A Dictionary of Cybernetics

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A dictionary

-- like the discipline whose terminology it aims to clarify --

is constantly in flux. It is aided by communal efforts and

in turn aids communication within the community of users.

Critical comments and suggestions, especially for including

new or omitting useless entries, for improving the wording,

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NOTE: This dictionary is <u>not</u> intended to represent the American Society for Cybernetics nor the opinions of any of its members; neither does it replace the current Cybernetics Glossary. Klaus Krippendorff has been kind enough to make his work available to ASC members in order to stimulate discussion on the language of cybernetics, as well as on the idea of a dictionary itself.

ABSOLUTE DISCRIMINATION: ->LIMIT OF ABSOLUTE DISCRIMINATION

ADAPTATION: STABILITY of success in the face of a changing environment. Two kinds of adaptation are distinguished. (a) Darwinian adaptation after Darwin who observed how organisms change their internal STRUCTURE when their environment makes existing forms no longer viable. E.g., Ashby's HOMEOSTAT searches for a new pattern of behavior as soon as disturbances in its surroundings drive or threaten to drive its essential VARIABLEs outside specified limits. (b) Singerian adaptation after Singer who described how organisms, particularly man, change the nature of their environment so as to eliminate threats to or prevent the destruction of their own internal organization. E.g., Agriculture, architecture and technology adapt the physical environment to human-social needs. The difference between "adaptive" and "adapting" BEHAVIOR (Steg) also reflects this distinction. Adaptation can occur in several levels of an ORGANIZATIONal HIERARCHY and may even apply to itself as in "amplifying adaptation" (Ashby) which is "adaptation to adapt" and has the properties of SELF-ORGANIZATION.

AESTHETICAL IMPERATIVE: "If you desire to see, learn how to act" (v.Foerster). The imperative is derived from assumptions of CONSTRUCTIVISM and emphasizes that cognition is an essentially circular process involving an observer and the observed (->SECOND-ORDER CYBERNETICS, ->SOCIAL SYSTEM).

AGGREGATION: A process by which the properties of a collection are described in terms of the sums of the properties of the units contained in that collection. The most elementary aggregative procedure is counting and a FREQUENCY so obtained represents the properties of a set by number rather than by the list of elements it contains. Aggregation gives rise to macro theories of micro processes and yields measures and insights not demonstrable by means of the units aggregated thereby. E.g., the statement "the average family has 2.5 children" describes the property of an aggregate, not of a real family. The CORRELATION coefficient is also a measure that aggregates numerous observations neither is capable of demonstrating that RELATION by itself. Quantum physics, economics and the social sciences are most successful in describing their objects as aggregates. Aggregation is justifiable whenever units are sufficiently INDEPENDENT and similar, e.g., in expressing political opinions through voting or market preferences through individual purchases. Aggregation leads to misleading indicators and theories whenever the whole collection exhibits an ORGANIZATION not expressed in a mere summation (->SYSTEM, ->EXTERNALITIES). In econometrics, that difference is represented in so-called interaction effects.

ALGEDONIC REGULATION: Literally, REGULATION by pain and pleasure,

more generally, by rewards and punishments for the products rather than the BEHAVIOR leading to it. E.g., people may be trained to perform a task by explaining to them the role their task plays within the larger SYSTEM (->METASYSTEM) of which they are a part. But they may also be trained algedonically by a series of rewards and punishments that offer no such explanations. The algedonic regulator must have an image of the expected system of behavior but it restricts fluctuations not in the behavior of its parts but in their OUTPUTs. In business and industry, algedonic regulation tends to lead to alienation from work. Elaborate grading schemes in universities tend to divert attention from the aquisition of useful knowledge and skills to achieving high grade averages which may have little to do with academic or practical competencies. A technical example is the use of three different computers to improve the RELIABILITY of computing risky military security decisions. If one computer yields a different result the other two are considered correct but if all three differ it may take months to find out why.

ALGORITHM: An explicit procedure for performing a complex OPERATION by carrying out a precisely determined and FINITE sequence of simple operations. E.g., the multiplication of large numbers in small steps involving only single-digit multiplications and additions, the detailed instruction for assemblying a piece of electronic equipment from components, a recipe. Algorithms can vary greatly in complexity and there are usually more than one for reaching a desired end. Algorithms have greatly enhanced the human capacity for performing complex intellectual tasks by organizing detailed plans, scripts and procedures hierarchically (->HIERARCHY). Algorithms are also built into formal social organizations which are geared to achieve particular ends. Finally, algorithms are the subject of all COMPUTER PROGRAMs and the object of higher order programming LANGUAGEs. Algorithms leave nothing undefined and require no intuition to achieve their end.

ALLOPOIESIS: The process of producing material entities other than those required for producing them. Most industrial production processes are allopoietic: An assembly line may produce cars but not the machines used in this form of production. Even reproduction in biology is allopoietic because the offsprings are materially distinct from the parent organism and occupy different spaces. Reproduction is not self-production. The primary value of the concept of allopoiesis is that it contrasts with AUTOPOIESIS.

ALPHABET: An ordered set of CHARACTERs which can be combined to form the ensembles, words or expressions of a LANGUAGE or to represent DATA. Whereas an alphabet is FINITE, the number of expressions to which it gives rise to may not be. A binary alphabet recognizes only two characters, e.g.,."0" or "1". The English alphabet has 26 characters and the Japanese more than 4000. The term "alphabet" is also synonymous with "repertoire" (of symbols, states, behaviors) or with a set or collection (of elements) in finite MATHEMATICS.

AMBIGUITY: The coexistence of more than one meaning or interpretation of a SYMBOL or message. Ambiguous sentences convey less INFORMATION than unambiguous ones but may be more enjoyable to the reader as are poetry and literature. In political discourse ambiguity is often intended so as to convince or attract a diversity of audience members (->DOUBLE TALK).

ANALOG COMPUTER: A COMPUTER that represents data in terms of physical measures or quantities and proceeds along a continuum constituted by its components. Analog computers are especially suited for the solution of complex non-linear equations and for the SIMULATION of multi-dimensional, parallel and continuous processes. There is no restriction on the physical processes analog computers may utilize. Most common media are fluids and gases which can be made to vary in numerous DIMENSIONs. Compared with DIGITAL COMPUTERs, the PROGRAMming of analog computers is time consuming and limited in scope.

ANALOGY: Likeness or similarities in STRUCTURE or FUNCTION but not in material existence. To argue by analogy is to infer from the fact that two SYSTEMs that correspond in some respect must also correspond in other respects as yet unexamined. Although the form of reasoning is appealing and has given rise to numerous inventions, it is particularly liable to yield wrong conclusions. In the theory of MODELs, an analogy between two systems is explained by one simpler system that models both but by different HOMOMORPHISMs.

ANALYSIS: Literally, reducing a WHOLE to its parts. In MATHEMATICS, analysis is the investigation of limiting processes and provides a firm foundation for the infinitesimal CALCULUS. Although Leibniz thought infinitesmals to be infinitely small but real quantities, modern interpretations consider these mere CONSTRUCTions as in quantum physics. In CYBERNETICS, analysis refers to the limiting process in a SYSTEM involving an observer and the observed. The observer draws distinctions which the observed opposes or violates forcing the observer to relate the parts distinguished until a stable description of the system involving the observer emerges (->SECOND-ORDER CYBERNETICS). In a cybernetic analysis, the whole is described not merely in terms of its parts but most significantly by the pattern that connects them (->RELATION, ->COMMUNICATION, ->ORGANIZATION). Such an analysis reveals the wholistic properties of a system without loss or destruction.

ANOMIE: Literally, without LAW, a condition of disintegration of a society into individual components resulting from the absence of CONVENTIONs, shared PERCEPTIONs and goals. A SOCIAL SYSTEM describable as a mere aggregate (->AGGREGATION), the state of maximum SOCIAL ENTROPY (Etzioni).

ANTHROPOMORPHISM: The use of METAPHORs ascribing human

characteristics to non-human forms. The most blatant anthropomorphism concerns the belief in supernatural beings, e.g., spirits, gnomes, all of which tend to assume human or super-human powers. Anthropomorphisms are most frequent in the ascription of intentions or purposes to causal phenomena, e.g., "the stone hit me," "this accident was meant as a warning," "this car doesn't like me." In scientific pursuits anthropomorphisms are frequent in studies of animal COMMUNICATION, e.g., teaching a dolphin to say "good morning," and in the use of COMPUTERs, e.g., when programmed "to understand" an English sentence, "to think" through a problem, "to evaluate and decide" a suitable cause of action (->ROBOT).

ARGUMENT: A term that denotes what a FUNCTION is a function of. The independent VARIABLE(s) determining a function's value, the DOMAIN of a TRANSFORMATION or the INPUT of a CODE.

ARTIFICIAL INTELLIGENCE: A branch of COMPUTER SCIENCE concerned with the PROGRAMming of COMPUTERs so that they exhibit apparently intelligent behavior, e.g., the design of ROBOTs, chess playing automata or theorem proving MACHINEs. Branches of artificial intelligence are pattern RECOGNITION, PROBLEM-SOLVING, LANGUAGE processing and game playing. The only moderate success of reproducing human INTELLIGENCE has nevertheless stimulated considerable insights into human cognitive processes and the use of computer METAPHORs in theories of mental activities is rampant (->ANTHROPOMORPHISM).

ASSOCIATION: In psychology, the cognitive connection between two or more CONCEPTs or ideas such that the presence of one tends to evoke the others. In Sociology, the process by which people become allied to one another and form groups as the result of such alliances. In statistics, the cooccurance of two or more events with a PROBABILITY above what would be expected by CHANCE. Dissociation is the logical complement of the statistical concept of association.

ATOMISM: A scientific doctrine which maintains that all complex SYSTEMs are aggregates (->AGGREGATION) of smaller ones and that any WHOLE can therefore be understood entirely from the knowledge of its parts. E.g., an atomistic social theory insists that all social institutions and events can be exhaustively explained in terms of the actions of individuals. A radical application of this doctrine suggests dividing a given phenomena into smaller and smaller units until they are no longer divisible. The resulting atoms are the ultimate constituents of the phenomena in question and until one has identified these there is nothing to investigate.

AUTARKY: Self-sufficiency concerning food and material resources. Autark SYSTEMs are closed to matter and ENERGY except for the continual flow of sun energy. Examples are a small isolated island economy in the Pacific Ocean on the one extreme and the "spaceship earth" on the

other. National policies of restricting economic exchanges across borders to promote self-sufficiency in food, energy and technology and to make a country more easily governable have always been undermined by INFORMATION flows and the mobility of people and could not be sustained for long. All biological organisms are open to energy and matter (->OPEN SYSTEM).

AUTOCATALYSIS: A process during which the probability of occurance of some property, event or object increases as a function of the number of such properties, events or objects already present in a system. Autocatalysis is not to be confused with multiplication through production including SELF-REPRODUCTION in which the growth of a population is an aggregate property (->AGGREGATION) of the productive capability of its individual members. In autocatalysis, properties, events or objects serve as their own CATALYSTs and are "self-breeding" so to speak. E.g., the invention of home air conditioning created the need for air conditioning hence the self-stimulated increase of air conditioners.

AUTOMATION: The CONTROL of production processes by machines with human intervention reduced to a minimum. E.g., the automatic pilot of an airplane, a COMPUTER-controlled pharmaceutical plant. During the industrial revolution, mechanization relieved man from the more extreme burdens of physical labor, while in the current information revolution, automation relieves man from certain repetitive and mathematically complex INFORMATION processing and control tasks (->ROBOT).

AUTONOMY: Attribute of an organizationally CLOSED SYSTEM, i.e., a SYSTEM whose ORGANIZATION is self-explanatory and by implication circular. The understanding of autonomous systems requires references neither to events outside that system e.g. causes (->(AUSALITY), nor to a METASYSTEM of which it maybe a part for reasons other than what constitutes its organization. Autonomous systems possess (a) a recursive form of organization of (b) processes which continually constitute their own UNITY by maintaining (c) a boundary within which its organization is realized (->RECURSION, ->RECOGNITION, ->CONSTITUTION).

AUTOPOIESIS: Literally, self-production. The property of SYSTEMs whose components (1) participate recursively in the same NETWORK of productions that produced them, and (2) realize the NETWORK of productions as a UNITY in the space in which the components exist (after Varela) (->RECURSION). Autopoiesis is a process whereby a system produces its own ORGANIZATION and maintains and constitutes itself in a space. E.g., a biological cell, a living organism and to some extend a corporation and a society as a WHOLE.

BASIN: A subset and part of a partition of a SYSTEM's STATEs such that no state in one basin succeeds or is succeeded by states in

another basin and any two states in one basin share at least one preceeding state or successor. Inasmuch as BEHAVIOR is defined as a sequence of states, the partition of a system's states into basins is also a partition of that system's possible behaviors, each defining a separately analysable BEHAVIOR SPACE or region thereof. Each basin may have one or more sets of EQUILIBRIUM STATES. Ashby visualized a basin as a geographical area, fully surrounded by mountainous water sheds within which all rivers end up in one or more lakes.

BEHAVIOR: A succession of STATEs (Ashby) starting with the first and ending with the last one observed. The protocol of an observed SYSTEM's changes from one state to the next. Whether behavior is merely identified by its name described in terms of a TRANSFORMATION or FUNCTION, or represented by a GENERATIVE device, it must ultimately refer to or reproduce a sequence of states or a trajectory in space.

BEHAVIOR SPACE: The collection of BEHAVIORs a SYSTEM can follow, the set of paths a system is capable of taking. A behavior space represents, sometimes graphically, and/or abstractly, and, often within many dimensions, just what a system can do so that what it actually does can be seen as a special case determined by initial conditions, circumstances, purposes, etc. (->CONSTRAINT).

BEHAVIORAL SCIENCES: All disciplines which conform to the behaviorist doctrine (->BEHAVIORISM) but particularly a large part of American psychology.

BEHAVIORISM: A movement particularly in American psychology, which calls for an EXPLANATION of the behavior of organisms in terms of RELATIONs between INPUTs and OUTPUTs, in psychological terms, between stimuli and responses, in sociological terms, between independent and dependent VARIABLEs. Behaviorists minimize the importance of mental or creative processes and believe that a system's output is uniquely determined by past and present inputs. The inclusion of an organism's internal STATE, predispositions, MEMORY or mediating variables in behaviorist explanations does not modify this basic contention. Behaviorist explanations exclude cognitive CONSTRUCTIONs, circularities such as SELF-REFERENCE and the GENERATIVE processes of mental activity (->INTELLIGENCE). Behaviorism is also manifest in numerous analytical techniques, e.g., in efforts to explain one variable in terms of other variables by means of regression equations.

BINARY: Two-valued. A binary RELATION states how two kinds of elements are linked, e.g., "is married to," "is talking with," "is larger than," "preceeds." A binary ALPHABET contains two kinds of CHARACTERs, e.g., "0" and "1," "yes" and "no." A distinction, e.g., between "inside" and "outside," is a binary OPERATION. Binary contrasts with unary = one-valued, ternary = three-valued, etc.

BIONICS: Comes from bioiological electronics and denotes an effort (a) to use biological design principles to create novel technological devices and (b) to create mechanical substitutes for the extension of biological organs. (a) has in part been taken over by ARTEFICIAL INTELLIGENCE, whereas (b) has become part of bio-engineering. CYBERNETICS was involved in bionics by providing the FEEDBACK-CONTROL framework in which both tasks could be realized.

BIOSPHERE: A term coined after "atmosphere" referring to the totality of living organisms and societies, that draw INFORMATION from and contribute to the NOOSPHERE on the one hand and materially realizing themselves in the ECOSPHERE on the other.

BIT: Acronym for BInary digiT and the unit of MEASUREMENT for VARIETY, UNCERTAINTY, STATISTICAL ENTROPY and INFORMATION, all of which are quantified in terms of the (average) number of binary digits required to count a given number of alternatives (->DEGREE OF FREEDOM) Equivalent interpretations of this unit are the average number of DECISIONs required to exhaust a given number of alternatives, the average number of relays needed to represent a certain number, the average number of answers to yes-no questions necessary to select one out of a given number of objects. Thus the answer to a yes-or-no question conveys one bit of information. Two distinctions create four alternatives and not knowing which is desirable measures two bits of uncertainty. A Hollorith card with 12-by-80 places, each of which may be punched or left solid, can store 960 bits of information. More generally, n equally likely alternatives correspond to $\log_2 n$ bits (->LAW OF REQUISITE VARIETY).

