Coming Concepts: The Cybernetic Glossary for new management

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The design of this workbook represents a collaborative effort. Stafford Beer provided guidance. and criticism on specific sections in addition to his own materials. His influence is felt not only on the materials themselves: but on the thinking and professional development of all of us who have been fortunate to work with him.

This work began with a project done with Barry Clemson which was sponsored by Paul Rubinyi, then with Ernst & Whinney in Montreal to develop a pamphlet for managers on the concepts used in *management cybernetics.* A version of this also appeared as Technical Notes in Barry's book **Cybernetics: a New Management Tool** (Tunbridge Wells: Abacas Press, 1984)

I am indebted for suggestions for the structure and to Javiar Livas and especially for the idea of including counter examples and probable errors to Irene Livas.

The discipline of management cybernetics itself has drawn upon the findings of many scientists in addition to those formally cited. Some of them, in truth, had no idea that their discoveries in physics, chemistry, mathematics, medicine and the social sciences would prove to have general application in areas far removed from the disciplines in which they originated. Others have worked with full knowledge of the transferability of their work and have advised and collaborated with researchers in cybernetics and general systems theory.

To all of these, my profound thanks.

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ADAPTATION

Adaptation is a process of change directed toward improving the 'fit' between a system and its environment. Adaptation may be a question of survival, of growth and development or of preference. The process depends on feedback (either positive or negative) to tell which alterations work best in the given environmental conditions. The process may take place in seconds, such as when our eyes adjust to a darkened room, or it may take generations such as in a society which develops the customs and crafts which fit it to its climate, its terrain or its neighbors. It may involve the actions of a single organism or individual or a collection: a biological colony or ecosystem or a human organization. Much of what has been learned about adaptation comes from biology and ecology.

Individual organisms adapt and evolve as they become more complex and as their environment changes. Failure to adapt on the part of a biological organism leads to death or extinction. The failure of an organization to adapt leads to bankruptcy, irrelevance or being voted or booted out of power.. Successful adaptation carries with it the risk of overspecialization. A certain amount of margin for error and flexibility is required to detect incipient instability and to adjust to change.

Adaptation cannot take place unless it is possible to recognize the desirable or stable state from which to move. An organism or an organization which is hit by new disturbances before it has had an opportunity to recover from previous ones has no stable state to use as a reference point from which to learn and to change appropriately. Catatonic responses in animals and alienation or cargo culture shifts in human societies are symptomatic of a rate of 'change which generates feelings of loss of control and of the capacity to adapt.

SOURCE

Adaptation comes from a Latin word meaning 'to fit'. Further information can be found in:

Sommerhoff, G. (1950). *Analytical Biology*. London: Oxford University Press.

DuBos, R. (1965). *Man Adapting*. New Haven: Yale University Press.

Holland, J. (1975). *Adaptation in Natural and Artificial Systems: an Introductory Analysis with Applications to Biology, Control and Artificial Intelligence*. Ann Arbor: University of Michigan Press.

EXAMPLES

- a retail shop which changes its inventory in response to the demographics of its neighborhood
- a soccer team responding to a style of play it has not encountered before from its opposition a salamander able to change color to match its background
- an individual who becomes accustomed to working a night shift instead of a day shift

NON-EXAMPLES

- a manufacturer who does not alter his product line to keep up with new technology
- a charity which does not redefine its mission as needs for non-profit services change
- a biological organism which becomes overspecialized and loses its environmental niche in a climactic change
- an organization whose environment is changing so rapidly that it cannot recognize the point of stability from which it can institute adaptive processes

PROBABLE ERROR

- Believing that the changes observed are accurately perceived and adequately accounted for by new tactics and strategies

SEE

Catastrophe Theory; Homeostasis; Directive Correlation; Environment; Requisite Variety

ALGEDONIC SIGNAL

An algedonic signal sends a preemptive message about pleasure or pain. If we should touch a hot stove, the sensory input from our fingers causes us to react instantly and we pull back without stopping to weigh the alternatives. This is not the kind of information that goes through normal channels and receives due consideration.

In biological systems, algedonic signals are tied to the system's essential variables. The arousal mechanisms that send algedonic signals to living organisms are an important survival mechanism, and we see the consequences immediately if a threat does not set off an arousal mechanism or if the organism misperceives a signal. Moths, for example, are attracted to light but do not recognize the threat of fire in a candle flame. Complex organizations also need to be aroused when a threat to their survival appears and to recognize quickly when a desired state has been reached. Too often, however, the non-routine channels for such information in a large organization are inadequate or non-existent and indications of danger are filtered out rather than amplified. Management must design non-routine channels so that it may act on non-routine information in time to avert disaster or seize opportunity.

SOURCE

Stafford Beer, Brain of the Firm. The word *algedonode* is coined from Greek words pointing to pleasure and pain.

EXAMPLES

- a fire alarm
- the first notice of a lethal design flaw in a piece of equipment
- a sudden change in an operation or its environment
- the death of the canary in a mine
- innovation or a substantial improvement in a product
- the opening up of a new market

NON-EXAMPLES

- the weekly report
- any after the fact analysis
- the normal top down chain of command

PROBABLE ERROR

- Designing algedonic signals with too narrow an awareness range,
- believing signals to be in place when they aren't.

SEE

Filter; Variety; Catastrophe; Distinction

AMPLIFICATION

When a signal is amplified it is increased in one of a number of ways. It may simply be louder - as when the sound of a musical instrument is picked up by a sound system. It may be more widely distributed, increased in effectiveness or extended from the specific to the general case or accomplished in a shorter period of time. In many cases, the signal to be amplified is masked by noise or blended in with other information. In these cases, amplification involves a selection of one signal from among many before it is enlarged.

In the study of systems far from equilibrium, there are many examples of a small fluctuation taking place near a threshold which is amplified throughout the whole system resulting in a change in the state of the system.

In management or regulation, the objective of amplification is usually to increase the manager's capability to handle the complexity generated by the operations under his or her control. This may be done by dividing the operational variety into important and unimportant elements, by establishing rules and procedures, by instituting training programs or by augmenting the manager's individual abilities by using staff assistance, computers, statistical quality control or other frameworks for distilling the particular bits of data which count.

SOURCE

The word amplify comes from a Latin word meaning to enlarge or extend.

EXAMPLES

- the discussion of research results
- the inclusion of events to be reported in the newspaper
- the use of equipment to pick up and broadcast a signal
- the process which occurs when a small fluctuation near a threshold or bifurcation point is carried throughout the system
- advertising new products
- conveying information in graphic as well as print form

NON-EXAMPLES

- an attenuated signal
- conditioning a market to choose from a small number of alternatives
- managing at the detail level of an operation

PROBABLE ERROR

- Choosing the wrong signal to amplify
- Assuming that a change is due to a major force rather than to the amplification of a small change

SEE

Attenuation; Channel Capacity; Algedonic Signal; Variety

ATTENUATION

Attenuation occurs when constraint is applied to reduce the effect of an action or a behavior. In the case of a signal, it may be reduced to prevent a large amount of information of one sort to crowd out the full range of the messages or damped to prevent a system from overreacting and going into a state of wild oscillation.

A regulator may balance regulatory measures between those that constrain or attenuate the variety of the regulated with those that amplify the variety of the regulator. A society may make laws and hire investigators and police to enforce them in order to keep the behavior of its citizens within prescribed limits.

In management, attenuation is employed to prevent the situation being managed from overtaking the capacity of the manager to cope with it. The same rule-making behavior which amplifies the manager's variety attenuates the variety of the operations being managed. In management, attenuation may be conscious or unconscious: e.g. ignorance is an unconscious attenuator.

SOURCE

Attenuate comes from a Latin word meaning to make thin.

EXAMPLES

- a many to one mapping
- when a culture of a virus or bacteria is weakened for use in inoculations
- the exclusion of events from being reported in the paper
- reduction of the channel capacity for a signal
- screening messages before forwarding them

NON-EXAMPLES

- an amplified signal
- the establishment of irrelevant rules
- the forwarding of messages without screening them
- a one to one mapping
- the distillation of a substance to reach a purer or stronger form

PROBABLE ERROR

- Believing that action taken to attenuate the variety of a situation has been effective without verification
- Choosing an ineffective means of attenuating variety
- Attenuating variety unknowingly due to limits of the capacity of a communication channel

SEE

Amplification; Syntegration; Transducer

AUTOPOIESIS

Autopoiesis is the process of self-production which maintains the identity of an organism or an organization as itself.

The process was first described by biologists Humberto Maturana and Francisco Varela who observed that most activity engaged in by living organisms was not directed toward reproduction but to self production. In complex organisms, autopoiesis is not a single process but a concatenation of processes linked together by homeostats or joined in a symbiotic relationship.

In biological organisms, there are external limits to autopoiesis at the individual level (an animal will eat until satisfied, and then rest) and at the evolutionary level (skeletal structure, food supply, lung capacity and other factors limit the growth of members of a species). In organizations, such controls are not so well established at either the individual or the evolutionary level. It is noticeable, however, when an organization's autopoietic activities have gone out of control and become pathological at the extreme, such as when an agency's budget exceeds the assets of the industry or activity it administers.

Detection of excesses of autopoietic activity at the organization level are sometimes difficult to discern because the particular activities may be performed with great skill and efficiency. The key is to look for the right balance between an organization’s producing itself, and producing something else such as its supposed or intended product. The production of something external to the organization or organism is called allopoiesis.

Preoccupation with organizational roles, rituals and procedures, internal emphasis on questions of turf and a decline in the adaptability of the organization to changing circumstances are signals that autopoiesis is out of control. This has been called pathological autopoiesis (by Stafford Beer), and its symptomology has been defined.

SOURCE

Maturana, H., & Varela, F. (1980). *Autopoiesis and Cognition*. Boston: D. Reidel.

Maturana, H., & Varela, F. (1992). *The Tree of Knowledge* (Revised edition ed.): Shambhala.

EXAMPLES:

Of Normal Autopoiesis

- eating to maintain life
- maintaining a reserve to ride through anticipated market oscillations
- attention to house style, code of ethics and other factors that reinforce organizational identity

Of Pathological Autopoiesis

- overeating to the point of obesity (except where climactic conditions give a substantial survival advantage to organisms who have stored a great deal of fat to last through the winter)
- preoccupation with internal coordination to the detriment of providing products and services to customers
- maintaining such a high level of reserves that the organization bypasses new opportunities and does not undertake needed adaptation
- a charity that spends most of its energy on fundraising
- hanging on to a constraining or rigid identity which blinds the organization to opportunity
- a cancer

Non-examples

- reproduction and raising the young in animal societies
- manufacturing goods
- adaptive behavior such as exploring a new market
- providing services to clients; curing the sick, training technicians, transporting goods

- long term planning, when not misconceived (as sometimes happens) as an activity in its own right

PROBABLE ERROR

- Drawing the line between necessary and excessive autopoiesis in the wrong place.
- Underestimating the resistance of a system to having its excess autopoiesis pruned (its basis is the instinct for survival, and perceptions of survival criteria may expand ad infinitum)

REFERENCE

Preface to *Autopoeisis and Cognition*, Heart of Enterprise Chapter 15, Brain of the Firm Chapter 19

SEE

Adaptation; Homeostasis; Self Reference

BLACK BOX

A black box is a model of a system whose inner workings are not open to examination. The workings of a black box may be studied or inferred by varying the inputs and analyzing the outputs. Some black boxes, such as captured enemy code machines or machines used in electrical engineering applications, are literally black boxes. It is very useful to regard most living systems and organizations as black boxes because they cannot be taken apart for study and retain their identity as wholes. Their inputs and outputs can be observed or manipulated and their activities thereby predicted, influenced or directed.

In organizational settings the observer or manager may have partial knowledge of what is going on within a particular unit. It is helpful to regard these as 'muddy boxes' because the view 'inside' will inevitably be affected by the purpose of the observer and by channel capacity limitations on the perception of that system's variety.

In management, subordinate units will be either black or muddy boxes to the upper level manager if he or she manages them at the appropriate level instead of attempting to do the job of the manager one or more levels down. In the absence of an algedonic signal the inside workings of a black box should not be subjected to scrutiny or interference. Their outputs are the proper focus of concern and their inputs may be adjusted to attain the desired outcomes.

SOURCE

Ashby, R. (1956). *Introduction to Cybernetics*. London: Meuthen & Company.

Ashby, R. (1960). *Design for a Brain*. London: Chapman and Hall.

EXAMPLES

- a baby
- a computer to a layman
- a work group
- a voluntary organization
- a market for a product
- a seed

NON-EXAMPLES

- a simple mechanism
- the organizational level in which you are embedded
- a computer to its designer
- a game

PROBABLE ERROR

- Working at too low a level of detail so that the variety reduction capabilities of the black box model go unused
- Assuming the black box is really transparent to anyone as clever as you are.

