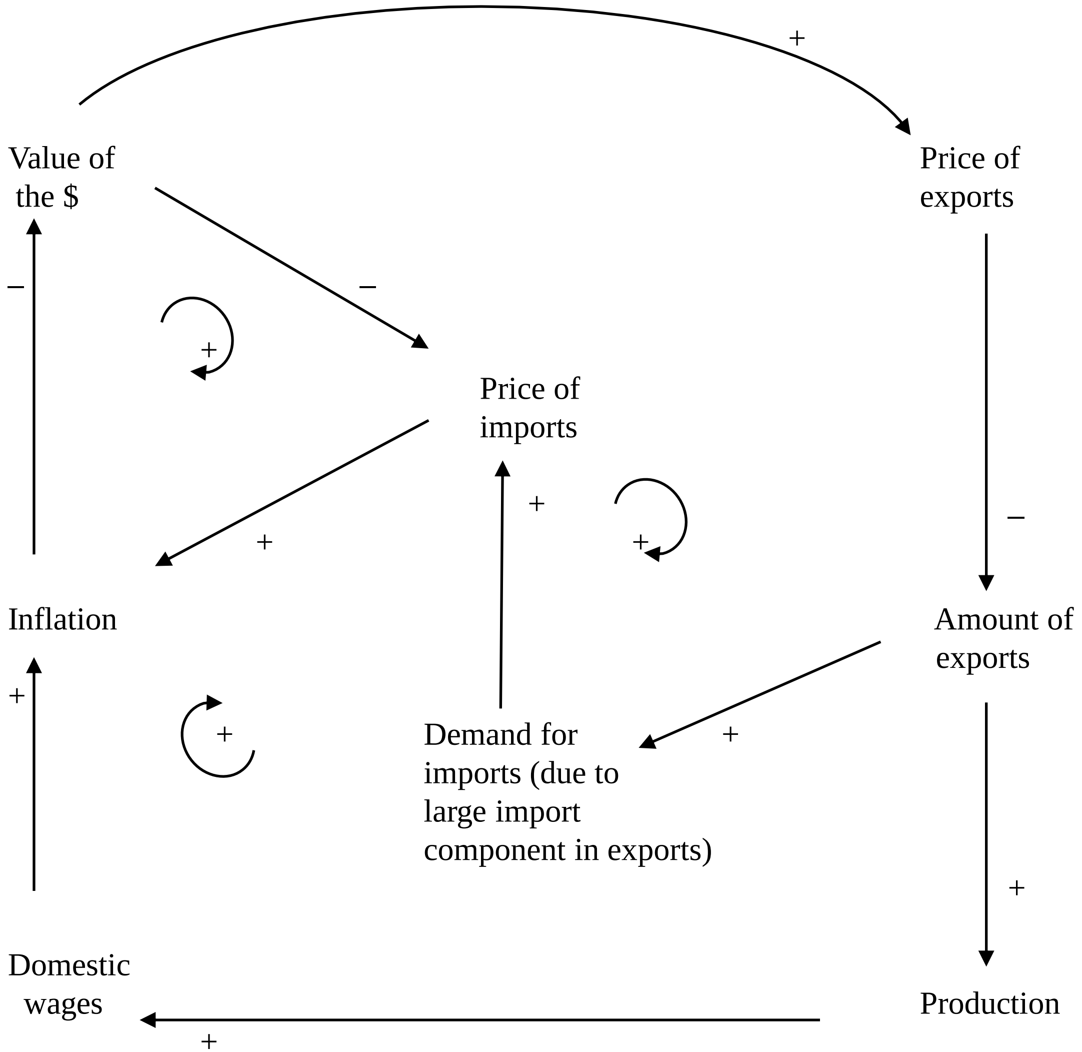
The conglomerate boom, variables



The venture capital boom



The credit cycle



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

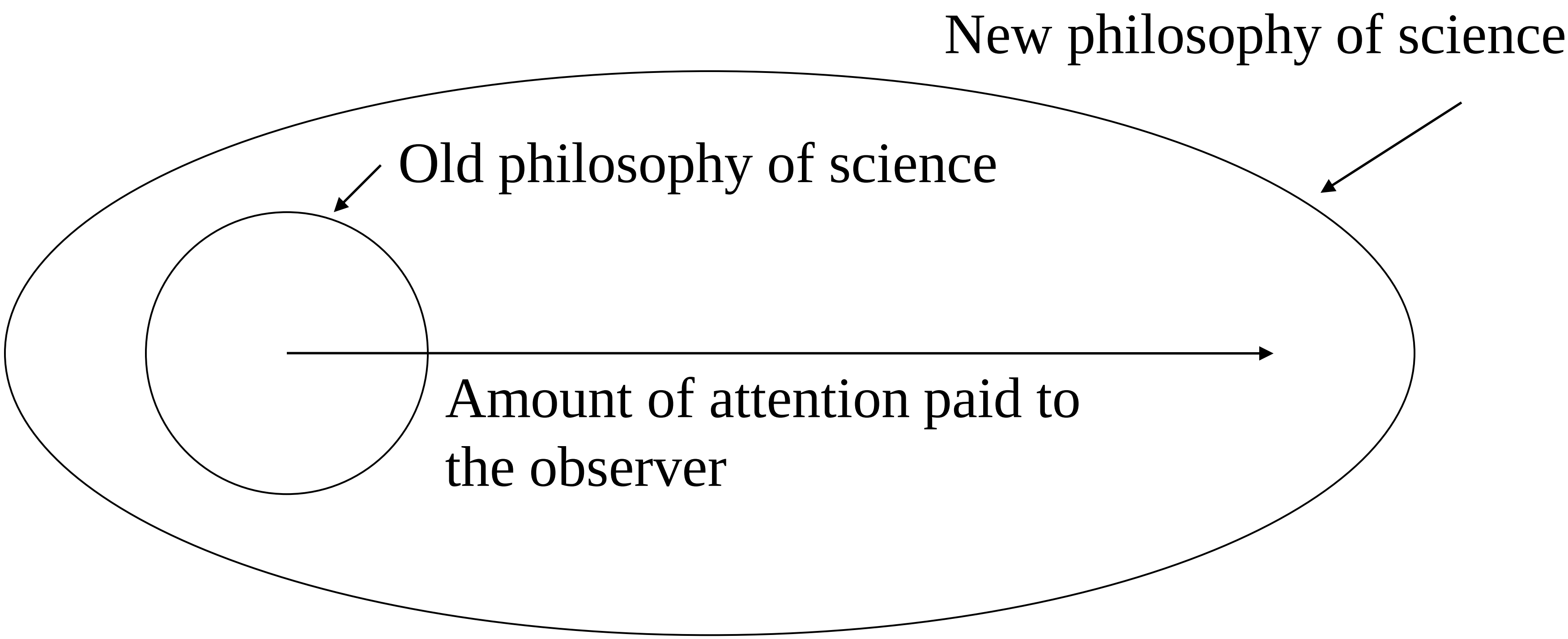
SCIENTIFIC REVOLUTION

Author	First Order Cybernetics	Second Order Cybernetics
Von Foerster	The cybernetics of observed systems	The cybernetics of observing systems
Pask	The purpose of a model	The purpose of a modeler
Varela	Controlled systems	Autonomous systems
Umpleby	Interaction among the variables in a system	Interaction between observer and observed
Umpleby	Theories of social systems	Theories of the interaction between ideas and society