BLACK BOX METHOD: A strategy for investigating a complex object without knowledge or assumptions about its internal make-up, STRUCTURE or parts. The method aims at either a formal description of the TRANSFORMATION RULEs linking INPUTs and OUTPUTs or the CONSTRUCTion of a MODEL exhibiting a BEHAVIOR that approximates what is observable from the outside of the "black box". Initially, the method codified the experiments an engineer would have to perform with a sealed piece of equipment in order to deduce what it does or how it could have been wired. The method is quite general, however. E.g., the linguist who can not utilize available knowledge of brain tissue for understanding linguistic production finds himself in a similar situation. The resulting model of a black box is considered "gray" inasmuch as its STRUCTURE is known, save for the knowledge of the internal make-up of that model's parts. The black box method applies to an extreme case. In practice an investigator may find and should utilize clues to the internal processes by non-experimental means. So, the engineer may conclude from the absence of a wire that a particular switch has nothing to do with a certain component just as the linguist may obtain insights about the use of language by being competent in that language himself. The ISOMORPHISM between the black box and its model, which the method aims to establish, does not imply structural correspondences between the two. One may be a mechanical device, a chemical process or

human organ, the other may be a mathematical formula, an ALGORITHM or electronic piece of equipment. However, the ORGANIZATION of such a model often leads to fruitful hypotheses concerning the structure of the black box.

BREMERMANN'S LIMIT: No material SYSTEM whether artificial or living can compute more than 2×10^{47} BITs per second and per gram of its mass. This limit refers to a self-contained system where the power supply is included in the total mass and where "COMPUTATION" is defined as the transmission of INFORMATION over one or more CHANNELs within the system. Recognizing that computation requires ENERGY for changing physical markers and for recognizing such changes in subsequent steps, the limit is obtained from Einstein's relation between energy and matter, $E=mc^2$, and Heisenberg's UNCERTAINTY PRINCIPLE, which specifies the inaccuracy or NOISE in the MEASUREMENT of energy. Current COMPUTERs are far from approximating this limit because they are not yet designed to utilize atomic events for the storage and transmission of information and are subject to thermodynamic limitations instead. Bremermann's limit applies to material systems and concerns real events, sign vehicles or descriptions. It does not apply to events outside the system that can or are represented within it (->SYMBOL).

BROWNIAN MOVEMENT: The apparently completely irregular motion of molecules in fluids and gases, caused by the motion of electrons which is uncoordinated across atoms and the earliest evidence of RANDOM processes in nature.

BUREAUCRACY: Ideal type of a formal ORGANIZATION in society, characterized by a hierarchical legitimation of authority with powers and responsibility assigned to the offices rather then to the salaried employees occupying positions in this HIERARCHY. A rational differentiation of GOAL-ORIENTED activities and BEHAVIORS assigning functions to each office or position, and a codification of legal RULEs of conduct, of written COMMUNICATIONS, records, documents and contracts regulating and maintaining the ORGANIZATION as a WHOLE (Weber).

CALCULUS: A SYSTEM of RULEs for the manipulation of CHARACTERs as in the logical calculus or in the differential calculus. If the characters are SYMBOLs, a calculus provides the basis for the ANALYSIS of what the symbols represent collectively and individually. INFORMATION THEORY is a calculus for analysing the amount of ENTROPY in an observed system into various quantities of INFORMATION exchanged within that system.

CARTESIAN PRODUCT: The collection of all ordered n-tuples that can be formed so that they contain one element of the first set, one element of the second,..., and one element of the n-th set. This collection can be seen as constituting an n-dimensional space in which

each n-tuple designates a cell. The simplest Cartesian product of two sets is a two-dimensional table or a cross-tabulation whose cells may be used to enter frequencies, to designate possibilities (->RELATION) or impossiblities (->CONSTRAINT), or to chart the transitions comprising the BEHAVIOR of a SYSTEM.

CATALYST: A property, event or material substance that must be present to synthesize or produce some other property, event or material substance without becoming part of the result of the process. In chemistry, catalysts speed up or slow down a chemical reaction without undergoing permanent chemical change thereby. An example of a catalyst in society is the justice of peace or the priest who is necessary to legalize a marriage but does not himself participate in it. The assembly of a machine according to INFORMATION carrying instructions is another example.

CATASTROPHY THEORY: A topological theory describing the change of a SYSTEM's STRUCTURE along a continuous "morphogenetic landscape" including occasional jumps. A critical aspect of the theory is that it considers the DYNAMIC of the system as imposed from the outside (->MORPHOGENESIS).

CATEGORY: Either (a) the name given to a class of things, processes or relationships which appear to be sufficiently similar and frequent so as to render a uniform predication of its members useful or (b) the class itself. Categories are the backbone of qualitative descriptions in the social sciences where a set of unordered but mutually exclusive categories is called a NOMINAL SCALE (->MEASUREMENT, ->VARIABLE).

CAUSALITY or CAUSATION: A process linking two or more events or states of affairs so that one brings about or produces the other. One event is the cause of another if (a) the event occurs prior to the effect, (b) there is an INVARIANT conjunction of the two events and (c) there is an underlying MECHANISM or physical STRUCTURE attesting to the necessity of the conjunction. Since (c) is not always demonstrable in empirical data the requirement may be replaced by tests assuring that no third VARIABLE CONTROLs both or mediates between the two events. Without this weaker test, a cause may be termed spurious and genuine otherwise. Social events are rarely uni-causal phenomena and as DETERMINISTIC as in the natural sciences. Causality in the social sciences therefore tends to be multi-causal and PROBABILISTIC (->PROBABILITY, ->INFORMATION THEORY). Philosophy of science has devoted much attention to the role of causality in scientific CONSTRUCTs. The theoretical importance of causal EXPLANATIONs is that one can apply them to explain what happened and predict what will happen. Their practical importance is that they lead one to produce or to prevent causally related events by direct or indirect intervention.

CHANCE: The absence of LAWfulness or regularity. While logic contrasts chance with necessity, CYBERNETICS focusses attention to the fact that chance events are inherently unpredictable and expresses the EXPECTATION of such events by their PROBABILITY (other than zero or one). Since chance presupposes alternatives (an event may or may not occur or may be of various kinds). One measure characterizing the probability DISTRIBUTION of chance events is ENTROPY. Thus entropy can be interpreted either as a measure of ignorance about possible events (->UNCERTAINTY) or as a measure of lawlessness or unpredictability. In COMMUNICATION processes, the uncertainty induced by the inherently unpredictable errors of transmission is called NOISE.

CHANGE: A difference in the VALUEs of a VARIABLE and in time. A difference in a SYSTEM's STATEs observed at different times. Change is basic to any PROCESS. Speed is a measure of change in an Euclidean Space and is expressed as the proportion of distance travelled to elapsed time. Gradual change implies ordered variables or continua such as temperature, weight, distance, Gross National Product and observations at smaller time intervals yields intermediate values thus revealing a curve in a space-time continum. Qualitative change is considered abrupt and refers to differences in structure, pattern or level which usually imply mutually exclusive descriptions, attributres or LAWs e.g., changes in the form of matter from gas to liquid to solid or transitions from a feudal to an industrial society. Quantitative changes are changes in numerical or mass variables such as in volume, wealth or transmission rate. Quantitative changes may be gradual as in population growth or occur in larger units or steps as in salaries. Quantitative changes may become qualitative when they pass the threshold of mutually exclusive types supported by the quantities involved, e.g. changes from an industrial to an information economy.

CHANNEL: That part of a COMMUNICATION chain in which signals are transmitted from a sender to a receiver. Unlike other processes in a communication chain (e.g., ENCODING, DECODING, TRANSLATION, TRANSFORMATION), a channel involves a single physical medium that spans the difference in time and in space which separates senders from receivers. A MEMORY is that special case of a channel in which the sender transmits signals to himself at a later point in time. A channel is characterized by the physical properties of its medium and imposes a CONSTRAINT on the capacity for communication: (1) its selective capability to store, retain, and transmit certain kinds of signals, (2) its sensitivity to nonsystematic distortions and decay (->NOISE, ->EQUIVOCATION, ->REDUNDANCY) and (3) its capacity to transmit INFORMATION. Primary channels in unaided human communication are audio (largely verbal and musical), visual (largely non-verbal and ICONic) and tactile. In modern society channels are differentiated mainly by the technical devices used, e.g., writing, printing, telephone, photography, television (video and audio channels), satelite communication, COMPUTER networks. Each has its own limitations and properties. It is well established that the social reliance on particular channels of communication profoundly influences how a society administers itself, develops and expands.

CHARACTER: A written sign, a physical mark, a hole in a DATA tape, a magnetic pattern, an electric signal or any discontinuity of matter which can be read or recognized (->RECOGNITION), is subject of COMPUTING and whose meaning depends on the combinatorial context of other characters. So a "0" has a meaning different from "1," but the meaning of the combination, "10," has nothing to do with either. In the BINARY system it means two and in the decimal system it means ten. Characters may become SYMBOLs through CONVENTIONally assigned meanings outside the recognition and computing process (->DATUM, ->MEASUREMENT).

CHUNKING: A process of recoding INFORMATION which reduces the number of different CHARACTERs in a message while increasing the number of different kinds of characters to be recognized. E.g., in the US, telephone numbers are grouped into area code, exchange number, and a remainder. Since the first two three digit numbers do not occur with equally probability, the user will remember these numbers like words, 215 means Philadelphia, 202 means Washington, 212 means New York, etc., and create similar chunks for the exchange numbers in his immediate vicinity so that he will dial first Philadelphia then the exchange and finally the number. This recoding may be motivated by the increased efficiency of information processing and may be entirely unconscious (->LIMIT OF ABSOLUTE DISCRIMINATION).

CLOSED SYSTEM: a SYSTEM whose BEHAVIOR is entirely explainable from within, a system without INPUT. Systems may be variously closed to matter/ENERGY, to INFORMATION, and/or to ORGANIZATION. Systems closed to energy are AUTARK, systems closed to information are INDEPENDENT, and systems closed to organization are autonomous (->AUTONOMY). Biological organisms are largely closed to organization, the latter being specified by the DNA at the point of inception. The OUTPUT has nothing to do with whether a system is closed. Systems without output are non-knowable through observation from the outside (->OPEN SYSTEM).

CLOSURE: A TRANSFORMATION is closed if its RANGE is contained in its DOMAIN. A SYSTEM is closed if it provides its own explanation and no references to an INPUT are required. Circularity is fundamental to most notions of closure.

CODE: A set of RULEs, a mapping or a TRANSFORMATION establishing correspondenes between the elements in its DOMAIN and the elements in its RANGE or between the CHARACTERs of two different ALPHABETs. INFORMATION maintaining codes establish one-to-one correspondences. Information loosing codes establish many-to-one and/or one-to-many corresondences. When a code relates a set of signs to a set of meanings by CONVENTION, a code can be seen to constitute SYMBOLs. When it maps a set of BEHAVIORs into a set of legal categories, a code can be seen to be one of law. When it accounts for the transformation of

one kind of signal into another kind of signal it can be seen to describe an INPUT-OUTPUT device. When applied to linguistic expressions it is a TRANSLATION. According to Webster's, "to codify" is "to reduce to a code," to systematize, to classify. Indeed, any many-to-one code defines an equivalence RELATION or classification of the elements in its domain. It is incorrect to call a set of signs (to which a code may apply) a code.

CODING: The process of applying a CODE to messages stored in one form or in one medium and thereby obtain TRANSLATIONs, transforms or rewritten versions of the original messages in another form or in another medium. Coding is often motivated by technical necessities or convenience, e.g., in COMMUNICATION proceses involving TECHNOLOGY.

COGNITION: Originally used to separate the rational processes involved in the aquisition, organization and use of knowledge from the emotional, instinctive, or impulsive reactions, it now designates all INFORMATION processing activities of the brain (->ARTIFICIAL INTELLIGENCE), including PERCEPTION, thinking, DECISION making, linguistic COMPETENCE and motor CONTROL.

COGNITIVE SYSTEM: A CONSTRUCT, map or maze involving a collection of interconnected items of knowledge or beliefs held by an individual about himself, or about his physical or social environnment including the cognitive SYSTEM of others, it guides BEHAVIOR in the DOMAIN of this cognitive system. An individual typically possesses several separate cognitive systems. An ideology is the extreme case of a highly integrated and consistent cognitive SUPERSYSTEM governing all the important ones an individual may have.

COMBINATORIAL EXPLOSION: It occurs when a small increase in the number of elements that can be combined increase the number of combinations to be computed so fast that it quickly reaches computational limits (->BREMMERMANN'S LIMIT). E.g., the number of possible coalitions (partitions of unlike individuals into like parts) among 3 individuals is 5, among 5 individuals it is 52, among 10 individuals it is 115,975 and among 20 individuals it is 51,724,156,235,572, etc.

COMBINATORICS: That branch of MATHEMATICS concerned with the VARIETY of combinations of elements that are possible within given CONSTRAINTs including the number of selections, permutations, arrangements, patterns, and ORGANIZATIONs a system is capable of. Combinatorics is central to statistics and INFORMATION THEORY (->COMBINATORIAL EXPLOSION).

COMMENSAL: Attribute of a supplemenary RELATION between two essentially like SYSTEMs in which one obtains benefits from the other

without damaging it. (Contrasted with a SYMBIOTIC relation).

COMMUNICATION: Loosely, the transmission of STRUCTURE across SYSTEMs differentiated in time and in space, the process by which one mind affects another, interaction mediated by signals, SYMBOLs or messages. More formally and in CYBERNETICS, communication is that CONSTRUCT an observer requires when he cannot take a DYNAMIC SYSTEM apart without loss (->ANALYSIS), yet wants to distinguish, understand and say something about that system's parts, VARIABLEs or members, or alternatively, when he wants to explain the BEHAVIOR of any one of its parts yet cannot accomplish this adequately without REFERENCE to other parts of the system. Communication is what integrates and distinguishes the participation of individuals in such WHOLEs as groups, communities, societies. A more detailed analysis of communication processes reveals that they involve patterns that convey INFORMATION, are subjected to numerous CONSTRAINTS and are describable in terms of TRANSFORMATIONs, including ENCODING, DECODING, (->CODING), transmission, and distortions due to the characteristics of a CHANNEL. Historically, communication was thought of as a BINARY RELATION between a sender and a receiver. Modern conceptions of communication include complex NETWORKs possibly with FEEDBACK loops having the effect of MEMORY, COORDINATION, and COORIENTATION and exhibiting DYNAMIC properties not manifest in, and explainable by, reference to the properties of the communicators involved (->CONSTRUCTIVISM).

COMMUNICATIONS (plural: Originally transport, the SYSTEM of routes for moving vehicles, people or supplies, now, the kind of entities or messages actually exchanged in the process of COMMUNICATION (singular) like letters, telegrams, taped messages. Communications are the carriers of INFORMATION.

COMPETENCE and PERFORMANCE: A distinction introduced by Chomsky into linguistic theory but of wider application. Compentence refers to a speaker's knowledge of his LANGUAGE as manifest in his ability to produce and to understand a theoretically infinite number of sentences most of which he may have never seen or heard before. Performance refers to the specific utterances, including gramatical mistakes and non-linguistic features like hesitations, accompanying the use of language. The distinction parallels Varela's distinction between ORGANIZATION and STRUCTURE. The former refers to the RELATIONs and interactions specifically excluding reference to the properties of the SYSTEM's components, whereas the latter refers to the relations manifest in the CONCRETE REALIZATION of such a system in a physical space. Compentence like organization describes the potentiality of a system. Performance like structure describes the forms actually realized as a subset of those conceivable.

COMPILER: A computer PROGRAM which reads a computer program in a higher level (->ORDINALITY) LANGUAGE, usually in the one a human

programmer uses to state his problem ALGORITHMically, and translates it into the machine language of a particular COMPUTER.

COMPLEMENTARY: The quality of a RELATION between parts of contrasting IDENTITY or that behave so that the moves by one fit the moves by the other(s). E.g. the economic transfer of goods requires a buyer and a seller, neither exists without the other; a court of law requires a judge, a planitiff, a respondent and a stenographer, neither can enact the proceedings without the other's participation each complementing the other in forming the whole. Examples of other complementarities are subject/object, text/context, autonomy/control, stability/change, being/becoming, pleroma/creatura, self/other, all of which involve circular definitions of each other.

COMPUTATION: The process of COMPUTING

COMPUTER: A mechanical device for drawing conclusions from typically elaborate premises, for solving complex problems when the PARAMETERs are known, for aggregating (->AGGREGATION) DATA, for the SIMULATION or CONTROL of a SYSTEM. Because the original use of computers as arithmetic aids has been surpassed by recent technological accomplishments and because all COMPUTATIONal tasks involve INFORMATION, computers are often called information processors (->COMPUTING).

All computers have INPUT devices, arithmetic units and OUTPUT devices. Input devices read data in the form of Hollorith cards, magnetic tapes or disks, or accept signals from remote typewriter-like terminals or from the measuring devices applied at fixed points of a process. Output devices may print or display information on TV screens, prepare industrial drawings, produce data compatible with those read (->RECONSTRUCTABILITY) or generate signals to control a process (->AUTOMATION). The arithmetic unit processes information according to a PROGRAM which the computer user must supply or invoke. Whereas early computers were strictly input-output devices, e.g., for computing an algebraic expression, modern computers are capable of ITERATION by entering its computational results into its own input, capable of compilation (->COMPILER) by converting a higher order programming language more suitable to the human programmer into the machine language which organizes the arithmetic unit so as to engage in the intended computation, and capable of self-programming by computing a program suitable to computing a particular problem. Finally, the combination of computers and COMMUNICATION TECHNOLOGY has paved the way to peripheral and interactive uses, to the decentralization of computation facilities and to computer NETWORKs linking users and information resources in unprecedented ways.