SEE

Algedonic signal; Variety; Model; Information

BOUNDARY

A boundary separates a system from its environment or from its sub and supra systems. Boundaries are established for the consideration of particular systems with particular purposes. They are likely to differ among different observers of the same system unless the system under consideration has been defined by a common and explicit convention. Boundaries also differ in the precision with which they may be established. In some mathematics, boundaries may be established with exactitude. In other areas of mathematics, such as fuzzy sets, or in the natural and social environments, it is more difficult to draw a clear distinction between a system and its environment. Boundaries may exist in space, in time or in abstract concepts.

Information crossing a boundary between a system and its environment or between a system and its sub or suprasystem must do so by means of a transducer which leads the information across the boundary from the language of the system to the language of the environment. Confusion sometimes arises in complex systems when an activity overlaps different system and sub-system boundaries.

In many systems, perspectives or conditions may be different depending on how close they are to that system's boundary. In the natural environment, there are many examples of specialized boundary areas which are systems in and of themselves of which the shore line the tree line are perhaps the most familiar. A similar situation applies in an organization where staff members who spend most of their time representing the organization in its external environment will have a very different view from those whose activities are primarily internal. Sales and procurement staff, researchers, planners, and lobbyists have different perspectives from one another and from that held by the front office staff.

SOURCE

the word boundary refers to a setting of limits originally it applied primarily to territorial boundaries.

EXAMPLES

- a fence
- the skin of the human body
- a national border
- the end of a retail season
- the limits of a class in set theory

NON-EXAMPLES

- a particular decision track in an anasotomic reticulum, which is like trying to trace the origin of a particular bucket of water back through a river delta
- a link in a chain of causality
- any limit to a human ability when the available technology is not specified such as 'a day's journey'

PROBABLE ERROR

- misidentifying or mixing system and subsystem boundaries
- failure to take into account the different boundaries assumed by different observers of a system
- the assumption of the relevance of some technology which may well be superseded

SEE

System; Information; Complementarity; Environment; Transducer

CHANNEL CAPACITY

The capacity of a communication channel refers to the amount of information it can transmit in a given period of time. It must be able to distinguish the number of states (or the variety) it is to transmit and it must be able to do so in the time allotted. In a discrete channel such as a telegraph wire, the capacity is spoken of in terms of the " logarithm of the numbers of symbols of certain time duration... the number of such symbols handled . . the amount of information transmitted per second, using bits per second as a unit." The needed amount of channel capacity can be figured accurately for Morse code or teletype.

It is more difficult to figure the needed channel capacity for an information system for management but it must be able at a minimum to handle the variety in the capacities of the reporting units. Managers are likely to need answers to questions such as ' how can I find out what I need to know to make this decision by Wednesday?' or 'how much information about the new product can be handled in a press release?', or 'can we convey our plans sufficiently in a five page prospectus to secure the interest of investors so that they will undertake a full investigation?'. In these cases channel capacity refers to the limits of different formats of communication and the limits of the human beings involved to absorb oral, written and other kinds of messages.

SOURCE:

Shannon, C. E., & Weaver, W. (1964). *The mathematical theory of communication*. Urbana: University of Illinois Press.

EXAMPLES

- the number of agenda items that can be handled adequately in an hour long meeting
- the amount of new information an individual can take in before the threshold of information overload is reached
- the 'sound bite' in political campaigns
- the number of available channels for radio and television
- the neurological limits of human perception

NON-EXAMPLES

- questions relating to the content of messages
- whether or not the message is correctly addressed
- explaining the theory of relativity on a single page or to a small child

PROBABLE ERROR

- Choosing the wrong mode of communication for a message,
- Choosing inappropriate transmitting conditions,
- Not realizing that a given format or time and presentation delimits the complexity of the message,
- Not allowing for distortion of the communication due to noise.

SEE

Requisite Variety; Redundancy; Information

CATASTROPHE THEORY

Catastrophe theory is the study of sudden, substantial and sometimes irreversible changes in the state of a system as it moves from a type of change which is continuous to one that is discontinuous. It is pictured by the action of a marble in a three dimensional landscape of peaks and valleys which may suddenly fall off the edge of a cliff. It has been described mathematically, using topological algebra. "Catastrophes" are characterized by the crossing of a threshold of stability such as the range of normal oscillation or the point at which incremental change in a certain direction gives way to abrupt change in another direction. The direction of the change is not necessarily unfavorable to the system; it may signal a significant opportunity as well as a potential disaster.

Systems approach catastrophe through a region of instability from which they either return to equilibrium, or cross the boundary into a state in which they will either in turn find a new point of equilibrium or fail to survive. Systems can act to avert catastrophe by broadening the cusp of their zone of instability and giving themselves more time and space to recover from an disturbance.

SOURCE

Thom, R. (1975). *Structure, Stability and Morphogenesis*. Reading, PA: Benjamin.
For a popular treatment, see:
Woodcock, A., & Davis, M. (1978). *Catastrophe Theory*. New York: E.P. Dutton.

EXAMPLES

- a change from a fleeing to fighting mode of behavior in an animal
- an avalanche
- panic selling of stock
- the declaration of war
- the result of the addition of a crystal to a super saturated solution
- crossing a threshold of contamination which kills pond life

NON-EXAMPLES

- continuation of a trend
- managerial preference of 'evolution' to 'revolution'
- adaptation to a new set of circumstances
- a random happening

PROBABLE ERROR

- Failure to identify and anticipate regions of instability and either suffer a loss or forego an opportunity.
- The assumption that no discrete event (such as a coup, or a bankruptcy) is likely to happen.

SEE

Dissipative Structures; Equilibrium; Stability; Adaptation

COENETIC VARIABLE

Coenetic variables are those varying factors which are common to a system and its environment and affect both. Very often they are not recognized as such, because the boundaries of the system are drawn so as to exclude them. Through directive correlation, coenetic variables act to reduce the variety operating between a system and its environment and narrow the field in which adaptation occurs. The action of coenetic variables is one of the reasons that it is sometimes difficult to distinguish, or fix over time, the boundaries between systems and their environments.

The same set of coenetic variables can have very different effects on different parts of the environment. A snowstorm, for example, will be greeted as a boon to winter resort operators and a disaster to a shopkeeper who stocks highly perishable or date-specific goods.

SOURCE

Sommerhoff, G. (1950). *Analytical Biology*. London: Oxford University Press.
Sommerhoff, G. (1974). *Logic of the living brain*. London: Wiley.
The word coenetic (pronounced sennetic) was coined by Sommerhoff from the Greek word meaning 'common'.

EXAMPLES

- the effect of change in interest rates on the build-up of inventory and the terms offered to retailers
- the amount of rainfall on the harvest date and yield
- the change in traffic patterns resulting from the temporary closing of a major artery
- the impact of economic conditions on business investment

NON-EXAMPLES

- the behavior of a supervisor towards a subordinate
- the interaction of players in a game of chance
- the drop of support suffered by a political candidate charged with a crime
- the reaction of chemicals in a test tube when other factors are held constant

PROBABLE ERROR

- not allowing for the effect of coenetic variables on the reduction of variety in a system's behavior
- misidentifying a coenetic variable as a link in a cause-effect chain

SEE

Directive Correlation; Adaptation; System; Boundary; Environment

COMMUNICATION

In its broadest sense, communication refers to all the processes by which one system, human or machine, animate or inanimate, may affect another. Its means include speaking, writing, gesturing, radio and television broadcasting, artistic expression, electronic and manual switching, computer operations, and many others. All communication occurs in time and in a medium: air, wires, print, light bands, etc. It may be a one way or an interactive process. Much communication takes place by means of symbols, e.g. a word is a symbol for a perception of an object or a sensation. Information is 'what' is communicated and it can be measured quantitatively.

It has been said that two people who are aware of each other's proximity cannot 'not communicate' because even a decision to remain silent is a communication conveying information.

In the sense of the technical problem described by Shannon and Weaver ("How accurately can the symbols of communication be transmitted?"), communication maybe defined as a process whereby a message is transmitted- from a source, through a transmitter, over a communication channel to a receiver to its destination. Noise may drown out portions of the message or portions may be lost. For this reason, redundancy may be added to a message until a given probability of accuracy is reached. Shannon and Weaver's other two levels of communications problems, the semantic problem dealing with the meaning conveyed and the effectiveness problem dealing with whether the desired conduct took place, involve more complexity in the response made by the receiver.

SOURCE

Shannon, C. E., & Weaver, W. (1964). *The mathematical theory of communication*. Urbana: University of Illinois Press.

EXAMPLES

- a letter sent, received, read and understood to mean what was intended
- a telephone call completed
- the genetic code across generations
- a dance performance
- the signal of an automatic timer to a machine

NON-EXAMPLES

- an uncoupled signal or switch
- a letter sent, received and misunderstood
- books that never leave the shelf
- a radio message when the receiver is off
- hand signals in the dark

PROBABLE ERROR

- presuming a message was understood merely because it was received
- failure to allow for the effects of noise on a message
- static in a wire
- irrelevant data
- cross-cultural confusion
- the effects of a head cold suffered by the intended receiver
- SEE

Channel capacity; Transducer; Information; Entropy; Redundancy

COMPLEMENTARITY

Complementarity is a concept from physics which describes the circumstance where two models of a system will reveal some commonalities and some differences. It is necessary to be consciously explicit about the way in which the models are formulated, whether the model is a sophisticated simulation or a simple mental model, in order to avoid misunderstanding. In practice, most models are 'right' about some aspect or definition of the system under study. The question is which one applies or works best under the present circumstances. In management and social sciences the models of a system held by customers or clients, competitors, insiders from different departments and other interested parties may be very different indeed, with far reaching implications. When complementarity among models exists, it can be a powerful resource for acquiring a better understanding of the situation or it can degenerate into an unanswerable debate over who is 'right'.

Complementarity became an issue in wave mechanics when measurements made on the basis of an assumption that light came in waves and those based on the assumption that light came in particles were both found to be useful depending on the experiment.

SOURCE

Bohr, N. (1963). *Essays, 1958-1962*. New York: Wiley Interscience.

EXAMPLES

- "the government" as seen by the party in power, by the opposition party and by its neighboring states
- a plant closing seen by the company, the community in which it is located and the union to which its employees belong
- a new product as seen by R & D and sales
- a meeting seen from the perspective of each of its participants
- a new procedure viewed by management and workers

NON-EXAMPLES

- a game with agreed upon rules a set of systems with no relevant overlap

PROBABLE ERROR

- not recognizing when complementarity exists by not making differing assumptions explicit
- failure to recognize that many disagreements are rooted in the parties perceiving complementary systems
- compelling people to take sides about issues that reflect only the inadequacies in two complementary models

SEE

Observer; Model; System; Identity; Closure

CYBERNETICS

Stafford Beer has called cybernetics the science of effective organization, a more general and easier to grasp definition than Norbert Weiner's "communication and control in the animal and the machine". Its root is a Greek word meaning steersman and that has the right flavor. A steersman in a sailing vessel makes no claim to control of the winds or the tide. His skill depends on sensing and using the natural forces and movements to reach his own goal. His focus is on what this environment is doing right now and what it seems likely to do in the future, not what it is supposed to do or what it did yesterday.

Cybernetics as a science began in the 1940's when scientists studying control in disparate disciplines began to work together, first in connection with the Second World War and later at a series of conferences called to explore further the common threads that they had each been following. The language used in cybernetics reflects its multidisciplinary origins. To give just a few examples, phenomena in physics, such as entropy, were found to apply also to information theory and biology; implications of Godel's theorem were found in management: and findings in neurophysiology were used in the design of computers.

The cybernetic approach differs from that of traditional science because it studies the behavior of wholes and parts in interaction rather than of parts isolated and measured. As such, it can be used to handle situations of great complexity which operate on the basis of probability and include large areas of uncertainty. In addition, it rejects the claim of complete 'objectivity' in favor of the embedment of the observer in the situation being observed, through the choice of models and measurements and the ethical implications of the choices which are made.

A considerable - some would say complete - overlap exists between cybernetics and general systems theory. Such distinctions which are made are characteristic of new scientific fields and the establishment of their boundaries and need not trouble those who wish to utilize theoretical and practical insights under either name.

In its early years, operations research was considered to be closely associated with cybernetics with the former providing the theoretical base and the later the multi-disciplinary problem-solving strategies. More recently, operations research has focused more on the application of its tools, such as Markoff processes and linear programming, to problem situations.

SOURCE

Wiener, N. (1961). Cybernetics; or, Control and communication in the animal and the machine. New York: M.I.T. Press.

Ashby, W. R. (1956). Introduction to Cybernetics. London: Meuthen & Company.

McCulloch, W. (1965). Embodiments of Mind. Cambridge MA: MIT Press.

Beer, S. (1959). Cybernetics and Management. London: English Universities Press.

EXAMPLES

- the study of self organization in biological communities
- control devices such as Watt's steam governor or the standard thermostat that come back under control in the very process of going out of control as compared to, say, a prison governor
- the use of a continuous flow of information to guide goal directed activities.

NON-EXAMPLES

- deterministic models of situations
- accounts of systems that look at one part at a time, ignoring the interrelationships between them (the reductionist model)

PROBABLE ERROR

- Failure to recognize the organic nature of viable systems in, for instance and inexcusably - the practice of medicine
- More excusably, but still wrongly - social systems
- Ignorance of the cybernetic laws that govern the behavior of large, complex, probabilistic systems, thereby accepting that instead they are governed by chance.