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

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

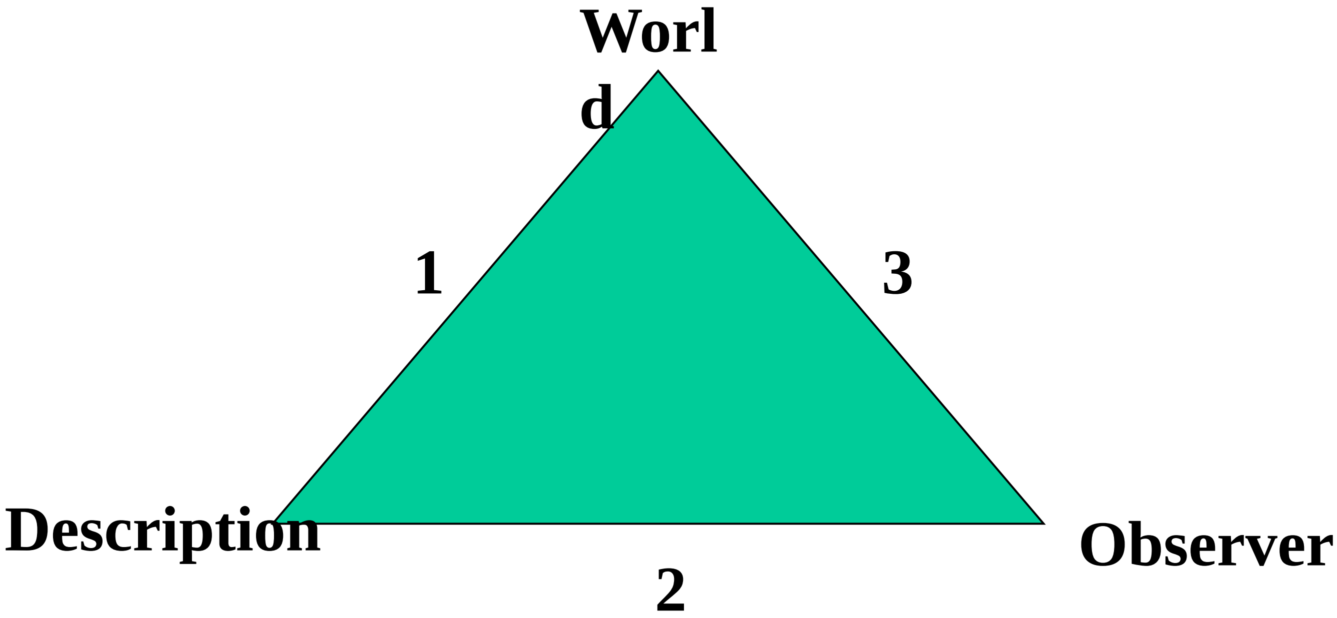
Three Versions of Cybernetics

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



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2

Syntactics	Semantics	***Pragmatics***
Rc(W,D)	Rw(D,C)	Rd(W,C)
Determined by an organism's behavioral potential	Determined by an organism's cognitive potential	Determined by an organism's perceptive potential
Gives rise to concepts such as "territory," "control," "objects," and "names"	Gives rise to concepts such as "volition," "action" "conceptions," and "propositions"	Gives rise to concepts such as "niche," "instinct," "reality" and "consciousness"

Von Foerster's epistemological triangle

Epistemological triangle

World and description	Observer and description	Observer and world
Syntactics	Semantics	Pragmatics
Representation concept of truth	Coherence concept of truth	Pragmatic concept of truth
British Empiricism	German Idealism	American Pragmatism
Inanimate Objects	Knowing Subjects	Social Reforms
Unquestioned Objectivity	Constructed Objectivity	Contested Objectivity
Form	Meaning	What works

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

Popper	**von Foerster**	**Kuhn**
A normative view of	A biological view of	A
sociological view of		
epistemology: how	epistemology: how	
epistemology: how		
scientists should operate	the brain functions	scientists
in fact operate		
Non-science vs. science	Realism vs.	Steady
progress vs.		
	constructivism	revolutions
Solve the problem of	Include the observer	Explain
turmoil in		
induction: conjectures	within the domain of	original
records vs. smooth		
and refutations	science	progress
in textbooks		

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

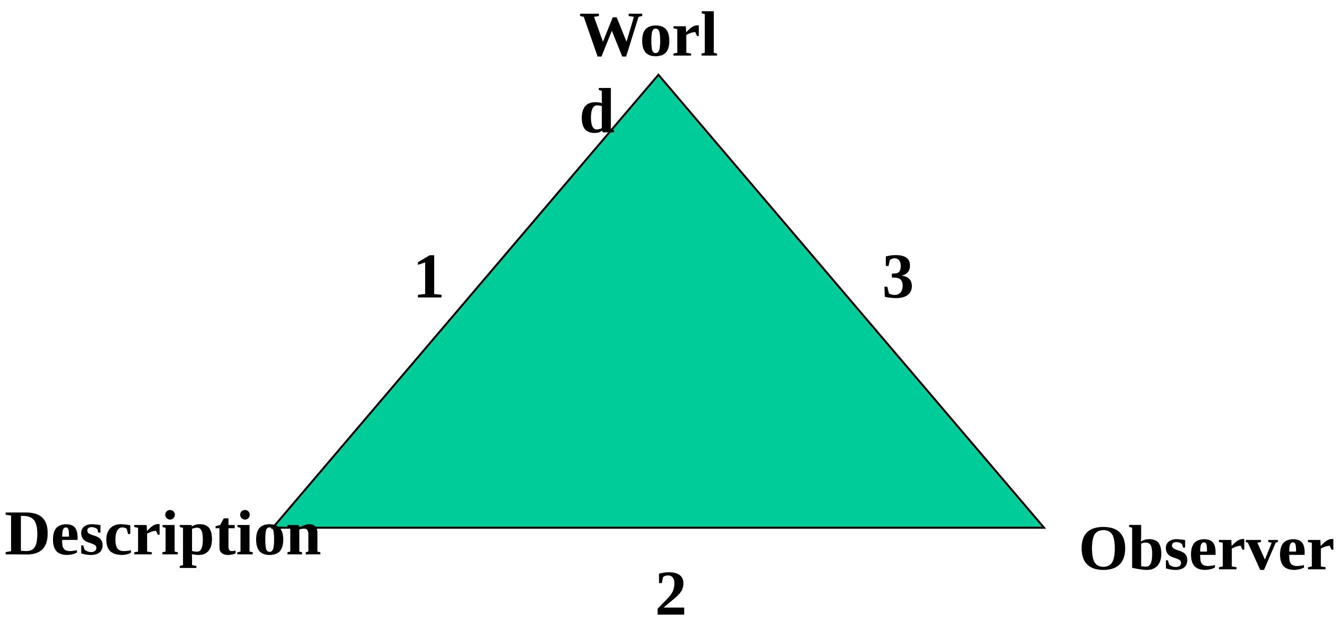
- The fact that ideas can be plausibly mapped onto a triangle carries no meaning per se
- However, an arrangement in the form of a diagram may reveal connections or missing pieces that had not been apparent before
- A graphical representation of ideas is simply a heuristic device

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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Observer
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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

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