Most computers are sequential machines in the sense that they do one thing at one time and at one place in the arithmetic unit. Networking has opened up the possibility of distributed computation and parallel processing. Here, computation may occur in different facilities simultaneously. At some point in time, their results are merged and then again distributed to other facilities, thus

establishing a network of computation very different from sequential processes. Parallel computation is also thought to be underlying computation by the human brain (->COMPUTING, ->ANALOG COMPUTERS, ->DIGITAL COMPUTERS).

COMPUTER SCIENCE: The study of the use, design and CONSTRUCTions of (largely DIGITAL) COMPUTERs. Computer science heavily relies on mathematical (->MATHEMATICS) and engineering insights. In spite of its mathematically sophisticated, academically demanding, and economically profitable appearance, its body of generally acceptable fundamental LAWs or principles, is small. A more appropriate name for this "state of the art"-like body of knowledge would be COMPUTER TECHNOLOGY.

COMPUTING: (From com-putare) literally, to reflect, to contemplate (putare) things in concert (com-). Any operation, not necessarily numerical, that transforms, modifies, re-arranges or orders physical markers in a medium. The physical markers maybe objects or events in their own right as in the computations carried out by the human cell or they may be SYMBOLs and descriptions of events as in DATA processing by a man-made COMPUTER. The early (1936) concept of computing by a Turing Machine involved writing and erasing CHARACTERs by specific RULEs on a theoretically infinite tape. Examples are the simple permutation of the three letters A, B, C into C, A, B, the obliteration of the commas between them, yielding CAB, and the semantic TRANSFORMATION that changes CAB into TAXI, the recursive association of various adjectives before TAXI, etc. (v.Foerster). Although computation by electronic computers is largely geared toward a desirable result (->ALGORITHM) computing does not imply a PURPOSE.

CONCEPT: The cognitive meaning of a term and the smallest unit of (conscious) thought processes. Concepts are neither true nor false but more or less applicable (a) to recognize an object as an instance of the concept, (->RECOGNITION) (b) to produce or to understand sentences in which the concept is expressed and (c) to develop CONSTRUCTs or COGNITIVE SYSTEMs using the concept in question. Regarding (a) concepts provide decision rules for determining class membership rather than extensional membership lists. E.g., the concept "TV commercial" specifies certain defining features which when present identify a sequence of TV images as an instant of the concept without prior knowledge of its class membership (->CONNOTATION).

CONCRETE: An attribute for something material which occupies a physical space as opposed to something abstract or representational.

CONFIRMATION: The support given to a hypothesis or MODEL (a) by evidence available in the form of DATA or observations or (b) by logical deduction from premises, ultimately from the axioms of a formal SYSTEM.

CONFLICT: A state of affairs in which two or more parties claim possession of something not all can have simultaneously. E.g., value conflicts, conflicts of interest, territorial conflicts. All social SYSTEMs contain conflicts and their definition and resolution marks social DEVELOPMENT (->MORPHOGENESIS, ->PARADOX, ->GAME THEORY).

CONSERVATION LAW: A principle of great importance in a variety of scientific CONSTRUCTs. In the physics of closed SYSTEMs, ENERGY neither increases nor decreases as the system evolves (->FIRST LAW OF THERMODYNAMICS). No known case has contradicted this LAW. Energy merely changes its form and usability with all quantities always summing to a fixed total. In INFORMATION THEORY the total amount of INFORMATION transmitted within a system is a similar constant. It can be decomposed in numerous ways leaving no quantity unaccounted for. Conserved quantities are also called INVARIANTs and the conceptualization of quantities such that a conservation law remains true usually leads to powerful theories or accounting algebras.

CONSTITUTION: An act of establishing by pointing to the fundamental components, procedures, LAWs or forms of ORGANIZATION that a SYSTEM must necessarily possess for it to be of a certain kind. So, the electoral process which determines the membership and composition of a governing group constitutes that government as a representative one. Organizational closure (and several other requirements) constitutes a system as an autopoietic one. "Self-definition" is a synonym for "constitution." In politics a "declaration of independence" or a formal "constitution" has this effect. In D'Arcy Thompson's principle that "GROWTH creates form, but form limits growth," growth and form constitute each other.

CONSTRAINT: The difference between a set and a subset indicating that the VARIETY that exists under one condition is less than the variety that exists under another (after Ashby). For an observer, constraints become apparent when he finds that a SYSTEM can assume fewer states than are logically possible or hypothesised by him. Within a CARTESIAN PRODUCT a constraint is the complement of a RELATION, the former contains all states excluded by the latter. INFORMATION is a measure of the constraint imposed by a condition or message.

CONSTRAINT ANALYSIS: A formal method for decomposing the CONSTRAINT within a WHOLE SYSTEM into several constraint within subsets of its VARIABLEs, (i.e., of an ORDINALITY lower than the original) so that the latter fully accounts for the former. Constraint analysis thereby reveals the component STRUCTURE of an observed system. The method, developed by Ashby who stated it in set theoretical and hence qualitative terms, is now also known by the name RECONSTRUCTABILITY analysis and stated in PROBABILISTIC and hence quantitative terms (->INFORMATION THEORY).

CONSTRUCT: A hypothetical VARIABLE or SYSTEM which does not purport to accurately represent or MODEL given observations but has a heuristic or interpretative value concerning them. Constructs may be (1) ideal types as the economist's CONCEPT of rational BEHAVIOR. Rationality can be formalized, leads to elaborate constructions for the motivation of economic behavior and stimulates empirical inquiries into why actual behavior does not quite conform to it. Constructs maybe (2) hypothetical entities, processes or MECHANISMs which would explain the connections between observed causes and consequences if those entities, processes or mechanisms existed. Human MEMORY is such a construct. It bridges the gap between past experiences and current behavior. Psychological examples are the Freudian id, ego, and super ego for which physiological evidence is principally unavailable. Finally, constructs may be (3) the ALGORITHMs capable of generating (->GENERATIVE) a certain process or product without evidence for whether this rather than another computational procedure is followed in practice. COMPUTER SIMULATION of an economy exemplifies the case where the computer algorithm is known to be entirely different from (but in the aggregate (->AGGREGATION) not incompatable with) the reasoning that may go on in the marketplace. Theory in computational linguistics similarly aims to construct mental processes algorithmically.

CONSTRUCTIVISM: In MATHEMATICS, the rejection of the proof of propositions and objects by reductio ad absurdum (i.e., by the demonstration that its negation would lead to contradictions) and instead the acceptance of the condition that objects be constructable from known elements by a FINITE number of explicit procedures, e.g., by an ALGORITHM. One consequence of this is the denial of the universal validity of the LAW OF THE EXCLUDED MIDDLE and the position of a third truth-value for classes of objects that are not so constructable: undecidable. In cognitive psychology, constructivism is a reaction against the Gibsonian view that knowledge and PERCEPTION are the result of sensation and maintains that (a) the nervous system, in order to be adaptive, must process available INFORMATION actively and CONSTRUCT an internal world and that (b) these processes be describable in a computer LANGUAGE and acceptable for SIMULATION by a COMPUTER. CYBERNETICS prominently participates in this movement by insisting that (1) all knowledge is created, invented and constructed by an observer, using his finite resources, that (2) the COGNITIVE SYSTEM is organized or organizes itself so as to compute a stable reality (v.Foerster) which implies that the construct that do survive the circular process involving an observer and his environment are those that remain unaffected by disturbances in the form of DATA which may enter the cycle involuntarily, and that (3) constructs, being descriptions (not necessarily of something else), may be communicated among observers who may include each other in their observations, (->PRINCIPLE OF RELATIVITY) thus constituting an autonomous ORGANIZATION involving a community of observers (Maturana) (->COMMUNICATION, ->CONSTITUTION, ->AUTOPOIESIS, ->SOCIAL SYSTEM).

CONTEXT: The environment of something that establishes or classifies its meaning (Arbib). In linguistics, the environment of a

particular word may disambiguate the meaning of that word, e.g., the word "play" in "I saw a play" vs. "I play the guitar." In COMUNICATION, the context of a situation, which is comprised of all non-linguistic CONSTRAINTs including the social roles ascribed to the communicators, specifies the INFORMATION of what is said relative to what could be said. In biology, the ENVIRONMENT of an organism is similarly crucial in understanding what the organism does (->GENERAL SYSTEMS THEORY). In CYBERNETICS, "TEXT" and context are two complementary components (the SUBSYSTEMs) of one SYSTEM each of which could be considered to constitute or define the other's meaning.

CONTROL: A constraining (->CONSTRAINT) effect on a VARIABLE, a directing influence on the BEHAVIOR of a SYSTEM, or the setting of the PARAMETERs of a system. Any one-way COMMUNICATION, which by its definition conditions a receiver's BEHAVIOR in some respects, involves control of a receiver by a sender.

CONVENTION: A regularly occuring BEHAVIOR of individuals in a given SOCIAL SYSTEM to which (a) nearly everyone conforms, (b) nearly everyone expects nearly everyone else to conform, and (c) this expectation gives nearly everyone some reason for wanting deviance, including his own deviance, discouraged (->SELF-REFERENCE).

CONVERGENCE: Literally, comming to a point with time. The values in the sequence 1, 1/2, 1/3, 1/4,... converge to zero whereas the values in the sequence 0/1, 1/2, 2/3, 3/4, ...converge to one. Convergence requires that the differences between neighboring values decrease. If they do not, they may tend to infinity as in 1, 2, 3,... or end up oscillating as in ... +1, -1, +1, -1,.... The convergence MODEL of COMMUNICATION postulates that as people communicate with each other they become more similar in knowledge and in attitudes and thus converge to form a homogeneous DISTRIBUTION.

COORDINATION: The act of organizing something; a process of COMMUNICATION from one source to two or more coterminous receivers which makes the receivers act in concert (regardless of or in addition to any communication that may exist among them). E.g., conducting an orchestra, the effects of any one group member on the STRUCTURE or ORGANIZATION of the group. In INFORMATION THEORY, coordination and COORIENTATION are logical complements and are measured in the same kinds of VARIABLEs but at different times.

COORIENTATION: The COMMUNICATION of relationships among communicators to any one of them; a process of communication in which a receiver responds not to the COMMUNICATIONS two or more sources emit, but to how these communications coocur or to how the BEHAVIOR of coterminous communictors is patterned. E.g., a child might respond to its parents neither as separate individuals, nor to the couple as a WHOLE UNITY, but to how it perceives the parents to relate to one

another. Coorientation is a fundamental process by which individuals integrate themselves into a social group (->INTERNALIZATION). In INFORMATION THEORY, coorientation and COORDINATION are logical complements and are measured in the same kinds of VARIABLEs but at different times.

COPYING: The material REALIZATION of a mapping or a CODE which applies to some original object or phenomenon in one space and which ideally produces an isomorph (->ISOMORPHISM) but sometimes also a homomorph (->HOMOMORPHISM) of this object or phenomenon in another space. Copying need not be repetitive (->REPLICATION) or be done by a SYSTEM resembling the product (->SELF-REPRODUCTION).

CORRELATION: Covariation of two or more VARIABLEs; a RELATION between the values of two or more variables that is manifest in the VARIATION of coocurrances. In statistics, that form of an ASSOCIATION in which an increase in the values of one variable tends to either increase the values of the other (positive correlation) or decrease the values of the other (negative correlation) rendering one variable (linearly or non-lineraly) dependent on the other.

CREATIVITY: The ability to see things from an unusual perspective and to produce from that insight a new ORGANIZATION of familar components, something that did not exist before, something original. In as much as creative acts are less probable (->PROBABILITY) than CONVENTIONal and routine ones, they provide more INFORMATION, sometimes so much that they exceed the level of comprehendability and are rejected for that reason.

CRITERION: Generally, any standard by which something is judged. In logic it is a contingent condition neither necessary nor sufficient for the truth of the judgement but a reliable indication thereof. In REGULATION, the degree to which the process to be confined approximates or matches the criterion determines the amount of INFORMATION that needs to be processed.

CULTURAL DETERMINISM; The conviction that the accumulated knowledge, the organized beliefs, and the way of life prescribed by a CULTURE (->NOOSPHERE) determine not only all other aspects of human cognition and social BEHAVIOR but also the DYNAMICs of the culture itself. Such a conviction sees culture as an autonomous CONTROL SYSTEM.

CULTURE: The social artistic and scientific heritage of a community or society. The intergenerational COMMUNICATION of INFORMATION, other than GENETIC INFORMATION, in the form of material artifacts (e.g., tools, weapons, buildings, works of art) distinctive forms of BEHAVIOR (e.g., songs, rituals, institutions, organizational

forms) and SYSTEMs of distinctions (classifications, histories, knowledge CODEd in SYMBOLs, ideas or beliefs). Culture incorporates individual and collective responses to environmental conditions and its content is continually subjected to EVOLUTIONary processes such as RANDOM MUTATION, recombination and selection.

CYBERNETICS: The term derives from the Greek word for steersman. Initially, the science of CONTROL and COMMUNICATION in the animal and the machine (Wiener). Before this modern definition, the science of GOVERNMENT (Ampere). Now an interdisciplinary approach to ORGANIZATION, irrespective of a SYSTEM's material REALIZATION.

Whereas GENERAL SYSTEMS THEORY is committed to HOLISM on the one side and to an effort to generalize STRUCTURal, BEHAVIORal and DEVELOPMENTal features of living organisms on the other side, cybernetics is committed to an epistemological perspective that views material WHOLEs as analysable without loss, in terms of a set of components plus their organization (->EPISTEMOLGY, ->ANALYSIS, ->SYSTEM). Organization accounts for how the components of such a system interact with one another, and how this interaction determines and changes its structure. It explains the difference between parts and wholes and is described without reference to their material forms. The disinterest of cybernetics in material implications separates it from all sciences that designate their empirical domain by subject matters such as physics, biology, sociology, engineering and general systems theory. Its epistemological focus on organization, pattern and communication has generated methodologies, (->METHODOLOGY) a logic, LAWs, theories and insights that are unique to cybernetics and have wideranging implications in other fields of inquiry.

In cybernetics, theories tend to rest on four basic pillars: VARIETY, circularity, process and observation. Variety is fundamental to its INFORMATION, COMMUNICATION and CONTROL theories and emphasises multiplicity, alternatives, differences, choices, NETWORKs, and INTELLIGENCE rather than force and singular necessity. Circularity occurs in its earliest theories of circular causation or FEEDBACK, later in theories of RECURSION and of ITERATION in COMPUTING and now involving SELF-REFERENCE in cognitive organization and in autonomous systems of PRODUCTION (->AUTOPOIESIS). Traditional sciences have shied away from if not exorcised the use of circular explanations. It is this circular form which enables cybernetics to explain systems from within, making no recurse to higher principles or a priori purposes, expressing no preferences for HIERARCHY. Nearly all cybernetic theories involve process and change, from its notion of information, as the difference between two states of UNCERTAINTY, to theories of ADAPTATION, EVOLUTION and GROWTH processes. A special feature of cybernetics is that it explains such processes in terms of the organization of the system manifesting it, e.g., the circular causality of feedback loops is taken to account for processes of REGULATION and a system's effort to maintain an EQUILIBRIUM or to reach a goal. Finally, observation including DECISION making is the process underlying cybernetic theories of information processing and computing. By extending theories of self-reference to processes of observation including cognition and other manifestations of intelligence, cybernetics has been applied to itself and is developing an

EPISTEMOLOGY of systems involving their observers (->SECOND-ORDER CYBERNETICS) qualitatively unlike the earlier interest in the ONTOLOGY of systems which are observed from the outside (->FIRST-ORDER CYBERNETICS).

The early contributions of cybernetics were mainly technological (->TECHNOLOGY), and gave rise to feedback CONTROL devices, communication technology, AUTOMATION of production processes and COMPUTERs. Interest moved soon to numerous sciences involving man, applying cybernetics to processes of cognition, to such practical pursuits such as psychiatry, family therapy, the development of information and decision systems, MANAGEMENT, government, and to efforts to understand complex forms of social organization including communication and computer networks. The full potential of cybernetics has not yet been realized in these applications. Finally, cybernetics is making inroads into philosophy. This started by providing a non-metaphysical TELEOLOGY and continues by challenging epistemology and ethics with new ideas about limiting processes of the mind, responsibility and aesthetics.

DATA: Plural of ->DATUM

DATA BANK: An organized and comprehensive collection of DATA, typically stored on Hollorith cards, magnetic tapes or disks and accessable for selective retrieval by a COMPUTER.

DATUM: (1) A material unit representing INFORMATION about a portion of the real world that can be processed by explicit procedures and maintains its characteristics during repeated use. (2) A FACT or figure transcribed in a readable LANGUAGE and on a durable medium (->CHANNEL). E.g., a completed questionaire, a taped interview, the recorded results of an experiment. Events that leave no physical marks cannot be traced through data and physical marks that can no longer be interpreted, e.g., because the CODE linking them to particular observations is unavailable, loose the status of data. A datum rarely stands alone, hence the common use of its plural DATA. Science typically processes large collections of data. In statistics each datum of a collection must contain the same kind of information.