SEE

System; Metasystem; Observer; Model
Feedbaack

DIRECTIVE CORRELATION

Directive correlation is a biological term describing the relation between independent but interacting variables. It connotes their reduction of variety and thereby concentrates an organism's goal directed behavior on a set of alternatives with a higher than average probability of success.

The degree of directive correlation is time dependent. Fewer choices are available as the goal itself becomes closer, e.g. a lion stalking a gazelle has many options before it is noticed, a smaller number when the prey begins to flee and almost no opportunity for adjustment after the lunge has commenced.

There is no definite limit on the number of variables which may be directively correlated (called the compass) but they must satisfy the condition of orthogonal independence - that any arbitrary combination of their values could be taken as the initial state. Perception of and adaptation to changes in the values of the relevant variables enables the goal directed activity to be correlated or refined as conditions are more precisely perceived.

There are three main types of directive correlation.

1. In the short term, contingent variations in the performance of a task are examples of *executive directive correlation*.

2. *Ontogenic directive correlation* takes place during the lifetime of the organism: it includes learning, maturation and adaptation to environmental conditions (such as the growth of a heavier coat of fur in a cold climate).

3. *Phylogenetic directive correlation* has been described as establishing the conditions for successful goal directed behavior as a species evolves toward maximum adaptation to its environment.

The three types are closely related. Execution implies maturation and, usually, learning; learning in turn implies an appropriately evolved structure. To illustrate: learning to fly is a fairly easy task for a baby bird while a great deal of effort can be expended by a man flapping his arms with negligible results. When the structure of knowledge grew to include design of aircraft, engine and propellers, human flight became practical.

Directive correlation also occurs in social systems when a process of learning and adaptation to increase the likelihood of success in reaching a goal is undertaken. This can be done by experiment, by simulation, or by using a technique, such as game theory, to reduce the number of alternatives to manageable size.

SOURCE

Sommerhoff, G. (1950). *Analytical Biology*. London: Oxford University Press.
Sommerhoff, G. (1974). *Logic of the living brain*. London: Wiley.

EXAMPLES

- the adjustments made by a gunner to keep a moving target in his sights
- changes made in an electoral campaign in response to issue polls
- the adaptation of wild species, such as raccoons and foxes, to an urban environment
- varying a television series' character development on the basis of ongoing audience research
- training needed technicians to implement a national development plan as the plan is being prepared

NON-EXAMPLES

- formulating a market strategy on the basis of a previously prepared campaign
- following through on a five year plan without making alterations proceeding to test a new idea at random

PROBABLE ERROR

- Mixing up causal with independent or orthogonal variables.
- Misidentifying the goal to which observed actions are directed.
- Mistaking a fortuitous outcome for goal directed activity.

SEE

Coenetic Variable; Adaptation; Environment; System

DISSIPATIVE STRUCTURES

Dissipative structures are dynamic structures which require energy to sustain their identity. They are open systems which interact with their environments. Dissipative structures are characterized by irreversibility and by probabilistic and non-linear change.

Dissipative structures tend to arise in situations - chemical, biological or social - which are in a state far from equilibrium. At or near equilibrium (Le Chatelier's Principle in chemistry), a disturbance will cause the system to shift slightly to maintain its equilibrium or a series of small fluctuations will average out around the equilibrium point. Far from equilibrium, a very different situation occurs. A small fluctuation can be amplified throughout the system if it occurs near a threshold or bifurcation point. When this occurs, the change is not determined but subject to probability. Some of the possible outcomes lead to a self-organizing process resulting in higher or different types of order, while others lead to disorder.

The early work on dissipative structures came out of thermodynamics and chemistry where questions about entropy and its irreversible nature were contrasted with classical physics and chemistry with its reversible dynamics. Current researchers are also studying the phenomena of dissipative structures in living systems which are operating far from equilibrium. Their work has made it possible to describe the dynamics of familiar problem areas, such as traffic management, which are characterized by the impact of local events when the system's normal operating capacity is near threshold levels.

SOURCE

Glansdorff, P. G., & Prigogine, I. (1971). *Thermodynamic Theory of Structure, Stability and Fluctuations*. New York: John Wiley & Sons.

Nicolis, G., & Prigogine, I. (1977). *Self-organization in Non-equilibrium Systems*. New York: John Wiley & Sons.

For a less technical treatment see:

Prigogine, I., & Stengers, I. (1984). *Order Out of Chaos*. New York: Bantam Books..

Jantch, E. (1980). *The Self-organizing Universe*. San Francisco:: W.H. Freeman and Company.

EXAMPLES

- the emergence of a new type of ecosystem after a catastrophe has destroyed the previous equilibrium
- the reorganization of a business after bankruptcy
- the formation of a new government after a coup
- a chemical clock
- an ocean wave
- gridlock affecting an entire city when one major traffic artery is incapacitated

NON-EXAMPLES

- gradual change in an existing ecosystem
- the formation of a new government after a routine election
- solar system whose predominant force is gravity
- a machine
- a regular crystal

PROBABLE ERROR

- Misjudging how close or far from equilibrium a system we are observing or disturbing has become
- Expecting change to be linear

SEE

Identity; Stability; Self-organization

DISTINCTION

The making of a distinction is the beginning of order. It establishes the cleavage between the object distinguished and everything else in the field of perception. The act of distinction is a choice made by an observer to select this object rather than another or this dimension rather than that one. The making of a distinction precedes the sending of any message, the assignment or recognition of an identity, and the determination of any criterion for judgment.

Distinctions are central to an account of beginnings, whether they are the beginnings of the world described in *Genesis or in Hesiod's Theogeny*, the beginnings of individual consciousness when an infant first becomes aware of the difference between self and other, or the agreement on a consensual domain at the beginning of a conversation.

The drawing of a distinction indicates a boundary and a context. Distinctions can be clear dichotomies with no overlap or gray area between them or they can be points on a continuous dimension. They may be absolute or conditional. They may indicate different objects or the same object in different spatial, temporal or social contexts.

Different standards apply depending on the nature and purpose of the act of making a distinction. When seeking a particular member of a set, such as a number from one to a thousand, the most economical process of distinction is usually preferred: dividing the group by halves each time. When the choice is more complex, the preferred method may be to eliminate large groups of unfeasible or conditional choices and proceed to make a detailed examination of only a few. In those cases where social and political choices are at issue, there are risks of narrowing the field of choice too early to balance against the risk of exceeding the channel capacity of the decision-making body. If either of these occurs, the distinctions made may reflect private criteria rather than the nominated ones.

The act of making a distinction itself may be a reflection of power or authority. Such distinctions include the primitive power of 'naming', the contemporary power to define 'an act of war' or 'unemployment', and sometimes the choice of a language itself. They may be made according to a hierarchy or cooperatively, on behalf of the entire community.

SOURCE

The mathematics of distinction is found in:

Spencer-Brown, G. (1979). *Laws of Form*. New York: E.P. Dutton.

For a discussion of social aspects, see:

Bourdieu, P. (1984). *Distinction: a Social Critique of the Judgment of Taste* (R. Nice, Trans.). Cambridge: Keegan-Paul.

EXAMPLES

- the enclosure of a space in geometry
- the naming of any set
- the choice of a product from the shelf
- the selection of a sample population for a study
- a just noticeable difference
- the recognition of change
- the choice of a plan by a zoning board
- the style of an artist

NON-EXAMPLES

- the mixing of apples and oranges
- sampling at random after the choice of a population has been made
- less than a just noticeable difference
- details outside the range of perception or interest of the observer

PROBABLE ERROR

- not being aware what distinction is being drawn when a choice is made
- assuming that two observers have made the same distinction when the scale or context has not been indicated.
- assuming that two observers are in opposition when they have made a different complementary distinction

SEE

Complementarity; Recursion; Stability

ENTROPY

Entropy is a measure of disorder or of the decay of order. Work., such as is accomplished by heat energy, causes a change to occur which in turn depends on a distinction between the one state and the other. In an analogous process, a message involves a choice and the distinction of one particular message.

Entropy measures the decay of the differentiation which permits work to be done or messages articulated. Because of its unidirectional progress, the most probable state is one where differentiation has been relaxed. Thus, " Entropy is a measure of a system's inexorable tendency to move from a less to a more probable state". Entropy can be described in general or precise terms based on the area of application. An organization requires new infusions of effort to maintain its vitality and offset its tendency to run down. An animal needs a continuous supply of food to maintain itself . Without it, it can no longer maintain its order and it moves toward maximum entropy - and death. The perception of disorder in a system varies according to the observer's definition of the system and its purposes. For example, in one organization, order may be perceived in terms of hierarchy while in another it will be seen in terms of a network of small self-organizing units.

As a measure of disorder in a system, the conception of entropy and the ways it is measured differ somewhat depending on the system under consideration.

In mathematics, entropy is expressed as the logarithm of the probability of a certain state.

In thermodynamics, entropy is the subject of the Second Law which says that heat in a system will tend to even out until none is available for doing work. If work is to continue, heat must be added to the system to offset the effect of entropy.

In statistical mechanics, entropy is a measure of disorder in the arrangement of atoms. The maximum disorder and the most probable-state is one of random distribution. The entropy increases as the degree of randomness increases.

In cybernetics and information theory, the amount of information corresponds to the degree of order in the system and the entropy to the amount of disorder. Thus, entropy and information are seen as opposing concepts with entropy defined as information with a negative sign. A system maintains its order through the addition of information. Entropy may be seen in some contexts as a measure of uncertainty. In information theory, entropy may be calculated for a given source and subtracted from its maximum entropy. This gives its relative entropy. The redundancy of the message is figured at one minus relative entropy.

SOURCE

For Thermodynamics, see Clausius; for statistical mechanics, see Boltzmann and Gibbs; For cybernetics and information theory see

Wiener, N. (1961). Cybernetics; or, Control and communication in the animal and the machine. New York: M.I.T. Press.

Shannon, C. E., & Weaver, W. (1964). The mathematical theory of communication. Urbana: University of Illinois Press.

EXAMPLES

- on the way from the delicatessen to your desk, the hot coffee gets luke warm and your ice cream begins to melt Before you ordered them, electricity supplied the energy to keep the coffee hot in the urn and the ice cream cold in the freezer
- holiday traffic is backed up for miles waiting for a backlog at the bridge to be cleared. The once orderly movement of cars is transformed to a collection of Frisbee games, picnics, people sitting on fenders, etc.
- a puppy overturns the garbage and messes up the yard.

- an untended garden becomes overgrown
- a sports team's plays become sloppy if they have not had enough practice

NON-EXAMPLES

- the members of a community organize themselves to maintain essential services after a flood has cut them off from normal sources of supply
- a message is transmitted with a given degree of accuracy a system grows and becomes more specialized
- an organization maintains and enhances its identity through participative planning sessions and training

PROBABLE ERROR

- viewing the progress of decay and disorder in a system as an aberration, neglecting to consider the allocation of resources to maintain system order

SEE

Information; Self-organization; Autopoeisis; Uncertainty

ENVIRONMENT

The environment of a system consists of all of the factors which may separately or in combination change its state. These include both essential variables, which are defined as those which may effect the system's viability, and those variables which may change the behavior of a system. The determination of what is in the system and what is in the environment is often highly subjective and is also subject to redefinition as the purposes of a system change or are better understood. Communication between a system and its environment takes place through transducers which operate at the boundary between them. A disturbance in the environment must be taken into account by the system.

Environments of systems are also conceived recursively. The environment of the suprasystem includes the environments of its subsystems plus the environment it interacts with as a whole system, which may often be incompatible with the subsystem's viewpoint. The interaction between systems and environments includes both intended and unintended effects.

While we commonly think of the natural world of air and water, flora and fauna when we speak about 'the environment', the concept of an environment applies equally well to organizations, markets, political and cultural contexts and abstract ideas.

SOURCE

Environment comes from an Old French word meaning to encircle or surround. Its early use was primarily to denote surrounding territories; more recently it has been frequently applied to biology and ecology.

EXAMPLES

- the market for a product
- the climate of public opinion in which a government initiative takes place
- the state of the world economy on an export business
- the internal state of a company when a group within suggests an innovation

NON-EXAMPLES

- Opinion leaders who do not affect the opinions of the actual market
- System behavior close to the boundary which is misperceived to be in the environment
- Behavior so far removed from a system as to have only a negligible effect

PROBABLE ERROR

- not noticing when a boundary between a system and its environment has moved,
- not making explicit the definitions of system and environment being used
- misperceiving the boundaries in the well known saying 'God grant me the courage to change what ought to be changed, the patience to endure what cannot be changed and the wisdom to know the difference'

SEE

System Boundary; Transducer; Openness in Systems

EQUIFINALITY

Equifinality is the phenomenon whereby open systems reach the same end state from different beginning states and by different paths. It is contrasted with the *convention used* in discussing closed systems where the final state is given if the initial state and process are *known and* where a change in the initial state or the process produces a different final state. If a final state is known or desired in an open system (which includes most of them), the alternative beginning points and paths may be altered to hasten, postpone or otherwise change the cycle. It follows that a pluralistic or fragmented approach may be called for depending on the mix of initial states and the availability of resources to facilitate the most satisfactory movement from the one to the other.