DECISION: The willful imposition of a CONSTRAINT on a set of initially possible alternatives. In the extreme case, the choice of one from a set of initially conceivable but after the decision and by virtue of that decision no longer available courses of action, messages, objects, properies, etc. The power of a decision is measured by the dual LOGARITHM of the logical PROBABILITY of the remaining to the initial set of possibilities (->INFORMATION, ->LAW OF REQUISITE VARIETY, ->BIT).

DECISION SCIENCE: (a) The study of how decision makers (individuals or groups) chose among a set of alternative courses of actions, and (b) the design of efficient procedures that either aid a

decision maker's effort or that evaluate his courses of action according to chosen criteria or policies so that a decision logically follows from the COMPUTATIONs. The decision theories respectively arising or underlying these efforts take into consideration the UNCERTAINTY of the situation, the INFORMATION available about consequences, the RISKs involved, the costs and benefits of each action and the time, resources and preferences a decision maker has at his disposal for making a DECISION (->OPTIMIZING, ->SATISFICING).

DECODING: The process of restoring original messages from the forms in which they were transmitted, stored or enciphered by applying a suitable CODE. In a simple communication chain decoding tends to be the inverse of ENCODING.

DEGREE OF FREEDOM: That measure of VARIABILITY which merely expresses the number of options available within a VARIABLE or space. In a SYSTEM with N states the degree of freedom is N. In statistics, of the N cells of a table of probabilities only N-1 can be arbitrarily filled, the last being determined by the requirement that probabilities must add to 1 (->PROBABILITY), hence the degree of freedom is N-1. The measure of UNCERTAINTY may be interpreted as a LOGARITHMic measure of the degree of freedom logically or statistically available.

DETERMINISTIC: Attribute of SYSTEMs whose BEHAVIOR is specified without probabilities (other than zero or one) (->PROBABILITY) and predictable without UNCERTAINTY once the relevant conditions are known. Deterministic systems leave nothing to CHANCE and are of necessity LAWful. There are no options. Deterministic Systems conform to the ideal of a MACHINE in which wear and tear, mechanical failures and unreliabilities are absent. Modern COMPUTERs are conceived as deterministic machines.

DEVELOPMENT: The process of a systematic unfolding of a SYSTEM's STRUCTURE. In biology, all molecular processes that underly the GROWTH to maturity of an organism. In psychology, the CORRELATION between age and the capacity to engage in certain BEHAVIORs, particularly in children. In the economics of underdeveloped countries, the concept is politically controversial because it implies PROGRESSive structural changes from primitive to advanced forms and because this current use of the term by Western economists may serve technological imperialism. Nevertheless, the unfolding and growth of structures to their natural limits and their eventual replacements by new forms is observable, particularly in society, and without the need to refer to life-cycles or to assume progress, making development an important adjunct of the cybernetic concern with ORGANIZATION.

DEVIATION AMPLIFYING FEEDBACK: Positive FEEDBACK. A circular causal process which may start from an initially unstable (->STABILITY) condition after which the difference between the value of a VARIABLE

and that condition progressively increases. E.g., underlying an arms race may well be the two countries' desire for peace but a kernel of distrust in the other's motivation to be satisfied with the balance in military power induces an imbalance into the equation which stimulates the production of more and more powerful weapons on both sides, seamingly without end (->RUNAWAY). Deviation amplifying feedback either disintegrates the system giving rise to it, runs to a new limit (->MORPHOSTASIS), or necessitates structural changes (->MORPHOGENESIS).

DEVIATION REDUCING FEEDBACK: Negative FEEDBACK. A circular causal process during which an initial difference between the value of a VARIABLE and a standard or CRITERION is asymptotically reduced, e.g., as in the REGULATION of the room temperature by a thermostat.

DIACHRONIC: Attribute of descriptions or of theories that focus on the DYNAMIC aspects of a SYSTEM's STRUCTURE or ORGANIZATION, on change, EVOLUTION and processes generally as opposed to SYNCHRONIC descriptions.

DIALECTIC: Historically, the process of finding TRUTH by dialogue. By Kant, the study of contradictions in empirical knowledge leading to principles of reasoning rather than an understanding of the phenomenal world. By Hegel, the process by which contradictions are absorbed in a system representing a higher ORDINALITY. The process is thought to direct both individual thought and world history according to the pattern: thesis + anthisesis => synthesis. By Marx, this triology is turned around. Contradictions are interpreted as class CONFLICTs that are inherent in the economic conditions of one SYSTEM and give rise to the emergence of another more inclusive system (->MORPHOGENESIS).

DIGITAL COMPUTER: A COMPUTER that stores DATA in terms of digits (numbers) and proceeds in discrete steps from one STATE to the next. The states of a digital computer typically involve BINARY digits which may take the form of the presence or absence of magnetic markers in a storage medium (->MEMORY), on-off switches or relays. In digital computers, even letters, words and whole texts are represented digitally. Unlike ANALOG COMPUTERs, digital computers can only approximate a continuum by assigning large numbers of digits to a state description and by proceeding in arbritarily small steps.

DIMENSION: A VARIABLE in spacial geometry. E.g., in relativity theory, an event is characterized by four numbers, three locating it in (the coordinates of a CONVENTIONal) space and one in time so that events are thought to be four-dimensional.

DIMINISHING RETURNS: ->LAW OF DIMINISHING RETURNS

DISCRIMINATION: The act of drawing perceptual, notational or spacial distinctions. In social life, discrimination often implies a differential (favourable/unfavourable) treatment of categories of persons on arbitrary ground, an overt manifestation of prejudices.

DISSIPATIVE STRUCTURE: A SYSTEM that exits far from thermodynamic equilibrium (->THERMODYNAMICS), hence efficiently dissipates the heat generatd to sustain it, and has the capacity of changing to higher levels of orderliness (->SELF-ORGANIZATION). According to Prigogine, systems contain subsystems that continuously fluctuate . At times a single fluctuation or a combination of them may become so magnified by possible FEEDBACK, that it shatters the preexisting ORGANIZATION. At such revolutionary moments or "bifurcation points", it is impossible to determine in advance whether the system will disintergrate into "chaos" or leap to a new, more differentiated, higher level of "order." The latter case defines dissipative structures so termed because they need more energy to sustain them than the simpler structures they replace and are limited in growth by the amount of heat they are able to disperse.

DISTRIBUTION: The set of values of a VARIABLE together with the probabilities (->PROBABILITY) associated with each. A tabulation of the frequencies of tokens by types.

DNA: Deoxyribonucleic Acid ->GENETIC INFORMATION

DOMAIN of a TRANSFORMATION: The set of states from which transitions are defined or the set of operands which an operation transforms.

DOMINANCE: A RELATION between pairs of elements of a set which designates which is superior, preferred to or in CONTROL of which other. E.g., hierarchies (->HIERARCHY) in social organizations, a "pecking order" which is characteristic in most communities of social animals, food chains in ECOLOGY, all of which can be described by dominance relations.

DOUBLE BIND: A paradoxical interpersonal RELATIONship involving (1) two or more individuals in an intense relationship, e.g., in family life, captivity, love, loyalty, (2) the COMUNICATION of a statement that is manifestly contradictory to what it says, e.g., an order to disobey the order, a punishment that is assertedly done for love (->PARADOX), and (3) the inability of the addressee of the statement to step out of the relationship with the significant other, the inability to METAcommunicate or to withdraw from the situation. The effect of a double bind is that the addressee cannot decide what is real and may develop pathologies (->PATHOLOGY).

DOUBLE-TALK: The deliberately ambiguous (->AMBIGUITY) use of words or expressions for PURPOSEs of deception in the exercise of power.

DUALISM: Any theory which is founded on the assumption that there exists a natural and irreducable distinction between two kinds of entities. E.g., the yin and yang in Chinese philosophy, Descartes' mind-body dualism.

DYAD, adjective DYADIC: A unit involving two related entities or a pair of objects as opposed to a monad involving only one, a triad involving three, etc. Social psychological studies of human COMMUNICATION that focus on sender-receiver dyads ignore RELATIONs of ORDINALITY larger than two.

DYNAMIC: An attribute emphasising motion, change, and process as opposed to "static."

DYSFUNCTION: An attribute used by the structural-functional school of sociology to indicate a social action that does not enhance the adaptability of the SOCIAL SYSTEM in which it occurs. In contrast, a FUNCTION enhances that adaptability (->ADAPTATION).

ECO SYSTEM: A SYSTEM involving interacting populations of species within a particular environment. An eco system is considered part of the ecosphere and an object of ECOLOGY.

ECOLOGY: The study of interacting populations of different species. The term comes from biology and was originally used in investigations of the DYNAMIC effects of food chains and cycles (of species feeding on each other or using common resources and thereby mutually determine their relative size). The inclusion of human beings and the generalization of the notion of species to include species of man-made objects has made ecology the study of complex interactions in the terrestrial environment of man (->ECOSPHERE, ->ECO SYSTEM). Typical forms of interactions among species are cooperation, parasitism, predation, competition, DOMINANCE, INDEPENDENCE, succession. An important task of ecology is to investigate the conditions under which population sizes are in EQUILIBRIUM. With the inclusion of human TECHNOLOGY into ecological equations, an important problem of ecology is to predict environmental changes and to evaluate the effects different corrective measures may have on short range and long range ecological balances (->EXTERNALITIES).

ECOSPHERE: A term modelled after "atmosphere" and "BIOSPHERE" signifying (a) the physical space occupied by all material things, including by biological organisms and (b) the processes of production,

destruction and assembly of material entities in this space. The latter extends ECOLOGY to include all physical processes man-made or natural and their interactions.

EFFICIENCY: The proportion of benefits to costs, the relationship between a level of performance and the resoures expended to achieve this level.

EIGEN VALUE: That value of a VARIABLE to which an OPERATION defined in that variable converges (->CONVERGENCE). Like EQUILIBRIUM, eigen values are stable points in the domain of computation and a property of the operation. E.g., x'=(x+1)/2 converges to an eigen value of 1 (->ITERATION).

EMBRYOGENESIS: The MECHANISM of DEVELOPMENT of organisms from the point of inception to reaching a STRUCTURal EQUILIBRIUM, usually conceived of as the adult state (Piaget). Applicable to social or technological development only if such a mechanism can be described in its own terms and applieed to an origin.

ENCODING: The process of applying a suitable CODE to an original message in order to change its form into one which is more advantageous for transmission, storage, reading, etc. In cryptography, the task of enciphering is one of encoding a readable message into a form that unauthorized receivers cannot easily decipher. In human COMMUNICATION, the process of translating mental imagery into linguistic expressions is charaterized as encoding (->TRANSLATION) just as is the process, embodied in a microphone, of converting acoustical signals into electrical impulses.

ENERGY: The equivalent of, or the capacity to perform, mechanical work, the difference between two states of THERMODYNAMIC ENTROPY before and after work has been performed. Energy is measured either as the product of force and distance (e.g., in lifting a weight a certain height) or as the product of power and time (e.g., in getting an object to move with a certain speed). Energy may be stored in a material structure as in a water resevoire or a barrel of oil or in a kinetic form as in the momentum of a wheel or of a bullet in motion. Electrical energy is measured in kilowatt/hours (kw/h), heat energy in Calories or in British thermal units (Btu), mechanical energy in horsepowers, light in Joules, explosives in tons of TNT, etc. Different forms of energy are inter-convertable due to the FIRST LAW OF THERMODYNAMICS which makes energy the most important CONSTRUCT of physics. All physical processes including COMPUTATION and COMMUNICATION are known to require energy (->THERMODYNAMICS).

ENTAILMENT: The converse of the relation of logical consequence. For p to entail q is for q to logically follow from p.

ENTROPY: ->STATISTICAL ENTROPY, a measure of VARIATION, dispersion or diversity; ->THERMODYNAMIC ENTROPY, a measure of unusable ENERGY. The similarity between the two types of entropy is merely formal in that both are expressed as the LOGARITHM of a PROBABILITY. The thermodynamic entropy S=k log W is a FUNCTION of the dispersion W of heat, with k being Boltsmann's CONSTANT. The statistical entropy of an event a is $H_a = -k \log p_a$ where p_a is the statistical probability of a and k is arbitrarily set so as to make the logarithm dual (->BIT). The negative sign gave rise to the notion of NEGENTROPY (Material entropy ->POLLUTION, ->SOCIAL ENTROPY).

ENVIRONMENT: (1) the SYSTEM of surrounding things, conditions or influences, especially affecting the existence or development of someone, something or another system (->HABITAT), (2) The art of environing, (3) The state of being environed.

EPISTEMOLOGY: A branch of philosophy concerned with how an observer may know, not with what he may know thereby. The latter is the concern of ONTOLOGY. Epistemology seeks to understand the origin, proceses and limitations of observation including such OPERATIONs as drawing distinctions, establishing RELATIONs, creating CONSTRUCTs and all consequences for knowledge resulting from COMMUNICATION between an observer and the observed and within a community of observers who may observe each other. The epistemology of a theory considers the observer and the observed as parts of the same system and theory as an emergent property of the interaction process. Epistemology asks not "what is," or "what can we know" but "how do we come to know."

EQUIFINALITY: A BEHAVIOR that is oriented towards reaching certain final conditions or STATEs regardless of where it started. Bertalanffy argued that equifinality characterises the behavior of biological organisms but not that of physical devices and therefore may be used to distinguish between these. The MODELling of such behavior by COMPUTERs has blurred this distinction (->GOAL ORIENTED, ->EQUILIBRIUM, ->STABILITY).

EQUILIBRIUM: Literally balance, here balance of forces acting on each other. In a static equilibrium forces compensate each other so that the SYSTEM is motionless, e.g., a scale at rest. If forces do not compensate each other fully at one instant in time, a system moves until it encounters higher-order CONSTRAINTs, e.g, after starting an engine, it accelerates to a point at which ENERGY supply and work load plus friction are again in balance. In such a DYNAMIC equilibrium, forces complement each other dynamically so that the system's BEHAVIOR is repetitive, predictable, does not generate new STATEs and the trajectory follows a regular cycle. E.g., mass production at a well-worked out assembly line, sterotypical conversation within a

family, routine administrative procedures. A system may have several distinct equilibria (->POLYSTABILITY). A system in equilibrium conveys no INFORMATION. One important equilibrium property is STABILITY. HOMEOSTASIS is a process of interaction favouring an equilibrium.

EQUILIBRIUM STATES: That set of a SYSTEM's STATEs which it can reoccupy indefinitely often, each succeeding another either directly or indirectly. Equilibrium states are constrasted with TRANSIENT STATES.

EQUIVOCATION: The reduction of VARIETY in a COMMUNICATION CHANNEL by classification, simplification, generalization or condensation of the signals or messages sent. Equivocation occurs when different signals are no longer differentiated by the receiver. INFORMATION THEORY quantitatively decomposes the sender's STATISTICAL ENTROPY into a quantity of transmitted INFORMATION and the quantity of equivocation. Equivocation is the logical complement of NOISE and undesirable from the sender's perspective.

ERGODIC: Attribute of a BEHAVIOR that involves only EQUILIBRIUM STATES and whose transition PROBABILITIES either are unvarying or follow a definite cycle. In statistics, ergodicity is called stationarity and tested by comparing the transition probabilities of different parts of a longer sequence of events. Ashby's "theory of incessant transmision" refers to the analysis of INFORMATION flows in systems whose transition probabilities are unvarying and hence ascertainable for the analysis. All systems eventually converge toward ergodic behavior (->NON-ERGODIC).

ERROR CORRECTING CODE: An ENCODING CODE which corrects messages that contain transmission errors of up to a certain number per message. A code is error correcting only if the HAMMING DISTANCE between the messages sent exceeds twice the number of transmission errors per message (->REDUNDANCY, ->ERROR DETECTING CODE).

ERROR DETECTING CODE: An ENCODING CODE which correctly identifies messages that contain transmission errors of up to a certain number per message without the ability to correct them. A code is error detecting only if the HAMMING DISTANCE between the messages sent exceeds the number of transmission errors per message (->REDUNDANCY, ->ERROR CORRECTING CODE).

ETHER: Because light consists of waves, the belief that all waves must be CHANNELed through a medium (as sound is through air or water) led 19th century physicists to construct ether as the medium supporting the propagation of light. However, the Michelson-Morley Experiment showed that if ether existed it could not be observed. It also demonstrated, more generally, that the CONSTRUCT of a physical medium is inessential for research into COMMUNICATION processes.

ETHICAL IMPERATIVE: An imperative derived from assumptions of CONSTRUCTIVISM: "Act always so as to increase the number of choices" (v.Foerster).

EVALUATION: The process of establishing whether an existing structure performs approximately as expected. The process of obtaining reliable DATA usually for administrators and governmental agencies about the effects, values and EFFICIENCY of social programs, particularly in education and economic DEVELOPMENT. Formative evaluation is often part of the program and designed to improve it. Algedonic (->ALGEDONIC REGULATION) evaluation is designed to establish its worth.

EVOLUTION: The theory concerned with how existing varieties of species of organisms, plants or animals, have come about through a PROGRESSive diversification of ancestral forms interacting with their respective environments. The theory pits essentially two processes against each other: First, VARIETY in the inherited endowment of a species is generated by the combination of genetic material through the mating of parent organisms and by essentially RANDOM mutations of a gene, or in the structure of chromosomes. Second, variety in the organisms that come into being as the result of suitable genetic endowments is reduced by natural selection, i.e., by elimination of those organisms that are either unable to develop, unfit or ill equipped to live in their environment. What survives the alternating pressures of these two processes is that genetic material which has proven not to be disadvantageous. For biology, evolution is a theory of COMMUNICATION of GENETIC INFORMATION in the presence of NOISE and through a selective CHANNEL provided by the grown organisms with selection criteria stemming primarily from organism-environment interactions. For CYBERNETICS, evolution is the process in which variety is alternatingly generated and destroyed so that which survives is not being effected by either.

To clarify three common misunderstandings: Evolution is an essentially STOCHASTIC PROCESS, not a DETERMINISTIC one. It applies to the interaction between species of organisms and their environments, not to particular organisms. Evolution lets survive all those organisms that do not develop or exhibit disadvantageous properties. It does not favour the fittest. Evolution is an opportunistic process, neither progressive nor guided by any particular goal. A "survival instinct" postulated by many biologists and ingrained in popular culture does not exist.

EXCHANGE: Two-way flow of values, commodities, INFORMATION or people with a CONSTRAINT on or RULEs for the amounts or proportions going either way. E.g., exchange of currency by a rate, reciprocal exchange of gifts or favours.

EXCLUDED MIDDLE: ->LAW OF THE EXCLUDED MIDDLE

EXPECTATION: Generally, the anticipation of something to occur at a certain time or place or in a certain way. In statistics, the PROBABILITY of an event in a universe inferred from the relative FREQUENCY of observing that event in a sample.

EXPLANATION: Any theory that logically implies or any SYSTEM that reconstructs or generates what has in fact been observed. The theory or system used in this process constitutes the explanans or the premises of the explanation. The thing to be explained is the explanadum or conclusion of the explanation. Explanation establishes a formal CONSTRUCT on top of existing DATA, whereas PREDICTION goes beyond them (->GENERATIVE, ->RECONSTRUCTIBILITY).

EXTERNALITIES: In economics, the effects that the acts of consumers or producers have on each other. Externalities range from POLLUTION and technological (->TECHNOLOGY) inventions to the change in the range of options available to consumers and are differentiated from internalities because current knowledge prevents the former from being included into the formal equations of an ANALYSIS. Externalities may also be regarded as the unanticipated side effects of calculated courses of action.

FACT: Anything described and held to be true; any DATUM that, within the domain of an observer's powers, cannot be ignored, modified or explained away and must therefore be included in that observer's CONSTRUCT or MODEL. Facts are contrasted with statements that are untrue or surmised, with untested hypotheses, beliefs and fantasies, and with phenomena that are subject to change, e.g., with a SELF-FULFILLING HYPOTHESIS.

FEEDBACK: A flow of INFORMATION back to its origin. A circular causal process in which a SYSTEM's OUTPUT is returned to its INPUT, possibly involving other systems in the loop. Negative feedback or DEVIATION REDUCING FEEDBACK decreases the input and is inherently stabilizing (->STABILITY, ->REGULATION, ->HOMEOSTASIS), e.g., the governor of a steam engine. Positive feedback or DEVIATION AMPLIFYING FEEDBACK increases the input and is inherently destabilising, explosive or vicious, e.g., the GROWTH of a city when more people create new opportunities which in turn attract more people to live there. Feedback is not the term for a response to a stimulus rather for the circularity implied in both.

FIGURE-GROUND: The characteristically unequal emphasis in human visual PERCEPTION on a figure, which stands out against an undifferentiated background, which merely contributes to that perception. This unequal emphasis is found in the distinction between a word and its CONTEXT between an organism and its environment or

between pattern and CHANCE. There are many visual examples of figure and ground reversals which are the equivalents of PARADOXes. CYBERNETICS has synthesised the paradoxes arising out of this alternating emphasis by the CONSTRUCTion of SYSTEMs of interacting SUBSYSTEMS in which each is simultaneously a figure in its own right and part of the background for the other subsystems.

FINITE: Countable. It contrasts with "infinite" and "unlimited" which is a product of MATHEMATICS and the human mind. The attribute focuses attention to the FACT that (a) no observer has endless amounts of time, can make infinitesimally small distinctions and can absorb indefinitely large volumes of DATA. What he can experience, what he can decide upon, and what he can do is strictly limited and the theories he may construct must take the finite nature of his DATA into consideration. For similar reasons (b) the amount of INFORMATION a COMPUTER, or more generally, any material SYSTEM may process (accept memorize, compute, and communicate) is limited (->BREMERMANN'S LIMIT) so that some problems which a computer programer may state are definitively unsolvable or not comprehendable within finite time (e.g., ->COMBINATORIAL EXPLOSION). Roughly anything material stops at about 10^{100} or about 300 BITs (Ashby). Finally (c) a constructivist (->CONSTRUTIVISM) who accepts only those entities which can be constructed from known entities by intuitively accepted procedures must come to the conclusion that CONSTRUCTs of some complexity may not be either true or false but in the absence of adequate proofs possess a third value: undecidable.

FIRST LAW OF THERMODYNAMICS: The law of conservation of ENERGY (->THERMODYNAMICS).

FIRST-ORDER CYBERNETICS: The CYBERNETICS of SYSTEMS that are observed from the outside as opposed to the cybernetics of systems involving their observers (v.Foerster). First-order cybernetics is concerned with circular causal processes, e.g., CONTROL, negative FEEDBACK, COMPUTING, ADAPTATION.

FRAME OF REFERENCE: The CONTEXT, point of view, set of presuppositions, assumptions, evaluative criteria (->CRITERION) in so far as they form a COGNITIVE SYSTEM with which a person perceives, judges or selectively constrains a course of actions or outcome thereof or with which a scientific observer delineates the subject matter of his theory.

FREQUENCY: The number of times a CATEGORY of events, of objects or of individuals has been observed, the number of members in a class (->PROBABILITY, ->LAW OF LARGE NUMBERS).

FUNCTION: In MATHEMATICS, a RELATION between two or more

VARIABLES so that the values of one are DEPENDENT on, determined by or correspond to values in the other variables, its ARGUMENTs; a TRANSFORMATION whose RANGE is uniquely specified by its DOMAIN. In algebra and set theory, functions are often called many-to-one mappings or images. In processes of COMMUNICATION, functions are found in equivocating (->EQUIVOCATION) CODEs. There is no presumption that a function must take numbers as arguments, nor that the correspondence be LAWful. It can result from entirely arbitrary CONVENTIONs (->SYMBOL). The structural-functional school of sociology sees the parts of a SOCIAL SYSTEM to behave in such a way that they satisfy human and social needs and maintain one another and the totality. In this theory, regularly occuring acts that serve this purpose are called functions whereas those opposed to this are called DYSFUNCTIONs.

GAME THEORY: A general theory of rational BEHAVIOR for situations in which (1) two (two-person games) or more (multi-person games) DECISION makers (players) have available to them (2) a finite number of courses of action (plays) each leading to (3) a well defined outcome or end with gains and losses expressed in terms of numerical payoffs associated with each combination of courses of action and for each decision maker. The decision makers have (4) perfect knowledge of the RULEs of the game, i.e., (1), (2) and (3) but no knowldege about the opponents' moves and are (5) rational in the sense of making decisions that optimize their individual gains. The MATRIX of payoffs can represent various CONFLICTs. In a zero-sum game one person wins what the other looses. In other situations gains and losses may be unequally distributed which allows the representation of numerous competitive and conflict situations. The theory proposes several solutions, e.g., in a minimax strategy each participants minimizes the maximum loss the other can impose on him, a mixed strategy involves PROBABILISTIC choices. Experiments with such games revealed conditions for cooperation, defection and the persistence of conflict. The theory and some of the results have found applications in economics, management science bargaining and conflict resolution among many areas of interest.

GENERAL SYSTEMS THEORY: A scientific effort to identify STRUCTURal, BEHAVIORal and DEVELOPMENTal features common to particular classes of living organisms. One "approach is to look over the empirical universe and pick out certain general phenomena which are found in many different diciplines, and to seek to build up general theoretical MODELs relevant to these phenomena," e.g., GROWTH, HOMEOSTASIS, EVOLUTION. The other "approach is to arrange the empirical fields in a HIERARCHY of complexity of ORGANIZATION of their basic 'individual' or unit of behavior, and to try to develop a level of abstraction appropriate to each" (Boulding). Examples are the generalizations the levels of cells, simple organs, open self-maintaining organisms, small groups of organisms, society and the universe. The latter approach implies a hierarchical "systems of systems" view of the world quite alien to that of CYBERNETICS. Because of its roots in biology whose forms tend to have long evolutionary histories and are somewhat more stable ORGANIZATIONally, structurally

integrated, and centrally controlled by DNA, among many other properties, general systems theory like the structural-functional school of sociology, has been recognized as favouring to favor the status quo when applied to social phenomena which are largely the product of structural changes, technical innovations and INFORMATION growth (->MORPHOSTASIS, ->MORPHOGENESIS).

GENERATIVE: Attribute of a SYSTEM capable of listing the descriptions of each of a certain set of alternatives. In linguistics, a generative grammar embodies a FINITE number of TRANSFORMATION RULEs for CONSTRUCTing a potentially infinite number of sentences of a language and lists potentially all and only the grammatical sentences of that language. In CYBERNETICS, a generative MODEL generates (exhibits or enumerates) hypothetical DATA that either match or approximate within acceptable limits those in fact observed on the system modelled. The use of such generative devices is CONSTRUCTIVISM's alternative to testing verbal hypotheses and theories with available data.

GENESIS OF STRUCTURE: ->LAW OF GENESIS OF STRUCTURE

GENETIC INFORMATION: The INFORMATION encoded (->ENCODING) in the genetic material with which all living organisms are endowed. The carrier of this information is a complex STRUCTURE of DNA. It represents an organism's biological inheritance and CONTROLs that organism's DEVELOPMENT, REPRODUCTION and self-repair. Within an organism, genetic information flows from DNA to protein and other products, first, by the transcription of portions of the DNA into so-called messenger RNA and, second, by the assembly of individual amino acids into polypeptides, including proteins. Thus the GROWTH of an organism is controlled. The absence of a MECHANISM that could reverse the direction of this flow from proteins to DNA is the basis for the FACT that the experiences an organism makes during its life time cannot be inherited by biological means (->CULTURE). Changes in the intergenerational COMMUNICATION of genetic information result from mutations (->NOISE) and are the target of natural selection (->EVOLUTION).

GENETICS: Historically, the science of heredity, i.e., the tendency of like to beget like. Now, a branch of biology concerned with intergenerational COMMUNICATION through molecular processes. CULTURE provides the other channels of intergenerational communication, largely through SYMBOLic processes.

GENOTYPE: The detailed description or classification of the GENETIC INFORMATION constituting a particular organism by heredity in contrast to that organism's PHENOTYPE which includes all of its observable characteristics, whether inherited or acquired. The distinction is important because it is the genotype not the phenotype

which is reproduced but it is the phenotype not the genotype on which natural selection acts (->EVOLUTION).

GESTALT: A configuration, originally limited to visual forms, or a pattern which is seen as a whole UNITY. The nearest English equivalent to this German word is WHOLE. The concept has given rise to various theories of perception and LEARNING, educational philosophies and schools of thought, e.g., gestalt psychology, GENERAL SYSTEMS THEORY and HOLISM.

GOAL-ORIENTED: Attribute of SYSTEMs whose BEHAVIOR is specified not only by its current STATE (->STATE DETERMINED) or its past history (->HISTORY DETERMINED) but crucially by some preferred future state or behavior, a goal toward which it converges (->CONVERGENCE) when left undisturbed or which it reoccupies after a disturbance is removed (->EQUIFINALITY, ->STABILITY).

GOEDEL THEOREM: ->INCOMPLETENES THEOREM

GOVERNMENT: The acts, RULEs, procedures, instruments of power and institutions by which the citizens of a country (or more generally the parts of a SYSTEM) communicate with (->COMMUNICATION) and exert CONTROL upon each other so that the country as a whole maintains its UNITY and is directed toward ends chosen from within that country (->SELF-ORGANIZATION, ->AUTONOMY). Its opposite is LAISSEZ FAIRE. In the reality of politics, government is rarely uniformly distributed and constituted (->CONSTITUTION) instead in a ruling elite, exercising institutional control over those governed. This unequal distribution of government is particularly prevalent in technical realisations. E.g., the governor of a steam engine, computer control of a production process. In biology, such control hierachies (->HIERARCHY) rarely exist which suggest that they may be an outgrowth of rational CONSTUCTions not a FACT of nature.

GRAPH: (1) A visual REPRESENTATION of a BEHAVIOR or FUNCTION, usually in two or more dimensions. (2) A mathematical STRUCTURE formed from two kinds of elements, a collection of objects (called points) and a collection of BINARY RELATIONs (called edges) linking objects by lines. Graphs are common in the description of COMMUNICATION NETWORKs, organizational charts, subway route maps, etc.

GROWTH: An increase in magnitude of some aggregate (->AGGREGATION) measure (->VARIABLE) of a SYSTEM, e.g., growth in gross national product or in complexity. Growth need not be desirable, e.g., growth in unemployment or in violence on television. There are two kinds of growth phenomena, (1) growth in numerority, e.g., population growth or growth in the number of cars produced, and (2) growth in STRUCTURE, e.g., growth of a crystal or of an enterprise. Without

reference to external conditions (->ADAPTATION), structural growth recognises several principles. Growth (a) by nucleation: in any system, a structure has a minimum size below which it cannot exist above which it may expand, (b) by AUTOCATALYSIS or (c) according to some kind of plan, e.g., by the REWRITE RULES of a grammer, or by the DNA (->DEVELOPMENT, ->EMBRYOGENESIS). In complex systems, (d) structural growth is likely to effect the parts of a system differentially, creating LAGs and stresses which call either (e) for compensatory activies, e.g., crisis intervention or CONFLICT resolution by a government, or (f) for mediating devices, e.g., EXCHANGE NETWORKS or COMMUNICATION TECHNOLOGY. (g) All growth creates forms but forms are limited by the pattern of growth (->CONSTITUTION) thus ultimately terminating in MORPHOSTASIS (Boulding).

HABITAT: In ECOLOGY, the region or natural environment that can sustain the life of a particular species, plant or animal. More generally, the physical space or CONTEXT in which some CONCRETE SYSTEM produces itself (->AUTOPOIESIS). other systems.

HAMMING DISTANCE: A measure of the difference between two messages, each consisting of a FINITE string of CHARACTERS, expressed by the number of characters that need to be changed to obtain one from the other. E.g., 0101 and 0110 has a Hamming distance of two whereas "Butter" and "ladder" are four characters apart (->ERROR DETECTING CODE, ->ERROR CORRECTING CODE).

HETERARCHY: ->NETWORK

HEURISTIC: A procedure or ALGORITHM to search for something by the incremental exploration an unknown terain according to some CRITERION. E.g., hill climbing optimisers, chess playing COMPUTERs which cannot evaluate all possible moves (->SATISFICING).

HISTORY DETERMINED: Attribute of SYSTEMs whose BEHAVIOR is specified or can be understood better by looking into its past history. In contrast to STATE DETERMINED systems, predictability of the future STATEs of such systems improves when relying not only on their current state but on a finite sequence of states preceeding them. E.g., higher-than-first-order MARKOV CHAINs (->MEMORY). It can be argued that all history determined systems are incompletely observed STATE DETERMINED systems and that the recourse into history has HEURISTIC value.

HOLISM: A philosophical position claiming (a) that WHOLEs cannot be taken apart (->ANALYSIS) and (b) that every apparent whole can be understood only in the CONTEXT of the larger whole containing it. This belief is epitomized in the statement that "a whole is more than the sum of its parts" (->SYNERGY, ->ORGANIZATION). Although the position

has merits, the infinite regression implied in the two-headed claim leads the wholist to believe in a hierarchical organization of the world (->HIERARCHY, ->GENERAL SYSTEMS THEORY). To understand anything requires him to explore larger and larger contexts, to seek refuge in increasingly universalistic kinds of understandings which renders him unable to simultaneously understand and cope with the particulars of a situation he started out with.