SOURCE

Bertalanffy, L. (1968). *General System Theory*. New York: Braziller.

EXAMPLES

- the limits of useful life of a machine
- the building of a road from point A to point B
- the progress of a life from birth to death
- the training of personnel to manufacture electronic components

NON-EXAMPLES

- the reactions of chemicals in a test tube
- a computer program
- games of certainty
- the plot of morality tales

SEE

Openness in systems; Variety; Entropy; Ultrastability; Information; Equilibrium

FEEDBACK

Feedback takes a part of a system's output and applies it to change or to maintain its input. It is based on the actual rather than the potential or expected performance of the system. Feedback may be either negative (error correcting) or positive (trend enhancing). " Positive feedback takes an increase in the output back to increase the input; negative feedback takes back an output to decrease the input - and is therefore stabilizing in principle°. Positive feedback is wisely applied to encourage desired growth but must be kept under close surveillance to assure that explosive growth does not destabilize the whole. Negative feedback loops must be designed with appropriate time frames or uncontrolled oscillation will occur (called 'hunting' by control engineers) . This may result in a 'correction' being applied in the wrong direction. This typically occurs in the management of economic policies because by the time the data are compiled the situation has often changed its trend.

Feedback is essential to control. In a well functioning system, feedback loops are designed so that the system is brought back under control in the act of going out of control. The Watt steam governor is a good example of such a system. As the engine acquires speed the whirling balls move up, blocking the supply of air on which combustion depends. As the engine slows, the balls drop, increasing combustion by allowing more air to enter.

Note: Feedback is sometimes mistakenly interpreted as simply a response, such as praise or criticism.

Feedback was an early subject of study of the Conferences sponsored by the *Josiah Macy Foundation* in the 1940's and 1950's on the behavior of phenomena exhibiting circular causality. These Conferences brought together scientists from many disciplines and are credited with the launching of the subject of study which was to become cybernetics.

SOURCE

The term feedback probably was first used extensively in control engineering and in radio and electronics.

EXAMPLES

- the message that the thermometer in a thermostat sends to signal the furnace to switch on or off (negative or error correcting)
- the escalation of a disagreement into a conflict (positive or trend enhancing)
- quality control inspections (negative)
- the use of sales data in adjusting the production mix (positive or negative)
- the self regulating mechanisms maintaining homeostasis (positive or negative)
- the power steering on a car (positive)
- biological specialization (positive or negative)

NON-EXAMPLES

- canned laughter included in a television program
- political poll taking when the constituency is unfamiliar with the candidates or the questions are stated in a biased manner
- taking polls (or requesting other kinds of advice) as a fund raising device or when there is no means or intent to develop or modify a policy
- market research among people who do not have a need for the product

PROBABLE ERROR

- Using the wrong feedback loop to adjust an input
- Sustaining feedbacks that actually have the wrong sign (as in practices that lead to war, divorce, etc..)

SEE

Homeostasis; Cybernetics; Relaxation time; Self-organization

FILTER

A filter is a device which stands between action and perception or the reverse. A filter may amplify (increase) or attenuate (decrease) a signal. The choice of filters is a major factor in the observer's definition of a system and its purposes. Our sensory organs filter out much that happens in the world around us that is either too small or too big to see, to subtle to touch, too fast or too slow, too high or low in frequency to hear, and so on. Filters may be intangible as well as tangible. The choice of logical levels or of a mathematics to use in a given situation determines what can and cannot be expressed. Language itself can act as a filter; much twentieth century complexity is inexpressible in, say, Old German. We may use a green filter on the lens of our camera to reduce the 'distortion' caused by bright sunlight. We may wear rose colored glasses when we have made a commitment to an ideology of optimism or do not wish to see indications that all is not well.

When information passes between a system and an environment, the transducer acts as a filter and must be consciously designed so that it does not reduce variety by filtering out the wrong information. In our normal activities, we filter out most of the sensory data around us. Otherwise we would be too overloaded to concentrate on any one activity. Both human beings and their organizations vary the sensitivity of their filtering processes to fit immediate circumstances. If we are intensely engaged in a task, our selection processes are set to filter out 'irrelevant' data. When the task is finished or we are more at ease, we will become aware of many more sensory perceptions. Without conscious attention to the way in which they are selecting or filtering out information, an organization under crisis management or an individual who is overextended may screen out messages vital to their longer term well-being or even survival.

In management, filters are necessary to attenuate the variety of the flow of incoming information and to amplify the important signals. Statistical filtering packages may be designed to screen indices for signs of incipient instability or to send an alert to notify the manager when non-routine information arrives. A staff usually filters out most of the data about the organization before it reaches the chief executive who needs to make a decision. If the staff is a good one, it will filter out the unimportant information and highlight the important. The distinction between the information which should be filtered in and that which should be filtered out is crucial. In some circumstances, data may appropriately be averaged: in others 'averaging' may eliminate the essential information. The study of disasters provides a litany of examples of filtering out exactly the information that should have been amplified.

SOURCE

Filter comes from a Latin word meaning filled wool or felt which was used to strain liquid.

EXAMPLES

- the range of sound audible to the human ear
- the selection of what to carry on the evening news
- standardized achievement and attitude tests
- the modeling process
- the legal system
- a decision by the marketplace

NON-EXAMPLES

- the range of curiosity of a small child
- the message drowned out by noise
- information overload
- a weighty management report

PROBABLE ERROR

- choosing the wrong filter for the purpose,
- Not taking account of the effect that both education and belief both impose massive filtration on future inputs

- Not recognizing how much the presence of a filter is affecting your assessment of a situation.

SEE

Variety; Observer; Feedback; Transducer; Channel capacity; Model

GAME THEORY

Game theory is the study of the characteristics and processes of games, considered as formal interactions that can be described mathematically. Thus it is a source of useful models for understanding alternatives, developing strategies and making decisions relating to a wide range of social behavior.

As models, games may be used to explore the following categories: alone or in combination.

Zero-Sum. In a zero-sum game, one player's gain is another's loss (one and minus one equal zero or, in a game such as poker, winnings are balanced by an equal amount of losses). The players have a purely competitive relationship. In a two-person zero-sum game, there is a 'best strategy' called the minimax strategy which will minimize losses to a certain point for both parties.

Non-Zero-Sum. In a non-zero-sum game, players have at least some common interests. In a labor contract negotiation, for example, both workers and management want to get the best share of the available resources for themselves but both understand that the profitability of the firm has a substantial influence on the total amount to be divided. The non-zero-sum game includes the possibility that both parties will lose (labor and management reach a deadlock and the factory doesn't reopen after the ensuing strike) as well as that both may win and share a collaborator's surplus.

Chance. In a game of chance, the outcome is determined by the laws of probability after a player has made a choice (heads or tails, odds or evens etc.) A player can play against another player who has an interest in the outcome or against "nature" which does not. Dice, black jack and solitaire are games of chance.

Skill. In a game of skill, the outcome depends on the relative abilities (knowledge, dexterity and the like) of the players. Twenty questions, ghost and golf are examples of games determined by skill. Many games and most real life situations to which game theory is applied are determined by combinations of chance and skill.

Finite Games. In a finite game, the players have a limited number of choices to make and the game is over after a finite number of moves. Bridge and timed sports are examples of finite games. This is in contrast to games such as scissors/ paper/ rock which can, in principle, go on indefinitely.

Games of Perfect Information. Tic-tac-toe or noughts and crosses, checkers and chess are games of perfect information.

They satisfy the conditions of strict determination: that is, there is a winning strategy which, if followed, will guarantee a win, or at least a draw for a particular player from the first move. In an actual game of chess or checkers, the number of possibilities, while finite, is too large for the human brain to hold. In tic-tac-toe, with its smaller number of moves, a winning -or at least a tie producing -strategy is demonstrable. Most card games are not games of perfect information because players do not know the contents of the pile or of their opponents' hands.

Language and Metalanguage. In some games, all players speak a language in which goals and moves can be clearly understood in terms of rules and mastery of certain strategies although this does not necessarily mean that all players are equally skilled or that all have the same knowledge of the complexities of the game. In other games, some players have goals and strategies which are concealed from their opponents or even their partners. These players are speaking a metalanguage, in which their articulation of goals and strategies occurs at a level not expressible in the terms and language of the game the other players are playing. Paradoxes are frequently associated with metagames although some may be as simple as playing to tie instead of to win in order to secure a more favorable opponent in a play-off series. Faking or deception may be expressed at either the level of language or metalanguage.

A game or a game theoretic analysis of a situation may combine or consider several of the above categories. A 'best strategy" such as the minimax strategy becomes less and less possible as the number of players and the number of options open to them increases. Mathematical models of the two person zero sum game are common but even three person games may become too complex to analyze completely.

Game theoretic models have been used in computer and manual simulations of conflicts and negotiations, to narrow the field of choices down to those worthy of serious consideration, to speed up decision making in a community or a corporation, and (at a metagame level) to study personal interaction and decision-making styles.

SOURCE

von Neumann, J., & Morgenstern, O. (1953). *Theory of Games and Economic Behavior*. Princeton, NJ: Princeton University Press.

Rappoport, A. (1960). *Fights, Games and Debates*. Ann Arbor: University of Michigan Press.

Rappoport, A. (1970). *N-Person Game Theory*. Ann Arbor: University of Michigan Press..

For a non-mathematical explanation, see:

Davis, M. (1970). *Game Theory*. New York: Basic Books.

EXAMPLES OF A GAME

- trading on the stock exchange
- professional sports leagues draft of high school and college players
- labor contract negotiations

EXAMPLES OF A METAGAME

- employing a dummy bidder at an auction to bid up the price up on various items
- personal conflict and one-up-manship behavior such as that described in Eric Berne's "Games People Play"
- tactical voting

NON-EXAMPLES OF A GAME

- the fulfillment of a contract
- the creation of a work of art
- a communication where the intent is to convey or elicit information

NON-EXAMPLES OF A METAGAME

- any situation where all parties are consciously operating in the same context

PROBABLE ERROR

- Not realizing that a game is being played
- Not recognizing the difference between a metagame and other examples of apparent non-rational behavior such as incompetence or ignorance

SEE

Metasystem; Metalanguage; Variety; Model

HIERARCHY

A hierarchy is a pattern of order along which objects may be ranked from a maximum to a minimum value along some dimension. The word is derived from the Greek words ~hiero', meaning sacred, and 'archon', meaning ruler. The pattern is often pictured as a pyramid or a vertical tree. It may be described in words or in the rigor of mathematics. Hierarchies are ubiquitous in nature, in human affairs and even in the abstract realm of ideas. This can be confusing; although they all share the unidirectional ranking they may differ in many other characteristics.

In some contexts, such as the Roman Catholic church, or the organization chart of a bureaucracy, hierarchy retains an association with authority. The source of these hierarchies is direct human action, whether it stems from divine messages, from the electorate or arbitrary factors. There are other contexts which are not associated with authority, although the source of the identified hierarchies still lies in their selection by human observers. Biology, chemistry and physics belong to this class. Finally, there are contexts where the distinction based on the influence of authority is not so clear. They include human organizations of all types from families, which have their counterparts in animal society, to complex manufacturing and financial organizations. This is the area of social investigation and innovation - and ultimately of political decision.

One of the most familiar forms of hierarchy is classification. In the process laid down by Aristotle, those criteria which yielded increasingly specific classes were chosen in preference to features like color and weight which did not. His scheme allowed for a relatively few decision rules to lead quickly to thousands of distinct species, each having many characteristics in common with others in the same genus, family and so on.

Hierarchical ordering in nature and in human affairs is a means of managing and facilitating complexity. Sometimes constraint and control emerge at threshold levels such as seen when the concentration of one celled animals suddenly begins to differentiate and a colony is formed or when human settlements reach a certain density and traffic and zoning by-laws are introduced. Pattee has noted that one of the paradoxes of hierarchy is that it both constrains and enhances freedom: e.g. the constraints of the genetic code on chemistry make the diversity of living forms possible while the rules of spelling and syntax permit the free expression of ideas. It has also been noted that hierarchical arrangements allow for experiments to be tried. In evolution, in a sub-routine for a computer program or in a stage in a manufacturing . operation, a change can be incorporated into the whole if it works or the damage contained if it doesn't.

Another factor which distinguishes hierarchies is the extent to which lower levels are recursively contained in upper levels. Allen and Starr point out that while nested hierarchies are very useful in modeling situations, it is not necessarily possible to use the same criteria for more than two levels in a row. In contrast, in non-nested hierarchies, the chosen criterion remains constant and comparisons may be made across many situations.

A heterarchy is an alternative to hierarchy. It may make decisions democratically or the idea of primacy may be retained but the identity of the leader or the preferred alternative will vary. Heterarchies tend to be pictured by rings or nets. The leadership may shift on the basis of who has the best information or the most expertise, according to rotation or according to logistical considerations. Warren McCulloch showed in 'A Heterarchy of Values Determined by the Topology of Nervous Nets' that with as few as three alternatives, (e.g. A is preferred to B, B is preferred to C and C is preferred to A) the establishment of a *summum bonum* could be impossible.

SOURCE

Pattee, H. (Ed.). (1973). *Hierarchy Theory: the Challenge of Complex Systems*. New York: Braziller.

Wyte, L. L., Wilson, A., & Wilson, D. (Eds.). (1969). *Hierarchical Structures*. New York: Elsevier.

Mesarovic, N. D., Macko, D., & Takahara, Y. (1970). *Theory of Hierarchical Multilevel Systems*. New York: Academic Press.

Allen, T. F. H., & Starr, B. (1982). *Hierarchy.* Chicago: University of Chicago Press.

EXAMPLES

- the pecking order of chickens
- the food chain
- in computers; from higher level to lower level languages to machine language to the physical properties of the computer or the reverse
- in natural language, phonemes, morphemes, words, phrases, sentences, paragraphs...
- in physics, forces binding atoms, molecules, macromolecules...

NON-EXAMPLES

- a pile of stones
- an alphabetical ranking of names
- a succession of waves along a beach

PROBABLE ERROR

- following the identification of a hierarchy with unsupportable assumptions about consistency in criteria, the place of information selection or the role of authority.
- failing to take advantage of the full rigor possible in analyzing some hierarchical situations.

SEE

- Self-Organization: Closure; Recursion

HOMEOSTASIS

Homeostasis is a process whereby critical variables are held within acceptable limits by self regulatory processes. The standard example of homeostasis is the maintenance of body temperature at a constant of 98.6° F. in an environment in which temperature varies considerably. If the self-regulatory processes fail, the system or organism goes into a state of catastrophe. If the temperature control processes in the human body fail, the result is a state of catastrophe called hyper or hypothermia, which rapidly threatens the body's viability. It is perhaps a measure of the lack of common understanding of this process that rescue workers have such a difficult time convincing people that they must take emergency measures at the first sign of hypothermia. It is characteristic of homeostasis that the processes usually involve complex coordination among different parts of the system to achieve this steady state. Living systems, including both organisms and organizations, generally include many control devices and processes to maintain the stability of their essential variables.

Cybernetician Ross Ashby built a device called a homeostat which returns to a stable state after absorbing randomly generated disturbances from the environment. Experiments with this device led to valuable insights on the nature of self regulation and the apparent simplicity with which complex responses may be generated. Control systems in management serve as homeostats by adjusting to meet changing environmental conditions with changes in its internal state.

SOURCE

Cannon first described homeostasis as the complex coordination of physiological processes in:

Cannon, W. (1932). *The Wisdom of the Body*. New York: Norton.

Ashby's work with the homeostat is in:

Ashby, R. (1960). *Design for a Brain*. London: Chapman and Hall.

EXAMPLES

- the maintenance of a given level of concentration of glucose in the blood
- the tendency to maintain the relationship between production costs and price
- the balance of trade between nations
- the management of inventory levels
- keeping a constant pressure in the cabin of an aircraft

NON-EXAMPLES

- government regulation of private conduct
- consistent overeating
- accumulation of toxic chemicals
- the sharing of wealth among the world's peoples
- hyper or hypothermia

PROBABLE ERROR

- Imposing external regulation on a process that is already self regulating,
- Not creating such a procedure when it would be more appropriate than direct intervention
- Not checking for the malfunction or absence of a homeostat when a process goes out of control.

SEE

Feedback; Black box; Self-regulation; Catastrophe Theory

IDENTITY

An identity is the mark of a whole, an indication of a distinction which may be consistently recognized or which persists over time. It refers to the closure which delineates the boundary between this thing or activity and another. An identity may be perceived by an outside observer or by a sentient being observing him, her or itself. There are a number of means by which identity may be revealed. Internally, it is served by memory, by a sense of body, one's position in a family, community or occupation. Externally it is observed by consistency in form, pattern, purpose or product. The external attribution of identity may vary according to the outlook of the observer; e.g. in one culture the second cousins will be considered part of an identity called 'the Jones Family', in others, not.

In mathematics, an identity is an operand which remains the same after undergoing a transformation (a = a'). Its boundaries are taken as given.

Individuals, objects, organizations, numbers and other symbols and actions in context possess identity. The criterion of being distinguishable marks an identity. But, what can be distinguished in one context may not be distinguishable in another. Questions of scale raise some problems but, once noted, they are easily acknowledged. When issues relate to culture, values or paradigms of any sort, it may be difficult to see what is distinguishable or not in the same way that it is difficult to say what is information and what is noise.

Organizational and individual identities may falter in the face of massive changes in themselves or their environments or become alienated from their sense of wholeness by disturbances or setbacks. When this occurs, they may compensate by focusing attention on the identities of their parts or those of the larger groupings to which they belong. In an organization, this may be a work group, division or one of the factions in an organization at one end of the scale or the industry. At the personal level it may be one or more of the current roles of an individual or a past role associated with pleasure or security.

In practice, an identity is recognized according to agreed conventions. For purposes of testing, what can be said of a red car of a given make and model can, with confidence, be said of a yellow one and we have a one-to-one mapping. In other circumstances, only the thing itself - such as an ecosystem- will do as an identity mapping. We, as observers, confer identity on parts of our world by selecting, ordering or perhaps, inventing them.

SOURCE

For the identity mapping:
Ashby, W. R. (1956). *Introduction to Cybernetics*. London: Meuthen & Company.
In the context of behavior, numerous texts in biology and psychology.

EXAMPLES

- a pebble on a beach
- a company asking the question What business are we in?'
- an emergent genre
- a characteristic cry or call
- a name

NON-EXAMPLES

- a pebble on a beach to someone standing twenty feet away
- two companies which have merged but have not made any headway in recognizing and synthesizing their disparate cultures
- a random assembly of objects; unless mounted or nominated by an artist
- an idea expressed in language we don't understand
- a process with an unknown context; e.g. running' without an indication of whether it is a jogger, the tide, the sands of time, melting chocolate or a movie

PROBABLE ERROR

- Ashby: mistaking an identical transformation for a nullity
- Not perceiving a threshold of change or closure of an activity
- missing the significance of an event in time

SEE

Closure; Distinction; Boundary

INFORMATION

Information is used in two senses; the technical, associated with the accuracy of transmission, and the semantic, associated with the conveyance of meaning.

Information theory deals with the technical aspects, measuring information by the freedom of choice of a message as measured by the logarithm of the number of choices. Its unit of information is the bit (for binary digit). This theory deals with the statistical processes describing the conditions under which information is transmitted, not with the content of the particular message. The lack of concern with content reflects the purpose of this early work: to design telephone and telegraph systems capable of transmitting any and all possible messages to a given degree of accuracy.

When we move to the areas of concern to management, questions of meaning become more important although it is wise to recall that unless the technical conditions have been met, (sufficient channel capacity, requisite variety in the transducer, etc.) the semantic problems cannot be addressed. Within the management structure (as in Beer's Viable System Model) some parts are connected directly to the outside environment while others have direct connections only to internal portions of the system. The job of management is to assure that the flow of information circulating within the system and the arrangement of amplifying and attenuating filters have requisite variety to handle the kinds and types of messages within a time frame that makes it possible to take necessary action.

SOURCE

The word information comes from the Latin 'forma' meaning to give shape.

Shannon, C. E., & Weaver, W. (1964). *The mathematical theory of communication*. Urbana: University of Illinois Press.

Wiener, N. (1961). Cybernetics; or, Control and communication in the animal and the machine. New York: M.I.T. Press.

Fisher, R. A. (1973). Statistical Methods and Scientific Inference. New York: Hafner.

EXAMPLES

- a signal acted upon by the receiver
- a message sent with an arbitrarily small error rate
- something that causes us to change our state
- a silence when a message is expected
- the medium chosen for a communication

NON-EXAMPLES

- a communication from which all choice has been removed
- a pile of data that no one will read
- noise: either static or irrelevant material

PROBABLE ERROR

- Lack of appreciation for the dynamics surrounding uncertainty
- lack of expectation that ambiguity will be a constant factor

SEE

Communication; Channel capacity; Entropy; Filter; Transducer; Algedonic signal

INVARIANCE

An invariance is something that stays the same while other aspects of the system change, or if it changes, it always changes in the same way with respect to its environment. The modeling process always looks for factors which remain the same or are predictable. This is true whether the system is deterministic (a ball dropped will fall to the floor) or probabilistic (a fair die will fall on a particular face one sixth of the time).

We may speak of invariances with varying degrees of rigor. The relationship of *pi* to the radius of a circle can be carried out thousands of places to the right of the decimal point if there is any need but we can easily agree that 3.14 will be adequate for our purposes. In a less precise manner, we know the shape of a learning curve and have little expectation of further gain after we are told that such a curve has leveled out.

Many invariances depend on a context for their validity. Such contexts include the physical, the biological and the social. They may be stated with varying degrees of formality from 'it's always crowded here at the holidays' to a set of axioms and postulates. In some cases whether or not an invariance holds depends on the level of abstraction or on a time scale, e.g. the pattern of a marketing campaign may be invariant although the products offered vary.

SOURCE

Invariance is the negative of variance which comes from the same Old French word as variety. See also Chapter 2:

Beer, S. (1979). *Heart of Enterprise*. Chichester: John Wiley & Sons.

EXAMPLES

- the boiling point of water at sea level
- the progression of the seasons
- the upper level of a machine's capacity
- the recognition of an identity
- an established ratio of output to input
- death and taxes

NON-EXAMPLES

- next year's fashion
- the outcome of a fair election
- the behavior of the stock market
- next week's weather

PROBABLE ERROR

- observing the system for too short a time to establish the correct pattern
- making incorrect assumptions about the initial state of a system
- misjudging the context in which an invariance holds

SEE

Coenetic Variable; Identity; Model

LAW OF REQUISITE VARIETY, OR ASHBY'S LAW

The Law of Requisite Variety states: only variety can absorb variety. A regulator of a system can only regulate if the variety disposed by the regulator is equal to the variety generated by the reguland. Variety regulation can be one-one, such as the players on a soccer team, or it can be one-many, such as a king and his subjects. Most regulation of variety, however, does not proceed from authority but from convention. Traffic flow, for instance, is mostly regulated by two conventions: that traffic going in one direction will stay on one side of the road leaving the other side clear for traffic going in the opposite direction, and that traffic will stop on the red light and move on the green light. Ashby said "In its elementary forms the law is intuitively obvious and hardly deserving statement-Where the law, in its quantitative form, develops its power is when we come to consider a system in which these matters are not so obvious ...when it is very large... (or) much too complex to be handled by unaided intuition."

SOURCE

Ashby, W. R. (1956). *Introduction to Cybernetics*. London: Meuthen & Company.

EXAMPLES

- the number of laws governing an activity
- the countering moves in a game
- the need to match players on a football team with their opponents
- the maintenance schedule for a plant

NON-EXAMPLES

- the capacity of the human brain to handle more than seven (plus or minus two) discrete items of information
- the behavior of a policeman at a traffic intersection when he cannot see the build-up ahead
- the attempt to control the economy through the banks or the money supply
- acts of multinational firms in the absence of international law
- the infection of a body by a new microorganism

SEE

Conant-Ashby Theorem; Game Theory; Model; Metasystem

LE CHATELIER'S PRINCIPLE

Le Chatelier's Principle is the name given to the tendency of a system to adjust internally and return to its former state after a disturbance. It is taken from the field of physical chemistry and the study of equilibrium processes. In these processes, when a new reactant or condition of temperature or pressure is introduced into a closed system, it does not result in a different state or a new substance but in a return to the state existing before the new condition was introduced.

Le Chatelier's Principle is applied to the way "business as usual" returns after new procedures or reforms are introduced and to the resiliency of organizations to adapt and survive. When a system in operation is hit by a disturbance, the only result may be a shift its internal point of equilibrium. Whether this tendency is seen as an obstacle or a resource depends on the goals of the observer.

SOURCE

the chemical process bearing the name of French chemist Henry Louis Le Chatelier

EXAMPLES

- the way certain peoples, such as the Chinese, have absorbed and assimilated a series of invaders
- the legitimization and institutionalization of protest and reform
- the persistence of customs held over from the past
- retaining previous compensatory activity after new technology which makes it unnecessary has been introduced
- giving lip service to new directives from above while continuing to do business as usual

NON-EXAMPLES

- a catastrophe (abrupt change) in the state of a system
- entropic drift
- autopoiesis
- adaptation

PROBABLE ERROR

- Underestimating the effort required to make a lasting change in the operation of a system,
- Not utilizing the system's natural tendencies to adapt to change.