HOMEOSTASIS: A process of interaction or MECHANISM which balances various influences and effects such that a stable STATE or a stable BEHAVIOR is maintained. Often that stable state or that stable behavior is essential to assume STRUCTURal stability (->MORPHOSTASIS) of a SYSTEM. E.g., the size of the pupil of the human eye is negatively correlated with the intensity of light entering the retina thus keeping the amount of light within the limits of optimal processing of visual INFORMATION. Too much light will destroy the light sensitive cones of the retina. The blood sugar content and many other chemical quantities are similarly balanced within the human body (see Cannon's Wisdom of the Body). Stable homestatic states or behaviors need not have this purposive interpretation, however. The "balance of power" idea in international politics denotes a homeostatic mechanism whose outcome presumably neither country desires by itself. In families, homeostasis may become pathological (->PATHOLOGY) when family members no longer prefer that state yet cannot escape it as a consequene of the way they interact with one another (e.g., DOUBLE BIND). During family therapy, a non-pathological homeostasis maybe aquired after therapist induced MORPHOGENESIS or through SELF-ORGANIZATION. Homestasis concerns states or behaviors whereas morphogenesis concerns STRUCTURE and ORGANIZATION.

HOMEOSTAT: A MACHINE built in the 1940's by W.Ross Ashby to demonstrate the BEHAVIOR of an ultrastable SYSTEM (->ULTRASTABILITY). It responds to deviations from certain essential values of a continuous variable caused by an experimenter in the environment of the machine with stepwise structural changes, and it comes to rest only when a BEHAVIOR has been found that keeps the values of that critical variable within desirable limits (->MORPHOGENESIS). The essential values maybe interpreted as a homeostatic state, goal or ideal and the structural changes are adaptive relative to these values (->HOMEOSTASIS, ->ADAPTATION).

HOMOMORHISM: A many-to-one mapping in effect representing (->REPRESENTATION) a pattern in the DOMAIN of the mapping by a simpler pattern in its RANGE. The product of applying a homomorphism is called a homomorph. Homomorphisms are important in establishing whether one SYSTEM is a MODEL of another and which properties of the original system the model retains. For each system one can CONSTRUCT a LATTICE of homomorphic simplifications. The inverse of a homomorphism is not a mapping.

HAWTHORNE EFFECT: Initial improvement in a process of PRODUCTION caused by the obtrusive observation of that process. The effect was first noticed in the Hawthorne plant of Western Electric. Production increased not as a consequence of actual changes in working conditions introduced by the plant's management but because management demonstrated interest in such improvements (->SELF-FULFILLING HYPOTHESIS).

HYPERSPACE: A space within more than three DIMENSIONs. Any geometrical CONSTRUCTion whose cells or points are characterized by more than three values (->CARTESIAN PRODUCT). Although hyperspaces can be depicted, just as a three-dimensional cube can be projected on a two-dimensional surface so can four-, five-, ...n-dimensional cubes be represented, but it is difficult for the human mind to imagine operating in such spaces. This poses many practical problems of visualizing multi-variate DATA especially in the social sciences.

HYPOTHESIS: An assertion, proposition or statement about RELATIONs or CONSTRAINTs whose truth-value is as of yet unknown but in principle determinable by tests involving generally empirical but also logical evidence. Hypotheses are generally derived from theories or MODELs and when these theories have some validity of their own, they consititute PREDICTIONs.

ICON: A sign that informs by its physical resemblance or similarity with features of its REFERENT.

IDENTIFICATION: The correspondence between a largely behavioral MODEL and the portion of reality it claims to represent. One can think of such models as having equations whose PARAMETERs must be chosen in order for the model to be specified. A parameter can either be assumed to have a certain value and is then hypothesized or it can be estimated (->ESTIMATION) from given DATA and is then said to be identified. A model may be under-identified when not all of its parameters are identified or it may be over-identified when there are two or more inconsistent estimates of a parameter.

IDENTITY: A TRANSFORMATION always reproducing the original, a COMMUNICATIONal ideal in which messages are received exactly as sent.

IMMUNITY: A state of resistance or refractoriness resulting from responses by an organism to the invasion of substances foreign to that organism. Immunity results from the production of antibodies matching, nearly one-to-one the foreign substances present. Whereas immunity refers to a state in which certain material substances are no longer disruptive, ADAPTATION refer to a state in which INFORMATION in the form of disturbances no longer affects certain essential VARIABLEs.

INCENTIVE: Roughly synonymous with reward, motivation, goal, it refers to the material and social conditions conducive for individuals to engage in work other than for themselves.

INCOMPLETENES THEOREM: Goedel's thesis initially about number theory but now found applicable to all formal SYSTEMs that include the arithmetic of natural numbers: "any consistent axiomatic system does include propositions whose truth is undecidable within that system and its consistency is, hence, not provable within that system." The SELF-REFERENCE involved invokes the PARADOX: "a formal system of some complexity cannot be both consistent and decidable at the same time." The theorem rendered Frege, Russel and Whitehead's ideals of finding a few axions of MATHEMATICs from which all and only true statements can be deduced non-achievable. It has profound implications for theories of human cognition, computational linguistics and limits ARTIFICIAL INTELLIGENCE in particular.

INDEPENDENCE: Self-suficiency concerning INFORMATION. Independent SYSTEMs are closed to information. VARIATION outside the boundaries of independent systems do not affect the variation within. There is no INPUT. In statistics, two VARIABLEs are independent if the coocurance of their values is mere CHANCE, e.g., zero CORRELATION. In logic and set theory, two variables are independent if the RELATION between them is the mere CARTESIAN PRODUCT of two properties. Two individuals are independent if each does what he wants to do, neither having to consider the BEHAVIOR of the other. A clock is designed to be independent of variation in temperature, geographical location including gravity while it is correlated with other clocks and communicating its OUTPUT STATEs to an observer. Independent systems maybe a source but not the receiver of COMMUNICATION (->CLOSED SYSTEM, ->CLOSURE).

INDEX: A sign that informs by its CORRELATION with or causal connection (->CAUSALITY) to its REFERENT (->SYMPTOM). In the social sciences, a valid measure of something else (->MEASUREMENT).

INERTIA: Resistance to change. The property of a SYSTEM to oppose acceleration when acted upon. E.g, mass is a measure of the inertia of matter.

INFORMATIK (INFORMATICS): A (largely European) term designating the study of all INFORMATION processing SYSTEMs, artificial and natural, and the application of knowledge gained in such efforts to design and implement DIGITAL COMPUTERs in society. In practice, informatik includes (the largely U.S.) COMPUTER SCIENCE, the more application oriented efforts of MANAGEMENT information systems, AUTOMATION of PRODUCTION but also DATA processing including statistics for DECISION making. Because of its technological committments, informatik has deemphasised the study of information flows and

COMPUTATION within organisms and largely ignored the ORGANIZATIONal consequences of information flows, human COMMUNICATION and the use of computers in large SOCIAL SYSTEMS. Epistemological (->EPISTEMOLOGY) considerations which are characteristic in CYBERNETICS are absent in informatik.

INFORMATION: Literally that which forms within, but more adequately: the equivalent of or the capacity of something to perform organizational work, the difference between two forms of ORGANIZATION or between two states of UNCERTAINTY before and after a message has been received, but also the degree to which one VARIABLE of a SYSTEM depends on or is constrained by (->CONSTRAINT) another. E.g., the DNA carries GENETIC INFORMATION inasmuch as it organizes or CONTROLs the orderly GROWTH of a living organism. A message carries information inasmuch as it conveys something not already known. The answer to a question carries information to the extent it reduces the questioner's uncertainty. A telephone line carries information only when the signals sent correlate with those received. Since information is linked to certain changes, differences or dependencies, it is desirable to refer to these and distinguish between information stored, information carried, information transmitted, information required, etc. Pure and unqualified information is an unwarranted abstraction. INFORMATION THEORY measures the quantities of all of these kinds of information in terms of BITs. The larger the uncertainty removed by a message, the stronger the correlation between the INPUT and OUTPUT of a COMMUNICATION CHANNEL, the more detailed particular instructions are the more information is transmitted.

INFORMATION THEORY or statistical COMMUNICATION theory: a CALCULUS of VARIATION, VARIABILITY and VARIANCE initially developed by Shannon, to separate NOISE from information carrying signals, now used, to trace the flow of INFORMATION in complex SYSTEMs, to decompose a system into independent (->INDEPENDENCE) or semi-independent SUB-SYSTEMS, to evaluate the efficiency of communication CHANNELs and of various communication CODEs (->REDUNDANCY, ->NOISE, ->EQUIVOCATION) and to compare information needs with the capacities of existing information processors (->COMPUTER, ->BREMERMANN'S LIMIT), etc. The basic quantity this calculus analyses (->ANALYSIS) is the total amount of statistical ENTROPY given DATA contain about an observed system. The calculus provides an algebra for decomposing and thus accounting for this entropy in numerous ways. E.g. the quantity of entropy in an observed system equals the sum of the entropies in all of its separate parts minus that amount of information transmitted within the system. The latter quantity is the amount of entropy in a system not explainable from its parts and an expression of the communication between these parts. This formula is another example of the cybernetic ANALYSIS of systems, according to which any whole system is accounted for or defined in terms of a set of components and its ORGANIZATION. The total amount of information transmitted is a quantitative analogue to and hence can be thought of as a measure of a system's STRUCTURE. Information theory has provided numerous theorems and algebraical identities with which observed systems may be approached, e.g., the LAW OF REQUISITE VARIETY, the TENTH THEOREM OF INFORMATION THEORY.

INFRASTRUCTURE: The basic capital investment of a country or enterprise in buildings, PRODUCTION facilities, COMMUNICATION NETWORKs, institutes of LEARNING, labor force, etc. which must be taken into account to determine whether a desired DEVELOPMENT is possible, feasable or desirable.

INPUT: A VARIABLE at the boundary of an organism or MACHINE through which INFORMATION enters, the set of conditions, properties or STATEs which effect a change in a SYSTEM's BEHAVIOR, the medium of exogenous CONTROL (->OPEN SYSTEM, ->OUTPUT).

INPUT-OUTPUT ANALYSIS: A technique used in economics for tracing resources and products within an economy. The SYSTEM of producers and consumers is divided into different branches, which are defined in terms of the resources they require as INPUT's and what they produce as OUTPUTs. The quantities of input and output for a given time period, usually expressed in monetary terms, are entered into an input-output MATRIX within which one can analyse what happens within and across various sectors of an economy where GROWTH and decline takes place and what effects various subsidies may have.

INTELLIGENCE: Originally, an innate general cognitive ability underlying all of an individual's processes of complex reasoninng. Now, the dual ability to draw appropriate distinctions and to make appropriate, and to a degree better than chance, choices among the things distinguished. The first part of the process is creative (->CREATIVITY) and concerns the CONSTRUCTion of a COGNITIVE SYSTEM limited by the amount of UNCERTAINTY tolerable. The second part of the process, largely attended to by Ashby, is reductive and concerns how much INFORMATION is brought to bear on a situation, e.g., for giving the correct answer to questions on an intelligence test, for selecting a successful course of action out of all possible ones, for saying the right thing at the right moment to the right person. Culture bound intelligence tests assume predrawn distinctions, offer fixed number of alternatives and thus provide a normative measure of only the information processing ability part of intelligence. The constructive and uncertainty increasing ability part of intelligence is manifest in innovations, unCONVENTIONal perspectives, avantgarde art but also in social deviance.

INTELLIGENCE AMPLIFICATION: A process by which the power of appropriate selection is increased beyond the INTELLIGENCE of the SYSTEM which CONTROLs that process. E.g., if the programmer of a chess playing COMPUTER explicitly specifies all "good" moves, the computer can be no better than its designer. But if this computer is programmed to compute more alternatives, recalls successes and failures with increasing perfection and makes better and faster decisions than its programmer could make, then it exceeds or will soon exceed that

programmer's manifest ability to make informed DECISIONs. According to Ashby an intelligence amplifier typically involves (a) two separate systems, one that generates (->GENERATIVE) descriptions of alternative courses of action and another that selects among them those appropriate, to a degree better than CHANCE, using an externally specified criterion, (b) a circular flow of INFORMATION between the two which (c) stops when the criterion is satisfied. The intelligence thereby amplified enters a system through the exogenous choices of a criterion and through the construction of the MACHINE. The designer may not and does not need to know the full range of alternatives among which an intelligence amplifier makes appropriate choices.

INTERFACE: Originally, the connections between two pieces of electrical equipment. Now, the TELECOMUNICATION equipment, INFORMATION carriers, INPUT-OUTPUT devices and COMPUTER networks mediating between people, computers and PRODUCTION processes.

INTERNALIZATION: A LEARNING process whereby the components or SUBSYSTEMs of a SYSTEMs acquire a METASYSTEM that represents the requirements, controls, goals, values and PURPOSEs of that system and thereby relieves that system of some of its original regulatory (->REGULATION) and CONTROL burdens. E.g., the acquisition of values, norms and a conscience provides individuals with criteria for DECISION making within a social system whose use is more efficient than if such determinations would have to be made repeatedly and in large numbers by legal or governmental procedures of the larger system. Through internalization a SOCIAL SYSTEM decentralizes regulation and control by providing its members with suitable CONSTRUCTs of their environment including themselves.

INTERSUBJECTIVELY VERIFIABLE: The quality of a description that indicates its reproducability (->RELIABILITY) under varying conditions and agreement among INDEPENDENT observers concerning the meaning of that description, both established by scientific methods. Intersubjective verifiability is a weaker but more easily achievable form of objectivity (->OBJECTIVE).

INTUITION: The immediate knowing of something without the conscious use of reasoning (Webster's). There is some evidence that intuition does not proceed along analytical lines but apprehend experiences wholistically. "It is by logic that we prove, but by intuition that we discover" (Poincare).

INVARIANT: A RELATION or TRANSFORMATION which represents (->REPRESENTATION), explains (->EXPLANATION) or predicts (->PREDICTION) any unchanging (->EQUILIBRIUM) feature of a BEHAVIOR, process, grammar, CONSTRUCTion or a situation.

ISOMORPHISM: A one-to-one mapping representing a pattern in the DOMAIN of the mapping by another pattern in its RANGE without loss of INFORMATION. The product of applying an isomorphism is called an isomorph. SYSTEM that is a MODEL of another by virtue of an isomorphism offers no simplifications. This maybe useful, e.g., when one seeks an electronic substitute for a cognitive process such as the automatic pilot for an airplane. The more common simpler models, from a street map to a SIMULATION of economic processes call for HOMOMORPHISMs not isomorphisms.

ITERATION: A process for COMPUTING something by repeating a cycle of operations. Although circular and repetitive processes can be divergent, iteration should converge to the desired result (->EIGEN VALUE), improving the approximation with increasing numbers of cycles (->ALGORITHM, ->HEURISTIC).

K: A unit for expressing the capacity of MEMORY equal to 2^{10}=1024 CHARACTERs. If the characters are BINARY, one K equals 1024 BITs. But if there are N kinds of characters, (e.g., 10 numerals of the decimal system, and/or 2 x 26 upper case and lower case letters of standard English) K = 1024 $\log_2$ N BITs of storable INFORMATION. Because N is variable, K is a meaningful quantity only in the CONTEXT of the knowledge of the number of characters involved. E.g., in English word processing systems, N is determined by the keyboard of the INPUT device.

LAG: Metaphorically, trailing behind. In DEVELOPMENT, some VARIABLES may change faster than others and if they are dependent on each other these temporal differences, called Lag, can cause STRUCTURal stress within a SYSTEM. E.g., in modern society, institutional developments tend to lag behind changes in TECHNOLOGY causing many social PROBLEMS from alienations to social inequalities and conflicts. In CYBERNETICS, lag refers to the time for INFORMATION to pass through one complete FEEDBACK loop. Lag makes REGULATION difficult. E.g., if the time for a gunner to obtain information about his target plus the time for his projectile to reach its destination is large, a hit is considerably more difficult than if that lag is small. A regulator's LEAD may compensate for the LAG in a feedback loop.

LAISSEZ FAIRE: The extreme form of a market economy in which GOVERNMENT is virtually absent and the whole results from the sum total of individual self-serving acts.

LANGUAGE: A combinatorial SYSTEM for arranging CHARACTERs into words and complex expressions subject to the CONSTRAINTs of a syntax, a logic and a SEMANTICS. A syntax rules out some combinations of characters as ungrammatical and designates the others as legitmate linguistic expressions. A logic orders the legitimate expressions implicationally and informationally. A semantics relates these

expressions to the larger system of which a language is a part thus constraining the expressions according to what is appropriate in the non-linguistic CONTEXT of a situation (the larger system). The combinatorial properties of a language are responsible for the chosen expressions to carry INFORMATION relative to the expressions possible in a given context. The sharing of facilities to generate linguistic expressions (->GENERATIVE) and the ability to make comparisons within the system of possible expression brings linguistic COMMUNICATION to a logical level higher than communication without language.

LARGE NUMBERS: ->LAW OF LARGE NUMBERS

LATENT FUNCTION: -> MANIFEST/LATENT FUNCTIONS

LATTICE: A regular arrangement of points and lines with or without arrows connecting them directly or indirectly, a GRAPH systematicaly CONSTRUCTed by a RULE. E.g., the edges and corners of crystals, the ENTAILMENT structure of all expressions that can be formed by the union and intersection of a finite number of sets (Boolean lattice).