SEE

Adaptation; Equilibrium; Ultrastability; Autopoeisis; Catastrophe

METALANGUAGE

A metalanguage is a language of a higher order which is capable of discussing propositions which are undecidable in the lower level language and of discussing the limitations and operations of lower level languages. The concept of a metalanguage is rooted in logic and its formal expressions. It has been extended in both directions: to mathematics where Kurt Goedel's Incompleteness Theorem proved that in any given arithmetic, there will be propositions that cannot be decided upon without recourse to a higher level arithmetic, and to everyday language where it is expressed as paradox. For example, in the classical paradox of the liar, a Cretan announces to a stranger "all Cretans are liars". Any way this statement is interpreted in the standard language it is a puzzle.

Understanding the *interaction of* language and metalanguage is necessary when the *communications between* subsystems of a whole system are evaluated, when accommodation must be made to the needs and interests of conflicting parties, and when there is a great deal of external uncertainty which affects an operation. The employment of a metalanguage allows for 'completion from without' at a higher order of perception and logic.

In psychology, the interaction of language and metalanguage has been studied in the *phenomenon of* the double bind where the individual finds him or herself caught trying to fulfill mutually exclusive demands. The command "be spontaneous" and the statements "a good child always obeys" and "a good child shows spirit and doesn't let people push too far" are examples of personal situations which *cannot be* resolved without recourse to a higher level of language.

Confusion and misunderstanding result when communications sent at one level of language are received and interpreted at another. In the story Being There by Jerry Kozinski, Chance, the gardener, becomes Chauncy Gardiner and his utterances about the growing season, the weather and the seasons are interpreted as profound statements about the state of the economy and society.

SOURCE

The word meta is a Greek word *meaning what* comes after or what lies beyond. It often indicates a change in the character of the topic under consideration, e.g. Aristotle's Physics and Metaphysics.

See also chapter 8 in:

Beer, S. (1959). *Cybernetics and Management*. London: English Universities Press.

Chapters ten and sixteen in:

Beer, S. (1966). *Decision and Control*. Chichester: John Wiley & Sons.

EXAMPLES

- the language in which an experiment is discussed by the experimenters in contrast with that employed by the subjects in the experiment
- instances where the operations and limits of natural language are discussed in natural language
- theories of mathematical proofs as opposed to individual proofs
- the determination of a set of procedures, e.g. Roberts Rules of Order, as opposed to the operation of a meeting within the chosen framework of rules
- in game theory, the language used to discuss rules or objectives over and beyond that of the game other players are playing

NON-EXAMPLES

- conflict between two parties which does not have recourse to resolution at a higher level of logic
- communication which occurs within a system negotiations, after the terms have been set

PROBABLE ERROR

- mistaking a situation for a deadlock without recognizing the undecidable nature of the questions raised.
- believing that parties agree when language and metalanguage are mixed

SEE

Metasystem; Recursion; Hierarchy; Self Reference; Observer

METASYSTEM

A metasystem is a system which operates at a higher level of logic and which is capable of taking a larger view of system behavior. The explicit employment of a metasystem allows questions which are not decidable between competing systems or within the boundaries of a system to be discussed in a language (or metalanguage) of a higher order.

A metasystem does not need, and often does not have, formal authority over the systems it discusses. It may even be constituted of members of the actual systems under discussion who have agreed to wear another hat representing the whole of which they are parts.

Kurt Godel proved in a mathematical paper that there will always be problems in any arithmetic which are not solvable within that arithmetic. This proof established the limits of any closed logic, whether in the formal sphere of mathematics or the practical sphere of decision making.

SOURCE

the word meta is from the Greek and means over and beyond. The mathematical and logical theory are discussed in:

Nagel, E., & Newman, J. R. (1958). *Godel's Proof*. New York: New York University Press.

Hofstadter, D. (1979). *Godel, Escher, Bach*. New York: Basic Books.

EXAMPLES

- a language - for a conversation
- a board of directors which oversees several divisions of a corporation
- a professional association sitting in judgment on the behavior of an accused member
- a court of appeals
- the village elders for an tribe
- a discussion at a higher level of abstraction
- a metagame
- parents settling their children's disputes

NON-EXAMPLES

- a paradoxical situation
- two equal partners who cannot agree
- a discussion which does not rise to a higher level of abstraction
- a game

PROBABLE ERROR

- Moving between system and metasystem frames of reference without noticing
- 'Getting stuck' in an undecidable situation

SEE

Recursion; Metalanguage; Observer; Self-Reference

MODEL

A model is an informal or a formal representation of a system, made by an observer, to distinguish features of a system which are significant and to predict the consequences of a disturbance or change on the system. Modeling is a process everyone engages in every day. We have a model of the commuter traffic patterns on the way to work, models of the members of our family and our coworkers; in short a model of almost every significant aspect of our lives. If our models are good ones, we will be able to make sense of the world and predict, with some accuracy, how it will behave. Models come in many kinds and types, depending on the distinctions the observer wishes to make. The observer may choose a physical model, a working model, a mathematical model, a mental model, a game theoretic model or many others.

In "Cybernetics and Management" (Beer, 1959,) there is a helpful description of four key notions about models: "There is a scaling down in both size and complexity - a model of Shakespeare's birthplace, for instance, could stand on a table and would not be expected to incorporate miniature timbers in equivalent numbers to the building in Stratford Upon Avon. There is a transfer across, whereby actual parts of actual things are represented again in their relative positions. And arising from this is workability, by which I mean that the model can, in principle anyway, operate like the original. Thus a model train actually runs around a model railway, and it looks so much like the thing modeled that cine films of models can be substituted for film of actual trains and successfully pretend to be real. That this may be so, although the engine may be driven by clockwork introduces the fourth point. The mode is a good model if it is appropriate."

Models vary according to how rigorous they are, how comprehensive they are and so on. Two particular types of models are of special interest. An isomorphic model replicates each and every feature of the thing modeled on a one-to-one transformation. In a complex situation, the only possible isomorphic model is the thing itself: the identity mapping. An homomorphic model represents the situation as a many-to-one transformation, aggregating some features of the original and ignoring others. Sometimes there will be more than one homomorphic model of a system and they may be isomorphic with one another. In the limit, almost everything can be seen as a model of a given system with varying degrees of relevance.

SOURCE

The word model comes from the Latin 'modus' meaning a measure, conveying both its consciously chosen and its purposive features.

EXAMPLES

- a business simulation
- a balance sheet
- the report of a certified public accountant
- a civilization's mythology
- the ecological model of the Chesapeake Bay
- a tailor's dummy
- a map, chart or drawing
- a toy airplane

NON-EXAMPLES

- a random collection
- a political explanation that is based on bigotry rather than fact (although it may be a model of the source of the explanation)
- a fanciful account of an event

PROBABLE ERROR

- Failure to make the model of a system in use explicit, leading to confusion and misinterpretation, in the limit, the belief that the model is the system

SEE

System observer; Distinction; Filter; Environment; Conant - Ashby Theorem

NOISE

Noise consists of unwanted signals or signals that do not contribute to a message. It may be errors, random sound, or bits of other messages. It may even be "white noise" - the jumbled hum that is sometimes introduced into an environment such as a workplace to lower the level of distraction brought about by unaccustomed quiet or to muffle sudden sounds in an otherwise quiet area. What is "noise" and what is "information "depends very much on the purposes of the sender and the receiver. Even static on the radio could be information to someone in the vicinity who was interested in knowing when a power tool was turned on. Conversely, a report which consists primarily of raw data is very likely to be noise to a manager who receives it on a busy day. In this case it is not the content of the information which makes it noise but the form in which it is presented.

The same may be true if an attempt is made to explain a situation to someone who does not share the same language or the same frame of reference. When there is more than one observer, the same distinction between what is noise and what is the message may not be made.

Redundancy is the means most often used to assure that a message is understood despite the possibility of noise blocking part of the message or distortion due to error. Consider the difference if one character in "B4" or "before" is in error. The redundancy in the English language makes it unlikely that an error in the latter would lead to a misunderstanding of the message.

Much important early work in information theory was done to determine how to send an accurate message over a noisy communication channel. Noise is likely to interfere in any actual communication channel, although it is possible to reduce it to an arbitrarily low level given sufficient resources. Shannon's Tenth Theorem deals with the required capacity of a correction channel required to correct a message to this arbitrarily low level.

SOURCE

Shannon, C. E., & Weaver, W. (1964). *The mathematical theory of communication*. Urbana: University of Illinois Press.

EXAMPLES

- the static on the radio when you want to hear the news
- a speech given to the wrong audience
- any information; after the threshold of overload
- data in a survey that responds to a coenetic variable rather than the topic of the survey
- the conversation nearby that prevents you from hearing a presentation

NON-EXAMPLES

- a message received and verified
- a deliberate deception
- a sound that you wish to hear

PROBABLE ERROR

- Not recognizing all the factors that could make your message unintelligible to your intended receiver
- mistaking noise for information

SEE

Information; Channel Capacity; Redundancy; Complementarity; Filter

OBSERVER

The beginning of a cybernetic approach is with the observer. The observer may be you yourself, alone or with others or someone else. Systems are not 'given' a priori. Whether or not it is a conscious process, each observer defines the system under consideration: its purpose, its boundaries, and other relevant characteristics.

Observers change systems to a greater or lesser extent as they observe them. This phenomena may be immediate and substantial as in the case of a social scientist studying worker behavior, or indirect and subtle as in the case of physical sciences. An example of the former comes from Roethlisberger's experiments varying factors such as lighting to measure the effects on worker productivity. He and his associates found improvements when the light levels were increased, and still more improvement when they were decreased, until it was practically dark. This has been called the Hawthorne effect after the Westinghouse Hawthorne plant where experiments were conducted. Another example comes from atomic physics where physicist Werner Heisenberg found limits on the accuracy of measurement imposed by the act and the means of observation. This phenomenon is referred to as the Heisenberg's uncertainty principle.

Different observers in the same situation may look around them and share perceptions of a system or systems with others to a greater or lesser extent. Observers necessarily operate in an atmosphere of uncertainty because the outcome of most observed events is governed by laws of probability and statistics. When two or more observers see the same 'system' with partially corresponding purposes and characteristics, or a single observer looks at the same system from different experimental approaches and sees overlapping but not identical pictures, models of the system will be conceived which reveal somewhat different findings. In physics, this is a commonly experienced phenomenon called complementarity.

Observers are limited by their sensory perceptions, the ways in which they have been socialized or habituated to their circumstances and their thinking processes. The sensory organs may be extended through telescopes, microscopes, radar, sonar, and other instruments. The effects of socialization and habits of thought may be extended through learning and adaptation, through techniques such as brainstorming or elicitation and through spiritual disciplines. Human thinking processes are more difficult to circumvent. We may use biology and our models of animal processes to extend our understanding of perception and behavior or we may extend specific capabilities through the use of computers and artificial intelligence but even here we are not able to model or extend what we cannot first conceive.

SOURCE

von Foerster, H. (1982). *Observing Systems*. Seaside, CA: Intersystems Press.

EXAMPLES

- an experimenter conducting an experiment
- an accountant conducting an audit
- a supervisor inspecting work on the shop floor
- the public relations staff compiling the annual report

NON-EXAMPLES

- someone who conceives the system according to an incorrigible prejudice
- the naive reader who accepts the accountant's report as facts
- an unreflective subject in an experiment
- someone who is looking the other way

PROBABLE ERROR

- Not giving enough weight to the importance of the subjectivity of the observer in determining the system observed,

- the failure to identify the observers and their purposes before applying the results of their observations in a different context
- accepting conclusions without determining the observer's assumptions and choices

SEE

System; Complementarity; Model

OPENNESS IN SYSTEMS

For the most practical purposes, the designations 'open system' and 'closed system' relate to relative degrees of openness. Any 'open system' may be closed with respect to certain variables, and any 'closed system' is closed mainly by convention or by the assumption that outside environmental factors will remain within normal limits. The 'closed system' exists only as a convention because any distinction which demarcates a system takes place in a context and is made by an observer.

OPEN SYSTEM

An open system is one which exchanges matter, energy or information with an environment or one which may be changed by action of the environment.

SOURCE

von Bertalanffy, L. (1968). *General System Theory*. New York: Braziller..

EXAMPLES

- Living Systems
  - a cell
  - an organism
  - a bee colony
- Non-Living systems
  - the ocean currents
  - the monetary system of a nation
  - an academic discipline
- Systems with living and non-living parts
  - a country
  - a factory
  - a river

NON-EXAMPLES

- a novel
- a Mobius strip
- the planetary resources insofar as earthbound
- a combination of chemicals in a test tube (by convention)

PROBABLE ERROR

- Mixing elements of an open system such as a community with those of a closed system such an utopia and expecting consensus
- The introduction of a new product into a firm with a tight five year plan

SEE

System; Model; Homeostasis

CLOSED SYSTEM

A system which is isolated from the effects of an environment or the changes brought by time. Closed systems are used in a manner comparable to Euclid's perfect planes, lines and points. They do not exist in reality but we may come as close to their ideal as our technology and our desire may take us.

EXAMPLES

- a work of literature or theatrical play
- standing by itself
- a game of chance or strategy
- a model under a bell jar

NON-EXAMPLES

- a work of literature seen in the context of its time
- a game affected by variations in the individual player's attention such as polo
- a simulation model into which real world data is fed
- the testing of pharmaceuticals in a colony of rats

PROBABLE ERROR

- Using results obtained in experiments with 'closed systems' in broader situations, Assuming variables to be constants when they aren't.

SEE

Open system; System; Environment; Distinction; Model

RECURSION

When a series of systems is embedded, one within other according to a common pattern, it is called a recursive structure. In a such a structure, the same features are repeated invariantly from a system to its metasystem to its metasystem as in a set of Russian dolls or Chinese boxes. Human organizations are often organized recursively. In primitive societies, the individual, the family and the tribe are typical recursions. In a business, the levels of recursion might run the individual, the work group. the department, the operation, the division and so on.

Complex systems, including human beings and organizations, are commonly embedded in many different recursive structures depending on the frame of reference chosen by the observer. As well as the family, an individual may belong to a business, a sports team, a chambre orchestra or a church. An organization may belong to an industry, a community, a supply chain and so on. These may be structures in which formal authority is exercised, but also include other criteria including level of abstraction, scope of interest or even geographical jurisdictions.

The recursive quality of human and other systems is basic to handling variety and building models. Some models, such as Beer's Viable System Model, are explicitly based on recursivity. The invariance of the dynamic aspects of these systems makes it possible to analyze them level by level and to look for trouble spots.

SOURCE

Recursive number theory has provided the mathematical description of these relationships. Some computer languages, LISP in particular, make use of recursive processes such as subroutines that call themselves. The word comes from 'recur'.

EXAMPLES

- a government department, such as health, which is repeated at the county, state, national and international levels
- a professional society from local chapter to international convention the automotive industry
- in the natural environment, the progression from micro environments (e.g. a sheltered southern exposure on a hill) to regions
- in fractal geometry, the repeating patterns from pebbles on the beach to an satellite photograph of the coastline
- a university with its departments, divisions, schools and colleges

NON-EXAMPLES

- a network of decision makers (see redundancy of potential command
- a collection of businesses under a single ownership without a coherent organizational structure
- a self-organizing system

PROBABLE ERROR

- Assuming a higher recursion to be based on seniority rather than comprehensiveness of language and purpose

SEE

Hierarchy; Metasystem; Viable System Model

REDUNDANCY

Redundancy, in general usage, means more than enough. What is enough depends very much on a number of circumstances and criteria. If we are concerned with information, such factors as the reliability of components, the importance of the level of accuracy of a message or the requirement for timely action in a diversified command situation, are needed to make appropriate decisions. If we are concerned instead with the distribution of food, the rate of spoilage over given distances at different the margins in our temperature conditions will be a key factor. In management, the use of a redundant network of committees, contacts in the field, social groupings and trade publications provides a hedge against error which is sometimes not given full recognition. The human brain operates on components which are redundant by a factor in the tens of thousands.

Several specific aspects of redundancy are of particular interest: in the information theory propounded by Shannon and Weaver, (p. 104) the redundancy is "the fraction of the structure of the message which is determined not by the free choice of the sender, but rather by the accepted statistical rules governing the use of the symbols in question." The English language is about fifty percent redundant, which makes it a good language for crossword puzzles. This usage of redundancy may be expressed mathematically as "one minus the relative entropy".

In the 'redundancy of potential command' described by Warren McCullough (p. 226) "knowledge constitutes authority". He described a naval battle in which each ship peers through the smoke and fog for evidence of the enemy's activity and relays that information to the others. The command passes from one ship with incomplete information to another according to who has the best information at that time. Victory was attributed to the early loss of the central command ship which eliminated the traditional command hierarchy.

SOURCE

The word itself comes from the Latin 'redundans' meaning overflowing. In addition to Shannon, Weaver, the mathematician John Von Neumann made significant early contributions-to the understanding of redundancy in information networks.

McCulloch, W. (1965). *Embodiments of Mind*. Cambridge MA: MIT Press.

EXAMPLES

- the additional portion of a message which enables it to be understood by the receiver even if part of the message is lost or obliterated by noise
- the additional number of channels or media required to get a message to an especially important receiver (such as in espionage)
- a critical proportion of dispersed receivers (such as are required if a marketing campaign is to work)
- the amount of backlog (described by queuing theory required to gain the most efficient use of a machine or an input channel

NON-EXAMPLES

- the creation of a management decision structure where a single unit decides for itself on a preset allocation of responsibility without consulting others
- sending an important message by a single route which may entirely fail (such as a letter) or introduce distortion (such as a corrupt messenger)
- building a building which needs ventilation with windows that don't open
- the absence of manual controls if automatic ones fail

PROBABLE ERROR

- Not allowing for necessary redundancy by looking at it as a constant (such as a cost cutting target) rather than as a variable to be adjusted

- Not realizing the vulnerability of a system
- Relying on a charismatic individual to advance a cause with no provision for succession
- Idiosyncratic information paths
- Historical dependence
- Unrepeatable circumstances

SEE

Information; Entropy; Channel capacity; Self-organization; Noise

RELAXATION TIME

The relaxation time of a system is the time it takes to return to equilibrium after a disturbance. When a disturbance hits a system, its effects ripple through the whole like the wake of a motorboat on a lake. The effects of the disturbance on the system are not necessarily in a direct ratio to the distance from the point of impact and the point affected (think of a picnic basket left at the water's edge when the motorboat speeds by). Generally speaking, the larger and more complex the system, the longer the relaxation time will be. Relaxation time ranges from almost instantaneous at the molecular level to a number of decades when a community has suffered a disaster.

Relaxation time becomes a serious problem for a system when the relaxation time is, on the whole, longer than the time between disturbances. Systems can only learn and adapt when they can recognize when they have returned to equilibrium. If the rate of disturbances overtakes relaxation time uncontrolled oscillation or a crisis pattern of response will occur and planning will be likely to be wrong or ineffectual. If the system cannot recognize its state of equilibrium, due to inadequate relaxation time it may not recognize when it is entering a region of instability which could result in catastrophe.

SOURCE

The term relaxation time first came into common usage in engineering and control theory. See also:

Beer, S. (1975). *Platform for Change*. Chichester: John Wiley & Sons.

EXAMPLES

- waiting to introduce new materials and procedures until after the current ones have been tested
- the time it takes for a product to regain its market share after a scare such as the Tylanol tampering case
- the recovery time of an economy after a depression
- the regrowth of a forest after a fire

NON-EXAMPLES

- the operation of a system such as waves in the ocean characterized by a pattern of dissipative structures where creation and destruction occur in a continuous cycle
- changing chief executive officers before the results of their initiatives have occurred

PROBABLE ERROR

- Underestimating relaxation time,
- Attributing system failure to adapt to lack of resources or leadership instead of insufficient relaxation time,
- Inability to distinguish normal oscillation from uncontrolled oscillation.

SEE

System; Equilibrium; Catastrophe Theory; Feedback; Stability

SELF-ORGANIZATION

A system may be said to be self-organizing if it can alter its internal structure to increase its level of adaptation. A self-organizing system may move beyond self-regulation to alter its feedback loops and sensory information. A self-organizing system may be seen as moving from a state in which its parts are separate to one where parts are joined but usually also includes a criteria of success based on a goal such as becoming better adapted to its environment. If the environment should change, the self-organizing system must change as well in order to remain adaptive.

Much of what is known about the properties of self-organization comes from biology. An egg, once fertilized and kept warm, becomes a chicken; a pine cone becomes a tree. Living systems tend to be self-organizing: moving from a less to a more probable state in a process which resembles entropy. They draw energy from the environment to maintain and increase their internal organization. Learning and evolution tend to reinforce examples of successful organization but not unsuccessful ones.

The self-organizing tendencies of people in groups is a large factor in the governing of communities or the management of large organizations. No leader or manager could command enough variety to organize at this level. Effective leadership or management uses the self-organizing properties of social systems by reinforcing desirable activities and altering the environment or the reward structure to discourage undesirable ones. Management studies of small group interaction have shown, for instance that different types of people emerge as group leaders under different conditions, e.g. specified goals, type of tasks or consistency of rules, The tendency of such groups to self-organize is a constant but the outcome is dependent on the environment and on the criteria of the observer.

SOURCE

von Foerster, H., & Zopf, G. W. (Eds.). (1962). *Principles of Self-Organization*. New York: Macmillan.

Itncludes papers by twenty-three investigators including Ross Ashby, Stafford Beer, Jack Cowen, Lars Lofgen, Warren McCulloch, Gordon Pask, Anatol Rapoport and Roger Sperry.

EXAMPLES

- a city
- a chess playing computer
- a slime mold
- a trade union
- an individual organism growing to maturity

NON-EXAMPLES:

- an assemblage where the parts do not affect each other
- a simple servomechanism
- actors performing a play

PROBABLE ERROR

- Not recognizing the degree of self-organization of a system
- Attempting to struggle against rather than work with the self-organizing properties of a system

SEE

Ultrastabilty ;Requisite Variety ;Coenetic Variable ;Homeostasis ;observer

SELF-REGULATION

The capacity for a system to monitor and control its behavior using information communicated from the environment is called self-regulation. The majority of self-regulating systems operate on the basis of negative feedback. They compare the current state of the variable or variables they are monitoring with the desired state and make appropriate adjustments as a divergence occurs. The major characteristic of self-regulating systems is that control is implicit. The action of a variable going out of control triggers the regulatory mechanisms to bring it back under control.

The household thermostat is such a device. There is a setting and the purpose of the regulatory activity is to maintain it; signaling the furnace to go "on" when its sensors tell it that temperature has fallen below the desired level and "off" when it has been reached. A modern device might also signal the air conditioning to go "on" when the desired temperature was exceeded. The limits of self-regulation are evident in the thermostat example. The heating system can control itself only to the extent that the necessary information loops are designed into its sensors. It does not have the capacity to step outside the loop and, for example, contract for more insulation to be installed.

Although self-regulatory devices may be quite simple, they may also be complex and may be set to probabilistic as well as deterministic feedback information. It may be geared to respond when it records the presence of the conditions under which error often occurs and make an adjustment before error actually happens. Or, it may be designed with enough flexibility to recover from disturbances that were not anticipated by its designer as well as from those which were anticipated. If it does so, we refer to it as ultrastable. Even very complex organizations such as families may act as if they were simple feedback-operated devices when for instance, children in a restaurant are shushed when they begin to talk too loudly rather than planning family outings to take their normal behavior into account.

SOURCE

Early work by Weiner, Ashby, McCulloch and others investigating the properties of internally controlled systems.

EXAMPLES

- the Watt steam governor
- self-correcting missiles
- a sprinkler system
- a manager operating on attenuated information

NON-EXAMPLES

- a farmer who reorganizes his crops on the basis of a proposed increase in the water available for irrigation
- a marketplace operating under a time lag which postpones feedback until too late for adjustment
- a system operating with a high degree of chance

PROBABLE ERROR

- Using a self-regulatory mechanism to perform a more complex regulatory task than it was designed to perform.
- Not taking advantage of existing self-regulatory capacities and overriding them

SEE

Self-organizing system; Ultrastability; Requisite variety

STABILITY

Systems exhibiting stability are in a state of balance or equilibrium in which a point representing a measurable value of an aspect of the system remains at rest or moves within set boundaries. Such boundaries may be set arbitrarily within a range, such as the setting of a thermostat, or at a particular threshold, such as maintaining stock in inventory. Essential variables are those which must remain stable to insure survival or maintain the identity of the system. A complex system such as an animal or a human being will have a large number of essential variables which must remain within their limits if the system is to survive and prosper.

Stable systems are characterized by their ability to return to a state of equilibrium after a disturbance. They often rely on negative (error correcting) feedback to retain or improve their stability. When the system improves its capacity to remain in or return to a stable state, we may say it has adapted to respond to its disturbances.

Whether a system is seen to be stable or not sometimes depends on the scale of time employed. Weather patterns, for example, appear unstable in the framework of planning an outdoor event but not in the framework of planting a garden. For an environmentalist concerned about the potential of man-made effects such as the 'greenhouse effect', it may be difficult to identify the point where the equilibrium range has been breached because of the normal large variations in weather patterns.

Stability is a quality which belongs to the system as a whole. It may result from a combination of subsystems which are either stable or unstable. Within such a system, parts retain veto power over the whole and their activities must be coordinated. Depending on your viewpoint, stability is not necessarily a desirable outcome: e.g. a population of rats infesting a building may learn to avoid traps and poison and maintain its stability in the face of efforts to eliminate them.

SOURCE

Ashby, W. R. (1956). *Introduction to Cybernetics*. London: Meuthen & Company.
Ashby, W. R. (1960). *Design for a Brain*. London: Chapman and Hall.