LAW: A statement, together with its qualifications, that postulates a CONSTRAINT on the conceivable observations and that is not contradicted by observations or counter examples . E.g., the conservation law in physics (->THERMODYNAMICS), and the LAW OF REQUISITE VARIETY in CYBERNETICS logically exclude what turns out to be empirically absent. Inasmuch as they exclude something , laws are CONSTRUCTions, not to be confused with observable FACTs, and are often self-referential (->GOEDEL'S THEOREM, ->SELF-REFERENCE, ->RULE).

LAW OF DIMINISHING RETURNS: An economic principle asserting that the application of additional units of any one INPUT (labor, land, capital) to fixed amounts of the other inputs yields successively smaller increments in the OUTPUT of a SYSTEM of PRODUCTION.

LAW OF GENESIS OF STRUCTURE: "Any process of COMMUNICATION among the components of a SYSTEM, once initiated and maintained with some regularity, leads to the genesis of (social) STRUCTURE (among communicators) within that system." (Krippendorff) The LAW presupposses that the individual components exhibit some regularities (e.g., conditional preferences, statistical biases in response to stimuli, rational behavior) and participate in the system for some time. The speed of structural genesis increases with the complexity of the COMMUNICATIONS, with the number of participating communicators, and with the length in time of the process. The speed decreases with the level of awareness and the number of messages controlled by each communicator. However, the law holds irrespective of whether the result is anticipated or desirable (Krippendorff)

(->SELF-ORGANIZATION).

LAW OF LARGE NUMBERS: A fundamental LAW in PROBABILITY theory and statistics stating that if an event of probability p is observed repeatedly during INDEPENDENT repetitions the proportion of the observed FREQUENCY of that event to the number of repetitions converges (->CONVERGENCE) towards p as the number of repetitions become large. The law also provides the basis for evaluating the power of statistical tests including the significance of qantities of INFORMATION.

LAW OF REQUIRED MODEL-REGULATOR IDENTITY: "Every good regulator of a SYSTEM must be or contain a MODEL of that system" (Conant-Ashby) (->REQULATION). This is a stronger version of the LAW OF REQUISITE VARIETY and posits that any regulator able to confine the fluctuations in the a system to be regulated must not only have adequate amounts of VARIETY available to CONTROL that system but also be or have a homomorphic (->HOMOMORPHISM) REPRESENTATION of that system.

LAW OF REQUISITE VARIETY: Its two interpretations are: (1) "The amount of approriate selection that can be performed is limited by the amount of INFORMATION available." More information might be wasteful but less information results in arbitrary decisions (->CHANCE). (2) To confine the VARIETY in SYSTEM with INPUT, the regulator (->REGULATION) of that system must have at least as much variety available as the variety disturbing the system through its inputs. "Only variety (in the regulator) can destroy variety (in the system being regulated)" (Ashby). The LAW OF REQUIRED MODEL-REGULATOR IDENTITY is a more general version of the law of requisite variety.

LAW OF THE EXCLUDED MIDDLE: In logic, the proposition "every proposition is either true or false" This proposition is on a logical level higher (->THEORY OF LOGICAL TYPES, ->ORDINALITY) than the propositions referred to.

LAWS OF FORM: A logical CALCULUS of distinctions and indications developed by G.S.Brown in a book by that title. The calculus is capable of representing SELF-REFERENCE and thus overcomes descriptive and theoretical limitations following Russell's THEORY OF LOGICAL TYPES.

LEAD: Metaphorically, moving ahead, often but not in CYBERNETICS, the opposite of LAG. In the CYBERNETICS of REGULATION, lead refers to the ability of a regulator to extrapolate (->PREDICTION) the BEHAVIOR of the regulated SYSTEM (beyond or ahead of available DATA) and act on that future STATE of the system which is anticipated to coincide with the arrival of the corrective action. Thus the lead may compensate for the lag involved in a FEEDBACK loop provided and to the extent that the BEHAVIOR of the regulated system is predictable.

LEARNING: A process of growing success in a fixed environment. E.g., mastering the violin, aquiring linguistic skills, increasing the accuracy of guesses, driving safer (Ackoff). Thus learning is not the same as aquiring knowledge through reception of INFORMATION even though this often preceeds manifest improvements. Learning is also different from PROBLEM SOLVING which involves making decisions of how to bridge the gap between a present and a desired STATE and ADAPTATION which implies changes in response to a changing environment not necessarily of growing success. It is only when BEHAVIOR noticeably increases the EFFICIENCY with which information is processed, desirable states are reached, errors are avoided, or a portion of the world is CONTROLled can one speak of learning. Consciousness may or may not be involved. Learning by trial and error is a process by which FEEDBACK on errors prevents unsuccessful behavior from reoccuring thus increasing success.

LIFE CYCLE: Circular regenerative processes originally in the BIOSPHERE, e.g., the carbon cycle which can be thought of as beginning and ending with atmospheric carbon dioxide and involving living organisms by processes of photosynthesis and ultimate degradation. Life cycles exist in the form of mass-energy conversions in the universe as well as in the form of the utilization (production, consumption and recycling) of resources in an economy, also called the business cycle. The circular process often leads to fluctuations or rythms, e.g., economic recession and boom accompanied by fluctuations in unemployment, capital investment, trade, etc.

LIMIT CYCLE: In a LINEAR SYSTEM (such as a vibrating string or a pendulum), if the system is displaced (the string plucked), it will start to vibrate or oscillate. However, by the SECOND LAW OF THERMODYNAMICS the system will decay to rest. In a non-linear system, e.g., a watch, a human, a working engine, supplied with a constant source of fuel or ENERGY, it is possible to obtain configurations such that if the system is started vibrating, oscillating, or running, it will continue, if the cycle thus formed operates INDEPENDENT of the precise initial starting conditions, in spite of the fact that the system is lossy and in spite of moderate disturbances that try to slow the process down or speed it up, then it is said to be a limit cycle (Iberall).

LIMIT OF ABSOLUTE DISCRIMINATION: Within one-DIMENSIONal continua, e.g., amplitude (loudness) of sound, brightness of color, humans can reliably (->RELIABILITY) distinguish, recognize or name no more than seven plus/minus two values. More and finer distinctions cause confusion, unreliability and rapidly increase transmission errors (G.Miller). This amounts to an INFORMATION processing limit for absolute judgements by humans of about 3 BITs.

LINEAR: A proportional RELATION between two quantities, e.g., in

the equation y=cx, c is the constant y/x and states that y is a linear FUNCTION of x. The term comes from the straight line with which such a function can be visualized within x-y coordinates. The notion of linearity is generalized to relations between many quantities, expressed in the form of linear equations, to a concept of time that progresses from an indefinite past to an indefinite future without parallel paths or loops, and to a causal NETWORK or LATTICE which proceeds directionally from antecedents to consequences without FEEDBACK.

LOGARITHM: A FUNCTION expressing any number by the exponent of a chosen base. E.g., with $512=2^9$, the dual logarithm (to the base 2) of 512, written $\log_2 512$ equals 9. Logarithms are used in the quantitative definition of INFORMATION and are fundamental to the algebraic properties which INFORMATION THEORY codifies. Its base of 2 assures that function's interpretation in terms of the number of BINARY DECISIONs (->BITs). Decimal logarithms have a base of 10 and natural logarithms a base of 2.71828.

LOGICAL TYPES: ->THEORY OF LOGICAL TYPES, ->ORDINALITY

MACHINE (ideal): A DETERMINISTIC and STATE-DETERMINED SYSTEM, a set of STATEs closed under a mapping (Ashby). The BEHAVIOR of an ideal machine is fully determined by knowing its TRANSFORMATION and its initial state.

MACRO-: A prefix denoting a global perspective, one that views many small phenomena as aggregates (->AGGREGATION), e.g., macroeconomics, macrolinguistics, as opposed to the concern for the phenomena being aggregated thereby (->MICRO-).

MANAGEMENT: The process of governing a country or administering an enterprise including the DEVELOPMENT of corporate strategy and longrange planning on the top and the REGULATION, COORDINATION and CONTROL of such activities as PRODUCTION, accounting, marketing, personnel, RESEARCH AND DEVELOPMENT in the middle, the supervised OPERATIONs being performed below. One key to effective management is the adequate flow of INFORMATION between and within strategic, functional and operational levels so as to allow for timely and appropriate DECISIONs to be made (->INTELLIGENCE). Management information SYSTEMs constitute a technological solution to information flow problems. Another key is the form of control exercised through spelling out OBJECTIVEs (e.g.->ALGEDONIC REGULATION) providing INCENTIVE schemes for production as well as cooperation, etc.

MANIFEST/LATENT FUNCTIONS: A distinction made within the structural-functional school of sociology referring to at least three kinds of DIMENSIONs of social BEHAVIOR. A distinction (a) between

proclaimed (manifest) and real PURPOSEs (latent) of particular acts, (b) between purposes of which the members of a society are aware (manifest) and of which these members are not aware (latent) or (c) between the effects of actions which are intended (manifest) and unintended (latent) (->EXTERNALITIES).

MARKOV CHAIN: The BEHAVIOR of an INFORMATIONally closed and GENERATIVE SYSTEM that is specified by transition probabilities (->PROBABILITY) between that system's STATEs. It is named after A.A. Markov who at the turn of the century studied poetry and other texts as stochastic sequences of CHARACTERs (SYMBOLs, letters, syllables, and words). The probabilities of a Markov chain are usually entered into a transition MATRIX indicating which state or symbol follows which other state or symbol. The order (->ORDINALITY) of a Markov chain corresponds to the number of states or symbols from which probabilities are defined to a successor. Ordinarily, Markov chains are STATE DETERMINED or of the first order. Higher orders are HISTORY DETERMINED. An unequal DISTRIBUTION of transition probabilities is a mark of a Markov chain's REDUNDANCY and a prerequisite of predictability (->INFORATION THEORY).

MATHEMATICS: Originally, the science of number and quantity. But with the birth of numerous more qualitative formalisms, (e.g., logic, propositional calculi, set theory), with the emergence of the unifying idea of a mathematical STRUCTURE, with the advent of the axiomatic method emphasising inference, proof and the descriptions of complex SYSTEMs in terms of simple axioms, and, finally, with self-reflective efforts such as META-mathematics, mathematics has become the autonomous (->AUTONOMY) science of formal CONSTRUCTions. Emphasising its formal character and its applicability to all conceivable worlds, mathematics has been likened to a LANGUAGE whose semantics is supplied by other sciences or by particular applications. Although all constructions are inventions of the human mind, cannot be found in nature and have no necessary connection with the world outside mathematics, they nevertheless arise in conjunction with solving certain kinds of PROBLEMs:(1) real world problems, (e.g., geometry evolved in efforts of measuring the earth, GAME THEORY grew out of concerns for social conflict resolution, statistics from the need to test hypotheses on large numbers of observations, recursive function theory from the desire for efficient ALGORITHMs,) (2) intellectual curiosity and playfulness, (e.g., MARKOV CHAIN theory stems from interest in poetry, PROBABILITY theory from games of chance, the four-color problem, symmetry and much of topology (see the Mobiusband) from interest in artistic expression), and (3) interest in the powers and limitations of mathematics and the mind, (e.g., Goedel's INCOMPLETENESS THEOREM from the inherent undecidability or incompleteness of SYSTEMs, the THEORY OF LOGICAL TYPES from disturbing PARADOXes, the differential and integral calculi from efforts to transcend the smallest distinctions practically possible). However, it is a characteristic of mathematics that the problems giving rise to its constructions are soon forgotten and the constructions develop a life of their own, checked only by such validity criteria as internal consistency, decidability and

completeness. Empirical DATA from an existing world do not threaten the products of mathematics.

MATRIX; A many-DIMENSIONal arrangement of numbers suitable to various TRANSFORMATIONs which form the basis of matrix algebra. A one-dimensional matrix is called a scalar. Most frequent are two-dimensional, n-by-m, matrices which might contain the coefficients (->PARAMETER) of a set of LINEAR equations or specify a mapping from an n-dimensional to a m-dimensional vector space (->HYPERSPACE).

MEASUREMENT: The process of ascertaining the attributes, DIMENSIONs, extent, quantity, degree or capacity of some object of observation and representing these in the qualitative or quantitative terms of a DATA LANGUAGE. Any empirical pursuit that places the observer outside his object of observation must consider measurement the fundamental process through which scientific CONSTRUCTs or MODELs are linked to reality (->INDEX, ->SYMPTOM). Otherwise measurement is only one section in a circular process of COMPUTING a stable form. The traditional levels of measurement are nominal, ordinal, interval and ratio scales.

MECHANISM: Derives from the use of the machine METAPHOR in sciences concerned with man and denotes any STRUCTURE or configuration of attitudes, social positions, cultural patterns, FUNCTIONs, interactions, etc. that facilitates or brings about a product or an end regardless of whether it is conciously implemented, has naturally evolved or is perceived by its participants.

MEDIA: A generic term for SYSTEMs of PRODUCTION and dissemination of INFORMATION and entertainment and of exertion of various kinds of social CONTROLs. Unlike a CHANNEL which is limited to a contiguous physical medium between the sender and a receiver of COMMUNICATIONS, media include the institutions which determine the nature, programming and form of distribution. E.g., mass media is the generic term for newspapers, book publishing, radio and television. Other media include the recording industry, movie industry and theatre. All media are associated with more or less elaborate forms of audience participation.

MEMORY: An observer's CONSTRUCT to describe a SYSTEM that appears to be HISTORY DETERMINED as a STATE DETERMINED system. It is based on the well grounded contention that past events can influence future events only if physical traces of them are somehow preserved within that system, and that history determined systems are merely incompletely observed, the forms of preservation being largely unknown. In MODELS of history determined systems, memory may be thought of as a specialized device for carrying records or accounts of the past into the present so that a system's behavior is described as a FUNCTION of both, the current STATE of the observed system and the current state of the memory. The human brain is often assigned the PURPOSE of retaining

past experiences although it does much more than that. In society, libraries tend to be attributed similar memory functions although most traditions and customs are retained elsewhere. The construct of a memory has found its most concrete application in the design of COMPUTERs.

MENTALISM: The belief that mental processes are autonomous (->AUTONOMY), can explain but not be explained by an organism's BEHAVIOR. Mentalism is opposed to BEHAVIORISM. N.Chomsky is its most recent advocate.

META-: A prefix meaning "changed in position," "beyond," "on a higher level," "transcending," etc., referring to the body of knowledge about a body of knowledge or about a field of study, e.g., metaMATHEMATICS, metaCOMMUNICATION (Walzlawick), or metaINFORMATION, i.e., information about information, which is on a logical level higher than indicated (->THEORY OF LOGICAL TYPES, ->ORDINALITY, ->META-UNCERTAINTY).

META-UNCERTAINTY: The uncertainty about the accuracy of estimating the UNCERTAINTY of a class of events. In INFORMATION THEORY, meta-uncertainty is calculated on the PROBABILITY DISTRIBUTION of possible samples drawn at RANDOM from a hypothetical universe having the same uncertainty or ENTROPY as the sample actually observed. E.g., statistical tests of the significance of a null-hypothesis involve a distribution of test results and if the latter is an uncertainty, the uncertainty associated with an uncertainty measure is meta-uncertainty. By the LAW OF LARGE NUMBERS meta-uncertainty decreases with increasing number of observations.

METAPHOR: A statement reflecting the cognitive process of linking two normally separate COGNITIVE SYSTEMs by placing CONCEPTs from one such system in the CONTEXT of another, thereby suggesting an understanding and experiencing of particular incidences of the concepts in the former system in terms of the RULEs, pattern of reasoning and ideas provided by the latter. E.g., the metaphor "love is madness" places the concept of "love" into the context of "mental disorder," entails a variety of more specific statements such as "I am crazy about her," "she is driving me wild" and makes many concepts from the domain of mental disorder available, such as "it is a healthy relationship" (Lakoff). Common metaphors in the social sciences include "society is an organism," "messages are containers for meanings," and in CYBERNETICS, "the mind is a computer." Although historically a concept of literature, metaphors account for differences in individual as well as societal BEHAVIOR, e.g., compare "war is a gamble," with "war is a religious commitment." Metaphors simplify the cognitive ORGANIZATION of MEMORY, but also contain the dangers of inappropriate reasoning (->ANALOGY, ->ANTHROPOMORPHISM).

METASYSTEM: A SYSTEM of a logical type higher (->THEORY OF LOGICAL TYPES) than a given system. A metasystem can consider criteria or decide on propositions the system of lower ORDINALITY may not be able to reflect or decide upon. So, a thermostat for the regulation of the room temperature is embedded in a metasystem involving humans being able to set a preferred temperature. The explanation of why chess players obey the RULEs of chess is not contained in the rules of chess, and requires the CONSTRUCTion of a metasystem involving human motivations, social CONTROLs and INCENTIVEs.

METHODOLOGY: A branch of the philosophy of science concerned with methods and techniques of scientific inquiry, their composition and ability to yield valid knowledge. Although "methodology" is often confused with "methods", their referents are related just as biology is related to living organisms or as sociology is related to society. The aim of methodology then is to describe and analyze not the objects or the products but the processes of scientific inquiry, to investigate the potentialities and limitations of particular techniques, to reveal their presuppositions and epistemological consequences, to suggest structural reasons for successes and failures, and to develop, test and offer generalizations about scientific procedures.