EXAMPLES

- the operation of a hot water heater
- maintaining a balance of orders filled to orders received
- supply and demand in a perfect market
- instances of homeostasis in the human body
- the cycle of an undisturbed predator/prey relationship

NON- EXAMPLES

- runaway inflation
- a high level of population growth
- the arms race
- a drop in a product's market share

PROBABLE ERROR

- Monitoring the stability of the wrong aspect of the system
- Fixing one variable which cannot then vary to remain in a stable relationship with related variables
- choosing an inappropriate scale of time, distance or speed from which to determine whether or not a system has or has not remained stable
- Failure to specify the framework or context in which the stability of a variable is discussed

SEE

Homeostasis; Self-Organization; Environment; Ultrastability

SYNERGY

Synergy is a behavioral characteristic of systems where the behavior of the whole is not predictable from the behavior of any or all of its subsystems. This behavior operates recursively so that the behavior of a suprasystem as a whole is not predictable from the behaviors of its component systems, and so on. The sign of a synergistic effect may be a plus or a minus in terms of the purpose of the system in the eyes of the observer. It follows as a corollary that if the behavior of a whole system and that of some of its parts is known, that the presence, characteristics and behaviors of other parts may be inferred and examined. Thus, when an operation is not going as well as it should, negative synergy between some of the parts maybe investigated and eliminated to improve its performance. Likewise, a better than average performance may be investigated to see if its positive synergy can be reproduced elsewhere.

If a management undertakes synergistic planning at a . metasystemic level; it may take actions that decrease the profitability of one or more of the parts in order to achieve a greater level of profitability for the whole. Without such planning the behavior of the whole may not differ much from that of the collection of its parts and its central management function will be ineffective.

According to Stafford Beer, an algebraic example of synergy may be found in a function such as the squaring of two variables, say a + b. This operation is carried out on the two variables yielding 'a' squared plus 'b' squared plus 2ab. This additional 2ab thrown off is the synergy.

SOURCE

Fuller, W. B. (1975). *Synergetics*. New York: MacMillan.

EXAMPLES

- the behavior of two different drugs taken together on the body
- the behavior of a team working together to achieve an objective
- the behavior of symbiotic pairs in biology
- two soldiers sitting back to back facing an attacker
- the efficiency of the well structured committee
- the improvisation of a jazz band

NON-EXAMPLES

- the efficiency of the average committee
- hierarchical chains of command without horizontal lines of communication
- separate categorization of common functions in an operation such as shipping two products on two different transportation services

PROBABLE ERROR

- Misidentifying the system level where an observed instance of synergy takes place
- Changing an operation that is going well and destroying its synergy, e.g. by computerizing it and losing human interaction that actually makes it work.

SEE

Recursion; Metasystem; System

SYSTEM

A system is a set of interrelated elements with a purpose as perceived in time by an observer. Until nominated by an observer, collections of elements do not constitute a system. One group of elements, say the parts of a radio, will be perceived as a system by a trainer of radio assemblers but not by someone who wants to listen to the news. From the listener's perspective, 'radio' may be regarded as part of a system called 'the media', and so on... The designation of a system is always subjective although some systems are more likely to be similarly perceived than others. For a simple system such as a home heating system, there is likely to be general agreement on its purposes, its elements and its boundaries. For complex systems, such as a transportation system, a company, or a code of laws, different observers inside and outside the system may have very different perceptions of purposes, elements and boundaries.

The designation of a system implies that it is perceived as a whole with different properties than those exhibited by its parts -separately or together. This is the distinction between a 'systems approach' and a 'reductionist approach'. Although many systems contain subsystems or may be viewed as embedded in a number of different larger systems, each may be considered as a whole with its own boundaries and environments.

The prevalence of trivial examples of systems in advertising, such as the 'personal storage system' which another observer might regard simply as a 'set of shelves', sometimes obscures the power of the systems approach to dealing with complex dynamic situations.

SOURCE

The word system comes from the Greek 'sustema' a standing or placing together. Early usages include ' the solar system' and 'the digestive system'. The adjective, still quite narrowly applied, is systemic (not systematic).

EXAMPLES

- the Earth
- an automobile
- a geometry
- a government
- a corporation
- a family public health
- a zoo to its administrators and staff

NON-EXAMPLES

- a random collection (unless purposefully selected such as a table of random numbers)
- any grouping or configuration which has no relevance to an observer
- a zoo to the children who visit it
- Liebnitz's monad
- an object outside of its context (readers of Homer may recall that Odysseus was bidden to wander until those he met took his oar for a winnowing fan)

PROBABLE ERROR:

- Failure to take appropriate note of subjectivity in system designation,
- Mistakenly assuming that a phenomenon observed in a subsystem applies to a larger system, e.g. drawing inferences from the election returns from a jurisdiction in a national election where local issues are dominant.
- The assumption that systems are somehow systematic

SEE

Identity; Complementarity; Observer; Boundary; Environment

TRANSDUCER

The transducer carries a message across a boundary, between a system and its environment, between departments, between management levels or among participants in a network. In each case, messages are conceived in the special language of the system or subsystem and must be transduced to another which has its own special language. The variety of the transducer must be least equivalent to the variety of the channel. A good transducer should neither amplify nor attenuate variety. A mechanical device or a human being may serve as a transducer.

In an organizational setting, the individuals who operate at the boundaries of the organization must be aware of the languages and distinctions which prevail on both sides of the boundary to be an effective transducer. Differences in language include those of marketing and R & D or 'the board' and the division as well as the obvious differences associated with nationality and culture.

SOURCE

The word comes from the Latin to lead across.

EXAMPLES

- a sales representative who knows his or her territory
- a manager who listens carefully to subordinates' reports and conveys their essence in turn
- the computer's operating system
- a company brochure
- a training package

NON-EXAMPLES

- an interpreter who translates the words but not the nuances of a speaker
- a partisan news story of an international dispute
- a report presented to a board in technical jargon
- a financial report presented to non-financial staff

PROBABLE ERROR

- Not noticing the extent to which variety is increased or cut down when it is transduced.
- Not designing transducers to be ‘variety efficient’ so that they just happen to destroy variety.
- Not realizing the extent to which different systems speak different languages

SEE

Variety; Channel capacity; Information; Filter; Boundary

ULTRASTABILITY

Systems which are able to return to equilibrium after disturbances which were not anticipated or foreseen by their designer are said to be ultra (meaning beyond) stable. Such systems may rely on multiple interacting measures or rules of thumb that suggest leaving a situation when it becomes problematical. Ultrastable systems may rely on algedonic signals or step functions to tell them that an important threshold has been breached even if they do not know the source of the problem. Typically such disturbances are infrequent and therefore cannot be predicted in detail.

SOURCE

Ashby, R. (1960). *Design for a Brain*. London: Chapman and Hall.

EXAMPLES

- leaving a party when people begin to show signs of intoxication
- selling an investment when the balance sheet becomes impenetrable
- adapting to a new situation

NON-EXAMPLES

- small, frequent disturbances that are anticipated

PROBABLE ERROR

- Not recognizing that a novel set of circumstances is occurring
- Not listening to the algedonic signal
- Denial of evidence that doesn't fit into a preconceived pattern

SEE

Algedonic Signal; Homeostasis

UNCERTAINTY

Uncertainty is a condition which is met whenever we leave the confines of closed or deterministic systems. It occurs in a general sense whenever probability is a factor. Later, it enters specifically as an inherent characteristic of experiments.

The first place we meet uncertainty is in our daily lives. The probability that the light will go on when we flip the switch is close to 1 (or certainty) but the bulb may have blown, the switch may have failed or the power may have been disrupted at source by an accident. If it is terribly important that the electricity not fail, e.g. a hospital operating room, an emergency power supply will be installed to support the whole system. For the rest of us, a few candles or a flashlight may do to take care of the gap between highly probable and certain. The idea of probability is implicit in many activities. Seeds planted in the spring are expected to yield summer flowers, but a late frost may kill the young plants. On the other hand, waiting until all chance of frost has passed guarantees a late blooming garden so most of us choose to run some risk. If our business is agriculture, we will probably take steps to make the implicit probabilities explicit on the basis of recorded weather trends.

In other areas we are familiar with uncertainty with respect to the limits of accuracy of predictions: the poll which is correct to within four percentage points 19 times out of 20 or the message which can be transmitted to an arbitrarily high (but never absolute) degree of accuracy.

In physics, we meet one type of uncertainty as soon as we leave Newton to consider the statistical theory of heat. In quantum mechanics, uncertainty is endemic in the design of experiments or the choice of the 'observation situation'. To quote Heisenberg,

> " ..in quantum theory the uncertainty relations put a definite limit on the accuracy with which positions and momenta, or time and energy, can be measured simultaneously."

Further, it became apparent that while the experiment itself could be designed to take objective (and reproducible) measurements, that the inferences and conclusions drawn from the experiments could no longer be accepted without qualification because the measurement itself intrudes into the event and cannot be separated from it.

This concept of uncertainty has been found to be applicable to many areas outside of physics where the choice of an observation situation and the act of observation cannot be separated from the phenomena observed. In behavioral and social sciences, not only the act of measurement but the self-consciousness of the individuals observed intrudes on the objectivity of the findings.

Another dimension of uncertainty has been explored through the mathematics of fuzzy sets, pioneered by Zadeh. He noted:

> "As the complexity of a system increases, our ability to make precise and yet significant statements about its behavior diminishes until a threshold is reached beyond which precision and significance (or relevance) become almost mutually exclusive characteristics."

Zadeh was particularly concerned with the extension of set theory to applications where the boundaries of the set could not be crisply defined. Sometimes the fuzziness was due to the lack of precision of natural language such as described by 'a good journal article' 'or a satisfactory paper'. Sometimes the dependency on context is a factor. Tall and short, or fat and thin describe very different situations depending upon whether you are speaking of a team of gymnasts or the customers for a men's clothing store. Finally, the number of relevant variables may be too large to be conveniently specified such as is the case where a quick decision must be taken in a high variety situation.

SOURCE

Heisenberg, W. (1959). *Physics and Philosophy*. London: George Allen & Unwin.
The Physicist's Concept of Nature. Westport, CN: Greenwood Press, 1958. L. Zadeh in Information and Control, Vol. 8 (1965) pp. 338-53..

EXAMPLE

- the effect of observation on the results of an experiment
- the natural language definition of most sets
- the planning of an action in a high variety environment

NON-EXAMPLES

- an exploration in abstract mathematics
- the application of Newtonian mechanics (in fuzzy sets)
- the presence of random variables

PROBABLE ERROR

- Noting the conditions of observation at the beginning of a report of an experiment and not following through on their implications
- Confusing undecidibility with uncertainty

SEE

Complementarity; Boundary; Observer

VARIETY

Variety is the primary measure used in cybernetic inquiries. Quite specifically variety is a measure of the number of possible states of a system. {n(n-1), or sometimes n(N-1)/2} It is the measure of complexity, the raw material of choice and the subject of regulation.

The way in which this measurement is made depends on the observer's definition of the system and its purposes. To take a simple example, consider a lamp in a room. The variety may be two: on and off, if someone just comes in to wait for a few minutes. If the person wants to read, placement and brightness become part of the variety. If there is a plan to redecorate the room, the lamp's color and style would matter. The insurance appraiser, the electrician, the parent of a toddler or someone bent on robbing the place would all have different criteria which would determine the variety they looked for in the lamp. Most situations, however are far more complex than the lamp in the room so the key is to learn to select the variety in each situation that counts as important.

The amount of variety observed depends on the breadth and depth of the observer's perception, but is almost guaranteed (except in contrived situations such as games) to be much less than the actual amount. If it is not to either surprise or overwhelm us, the variety of a situation must be managed. One set of techniques comes from communication theory. Variety may be filtered to attenuate the information about the trivial or routine states of the system and amplify the critical or non-routine states. The capacity of the communications channels in use must be examined to make sure that they can do the job. Are they likely to be filled with noise?... to suffer from transduction problems as they move from one system to another?... to be timely enough to catch problems or opportunities as they appear?... Answers to these questions may tell us that some communications channels are not coordinated, overused, underused or (sometimes) missing entirely.

Another set tools for handling variety is to build models of the situation which will meet the needs of the modeler for information and regulation. These models (including the Viable System Model) and techniques are the concerns of management cybernetics. They range from the metaphorical to the mathematically rigorous. The criteria for the models is Ashby's concept of requisite variety; e.g. is there enough variety in the model to correspond to the variety of the essential variables in the system being modeled?

SOURCE

The word variety comes from the Latin 'vacillant' indicating movement and diversity.

Ashby, W. R. (1956). *Introduction to Cybernetics*. London: Meuthen & Company.

Conant, R. (Ed.). (1981). *Mechanisms of Intelligence*. Seaside, CA: Intersystems Press.

For management cybernetics see :

Beer, S. (1979). *Heart of Enterprise*. Chichester: John Wiley & Sons.

Beer, S. (1981). *Brain of the First* (2nd ed.). Chichester: John Wiley & Sons.

EXAMPLES

- the available moves in a game such as chess
- the combination of numbers available for seven digit telephone numbers
- the range of ways a competitor can respond to your initiative
- the possible positions of a switch
- the range of options open for new product development

NON-EXAMPLES

- None; everything that exists or is conceived has at least a variety of one

PROBABLE ERROR

- Not recognizing the applicable variety in a situation.

- Employing ignorance as the principle attenuator of variety.

SEE

System; Observer; Filter; Channel; capacity ;Regulation; Transducer