MICRO-: A prefix denoting a narrow perspective, one that is concerned with the details of small phenomena which theories of aggregates (->AGGREGATION, ->MACRO-) may summarize, e.g., microeconomics, microlinguistics, microbiology but also micro-organisms, the microscope.

MILLER'S MAGICAL NUMBER SEVEN: ->LIMIT OF ABSOLUTE DISCRIMINATION

MODE: In statistics, (a) the most probable occurance in a PROBABILITY DISTRIBUTION of possible occurances and, if the occurances are ordered, (b) the occurance that is more probable than any nearby occurance. If a distribution contains two modes by the letter definitiona it is called bimodal.

MODEL: A SYSTEM that stands for or represents another typically more comprehensive system. A model consists of a set of objects, described in terms of VARIABLES and RELATIONs defined on these and either (a) embodies a theory of that portion of reality which it claims to represent or (b) corresponds to a portion of reality by virtue of an explicit HOMOMORHISM or ISOMORPHISM between the model's PARAMETERs and given DATA. Four kinds of models are distinguished: (1) Sampling models consist of a mere subset of mutually exclusive objects from a larger universe of objects. The REPRESENTATION is based on the assurance that each object of the universe had the same PROBABILITY to be included in the sample. (2) Iconic models (->ICON) are LINEAR transforms of a configuration of objects in the universe. The representation is based on the assurance that an iconic model retains

that universe's topological characteristics. E.g., scale models, photographs, the graphical representation of networks. In (3) behavioral models, the relations are TRANSFORMATIONs, equations or operating RULEs and the representation is based on the assurance that the BEHAVIOR of the model corresponds to the behavior of the SYSTEM modelled. This is established either by identifying the model's PARAMETERS and equations, or showing that the homomorph is not violated. E.g., the computer SIMULATION of an economy, the model of a plane built into an automatic pilot. In a (4) symbolic model the set of objects are SYMBOLs and the relations are expressed in the form of algebraic, computational or algorithmic statements exhibiting no behavior of its own. Symbolic models must be realized in or coupled with a machine in order to become a behavioral model of something else. E.g., a formal statement about a social process must be translated into the algorithmic form of a PROGRAM acceptable to a computer. Sampling models represent the materiality of the reality modelled. The other three do not. Their structural, behavior or symbolic correspondence makes no reference to the physical nature of the objects represented in the model.

MODEL-REQULATOR IDENTITY: ->LAW OF REQUIRED MODEL-REGULATOR IDENTITY

MORPHOCATALYSIS: A morphogenetic (->MORPHOGENESIS) change in a SYSTEM's STRUCTURE conditioned by that system's contact or co-presence with another system, VARIABLE or event which neither causes the change in the sense of forcing an ADAPTATION nor provides instructions directing that change in the sense of an ORGANIZATIONal INPUT (->CATALYST). E.g., a family therapy in which the therapist creates a condition for a family to change its pattern of BEHAVIOR and to find a new HOMEOSTASIS (->SELF-ORGANIZATION) without either directing the process (->GOAL ORIENTED) or expressing what he prefers.

MORPHOGENESIS: A Process of creating new organizational forms. In response to changing environmental conditions morphogenesis may be adaptive (->ADAPTATION). As a consequence of POSITIVE FEEDBACK among physical VARIABLES, morphognesis may be destructive like the crack in a rock that lets water in, then roots, and ultimately breaks the rock into pieces. Morphogenesis may be radical by the realization of inventions of entirely new ideas about institutions or technologies, or it may be gradual by elaborating (refining and adding on to) existing STRUCTUREs (->GROWTH, ->DEVELOPMENT, ->ORGANIZATION, ->MORPHOSTASIS).

MORPHOLOGY: The study of the formal properties of something as opposed to its CONCRETE material, physical or BEHAVIORal manifestations. The distinction goes back to the distinction between essence and substance which ignored the fact that the essence is also described by an observer.

MORPHOSTASIS: The process of retaining a STRUCTURE, ORGANIZATION or form. Morphostasis may be actively pursued as in the goal of perfect ADAPTATION or simply characterize a STATE of structural STABILITY. E.g., in sociology, "efforts to retain the status quo" refers to morphostatic forces which admit only those changes that do not threaten existing structures. Similarly, in the REGULATION of room temperature, the wiring of a thermostat with the furnace remains unaltered while interaction achieves a CORRELATION of heating efforts and external temperature fluctuations (->MORPHOGENESIS, ->HOMEOSTASIS).

MOTIVATION: The explanation for why a certain action was chosen, e.g., ambition, curiosity, incentive, power.

MUTATION: In biology, a change in a gene or STRUCTURE or number of chromosomes. It constitutes genetic NOISE in the intergenerational transmission of GENETIC INFORMATION. In EVOLUTION, mutation is the ultimate source of inheritable VARIATION.

NEGENTROPY: A non-recommendable near synonym for INFORMATION. The term has created considerable confusion suggesting that information processes negate the SECOND LAW OF THERMODYNAMICS by producing order from chaos. The history of the confusion stems from the mere formal ANALOGY between Boltzmann's thermodynamic expression for ENTROPY $S=k \log W$ and the Shannon-Wiener expression for information $H_a = -\log_2 p_a$. The only motivation for the negative sign in the latter is that it yields positive information quantities (the LOGARITHM of a probability is always negative). The PROBABILITY p_a of an event a and the thermodynamic value W including Boltzmann's constant k measure entirely different phenomena. A meaningful interpretation of negentropy is that it measures the complexity of a physical structure in which quantitities of energy are invested, e.g., buildings, technical devices, organisms but also atomic reactor fuel, the infrastructure of a society. In this sense organisms may be said to become more complex by feeding not on energy but on negentropy (Schroedinger).

NET: Adjective indicating the "essence" of a quantity, e.g., net income, the income from which all costs to generate it are subtracted, net population GROWTH, a population's birth rate adjusted by its mortality, net ENERGY, the energy extracted minus the energy consumed in the extraction process.

NETWORK: A SYSTEM of CHANNELS, COMMUNICATION links, paths of INFORMATION flows, roads, etc., resembling a fabric or wiring diagram and describable as a GRAPH.

NOISE: Unexplained VARIATION in a communication CHANNEL, RANDOM error in the transmission of INFORMATION. Noise is not merely auditory

as in the static on radio but may also be visual as in a blurred picture. It may occur in any MEASUREMENT process where one differentiates between related and unrelated VARIANCE, the latter being noise. The analogy between noise and THERMODYNAMIC ENTROPY is suggested by the FACT that in any COMMUNICATION process, noise can only increase and it does so at the expense of the amount of information transmitted from a sender to one or more receivers. INFORMATION THEORY quantitatively decomposes the receivers' STATISTICAL ENTROPY into a quantity of transmitted information and the quantity of noise. Noise is the logical complement of EQUIVOCATION and undesirable from the receiver's perspective.

NON-DETERMINISTIC: ->POSSIBILISTIC

NON-ERGODIC: Attribute of a BEHAVIOR that is in certain crucial respects incomprehensible through observation either for lack of repetition, e.g., by involving only TRANSIENT STATES which are unique, or for lack of stabilities, e.g., when transition probabilities (->PROBABILITIES) are so variable that there are not enough observations available to ascertain them. EVOLUTION and social processes involving structural changes are inherently non-ergodic. To understand non-ergodic behavior requires either reference to the underlying ORGANIZATION of the SYSTEM exhibiting it or the study of a large sample of systems of the same kind (->ERGODIC).

NON-VERBAL COMMUNICATION: Processes of COMMUNICATION without the use of LANGUAGE proper, e.g., body movements, gesture, smells but also such extra-linguistic features of speech as intonation, speed, pause. Non-verbal communication is expressive and manifest as oppossed to being about something outside the communicator. Non-verbal communication tends to provide the CONTEXT of verbal communication and has the power to disambiguate (but also to invalidate) the content of linguistic expressions.

NOOSPHERE: A Term modelled after "atmosphere" and "BIOSPHERE" signifying (a) the space occupied by the totality of INFORMATION and human knowledge collectively available to man and (b) the processes operating in this space, e.g., combinatorial mating, classification, reproduction, simplification, selective decay.

NORM: Either (1) the most usual BEHAVIOR within a community, the modal behavior (->MODE), or (2) the ideal behavior members of a community value, or hold in high esteem. The related adjective for (1) is normal as in the normal DISTRIBUTION and for (2) it is normative and implies a value judgement. The two meanings do not imply each other.

OBJECTIVE (adjective): The quality of something to exist independent (->INDEPENDENCE) of an observer (->ONTOLOGY). In

scientific pursuits, the quality of a description that is free of potentially contaminating properties of an observer, unbiased, value free and observer independent. The search for objectivity places an observer outside the SYSTEM he attempts to describe.

OBJECTIVE (noun): Something to which an effort is directed, the goal (->GOAL ORIENTED), PURPOSE or CRITERION a decision maker uses to evaluate alternative courses of actions. The choice of objectives constrains (->CONSTRAINT) possible BEHAVIORs.

ONTOLOGY: A branch of philosophy concerned with what really exists as opposed to what appears to exist but does not. The ontology of a theory is the set of real objects or events which the theory ascribes existence to by referring to them without REFERENCE to an observer. An ontology is implied in claiming knowledge of what is.

OPEN SYSTEM: A SYSTEM with INPUT, an entity that changes its BEHAVIOR in response to conditions outside its boundaries. Systems are rarely ever either open or closed but open to some and closed to other influences (->CHANNEL). Because of their need to combat decay within, food intake makes biological organisms and societies open to matter/ENERGY from their environment. But this property says nothing about openness to information. ADAPTATION, LEARNING and all manifestations of INTELLIGENCE require some openness to INFORMATION. Unlike biological organisms, COMPUTERs and social institutions exemplify openness to ORGANIZATION which indicates that structural changes are determined from the outside. Whether or not a system has outputs does not enter the distinction between open and closed systems. Systems witout output are non-knowable by an external observer, e.g., black holes in the visible universe (->ETHER). Systems without inputs are not controllable (->CONTROL, ->CLOSED SYSTEM).

OPERATION: A basic process that applies to an operand and yields a transform, e.g., the multiplication of two numbers, driving a nail with a hammer, baking. A TRANSFORMATION describes an operation, sometimes in terms of an ALGORITHM.

OPERATIONALISM: A radical empiricist doctrine which insists that all scientific CONCEPTs must be defined in terms of actual experimental OPERATIONs, applicable in a given situation to decide whether an incident of a concept has been observed. So, time might be defined by the clock that measures it, length by the procedures required to reliably establish that number, etc.

OPERATIONS RESEARCH (in Great Britian OPERATIONAL RESEARCH): Originally, the use of quantitative techniques in the domain of DECISION making in MANAGEMENT, GOVERNMENT, industry and in the military. Now, largely overlapping with SYSTEMS ANALYSIS. It includes

among others, optimization techniques, dynamic programming, DATA ANALYSIS including statistics, decision theory, SIMULATION and planning theory.

OPTIMIZATION THEORY: A mathematical technique for determining the most profitable or least disadvantageous choice out of a set of alternatives. Typically the set of alternatives is restricted by several CONSTRAINTs on the values of a number of VARIABLEs and an OBJECTIVE FUNCTION locates the optimum in the remaining set. The method is largely used in OPERATIONS RESEARCH and SYSTEMS ANALYSIS, e.g., for optimal scheduling of production processes (->PERT), for determining the best way for transporting a certain commodity.

ORDER THROUGH FLUCTUATION : ->DISSIPATIVE STRUCTURE

OPTIMIZING: ->OPTIMIZATION THEORY

ORDINALITY: Having a certain order of complexity or being defined on a certain logical level (->THEORY OF LOGICAL TYPES). A property, being defined within one VARIABLE or set is of ordinality one. A RELATION between two entities is of ordinality two, ..., a relation with n arguments is of ordinality n. A different convention of expressing ordinality is to count: unary relation or property, BINARY relation, ternary relation, quarternary relation,..., n-ary relation. A SYSTEM within n variables contains up to $n!/(m!(n-m)!)$ relations of ordinality m, $m<n$. The larger the number of a system's variables the higher its potential ordinality. The higher its actual ordinality the more complex a system is (->STRUCTURE, ->ORGANIZATION).

ORGANIZATION: Has at least three meanings (1) The act of arranging components to form a pattern different from what would occur by chance, by some CRITERION or better than it was before (->COORDINATION) e.g., conducting a political campaign; (2) A complex complementary conditionality in BEHAVIOR or in the coexistence of physical or living components (Ashby) as in an ecological system or in such social organizations as a family, a university or a government agency being constituted by its members through CONVENTIONal RULEs of conduct, legally recognized and interacted with by observers or by other social organizations; (3) The relations, and processes of COMMUNICATION, including coordination and COORIENTATION among the components or VARIABLES of a SYSTEM that (a) determine the DYNAMICs of interaction and TRANSFORMATIONs it may undergo in a physical space and (b) constitute (->CONSTITUTION) its UNITY whether only for an observer (->ALLOPOIESIS) or also for itself (->AUTOPOIESIS). In this third and largely cybernetic meaning, the properties of the components that realize a system as a CONCRETE physical entity do not enter the description of that system's organization. It follows that machines, organisms and social forms of vastly different materiality and components may have the same organization. Accordingly, a WHOLE system

may be explained in terms of the properties of its components and its organization (->ANALYSIS). The use to which a particular system may be put or who created it in the first place is not a feature of its organization. A theory of design (including engineering), management and of (concrete) organizational behavior is concerned with (1). A theory of organizations concerns (2) and attempts to provide generalizations about how cells, or organisms interact or how and why people work together and form larger unities (->GENERAL SYSTEMS THEORY). CYBERNETICS is concerned and has in fact been considered coextensive with an organization theory which concerns (3) and attempts to provide theories of or a logic for how unities and whole systems can arise or be maintained through the forms of communication (and more complex kinds of interactions and interdependencies) among components without reference to their materiality. The theory of modelling is a direct outgrowth of this organization concept. Like cybernetics generally, an organization theory is not disturbed by the possibility that some organizations may not be realized by man or by nature but it will be informed by the finding that they cannot exist (Ashby).

OROBORUS: The medieval SYMBOL of HOLISM depicting a snake that bites its own tail. Cyberneticians have used oroboroi to illustrate their interest in circularity and wholes. Varela's CALCULUS of SELF-REFERENCE employs an abstract oroborus as sign for self-reference.

OUTPUT: A VARIABLE at the boundary of an organism or machine through which INFORMATION exits. The products, results or the observable parts (->SUBSYSTEM) of a SYSTEM's BEHAVIOR (->ALLOPOIESIS). The medium through which a system may exogenously CONTROL others. The record left behind by a system of its own behavior. An output could conceivably include all of a system's behaviors, but it becomes an informative concept only if some of its variables remain inaccessable to an observer or have no effect. E.g., a COMPUTER prints or displays only the final results of a lengthy COMPUTATION thus invoking the distinction between output and internal (intermediate and inaccessible) variables. Human cognitive processes remain similarly hidden from view and are therefore distinct from the primary verbal, manual and gestural output of man. Here, output is the overt manifestation of human (including cognitive and hormonal) behavior.

PARADIGM: The pattern underlying the process of constructing theories and explanations and thereby affecting the form of the body of knowledge within a social domain, e.g., within 18th century science. Paradigms carry their own source of justification and are therefore less obviously related to or challenged by empirical evidence. Kuhn describes the history of science as a succession of paradigms, transitions resulting not only from the emergence of empirical phenomena an existing paradigm is unable to explain but also from socio-political interests within the scientific community.

PARADOX: From the Greek para + dokein, to think more,

conventionally, an argument that apparently derives self-contradictory conclusions by valid deductions from acceptable premises (Webster's). More generally, any description or situation that is compelling enough to lead an observer into a vicious cycle involving mutually exclusive interpretations, indications or acts, force him to step out of or transcend the cycle and to CONSTRUCT a logically more powerful (->ORDINALITY) COGNITIVE SYSTEM within which the vicious cycle has disappeared. E.g., "This sentence is false" is false when it is assumed to be true and true when it is assumed to be false. The resolution of this vicious cycle requires a logic that accepts SELF-REFERENCE which the propositional calculus does not. Paradoxes appear not only in logic but also in interpersonal COMMUNICATION, e.g., DOUBLE-BIND, in social ORGANIZATION and might be the stimulus for MORPHOGENESIS.

PARAMETER: That what distinguishes between systems of the same ORGANIZATION. The INPUT to a SYSTEM which determines its mode of OPERATION and thus defines what kind it it. In modelling, a value, usually a coefficient in an equation, that can be made to vary across different MODELs with otherwise similar STRUCTURE or across different SIMULATIONs by the same model but is constant in each application. The choice of parameters allows an experimenter to fit the model to a given situation.

PATHOLOGY: The systematic study of the STRUCTURE and ORGANIZATION of SYSTEMs that make some of its VARIABLEs depart from NORMality. Originally restricted to health and bodily function, e.g., illness in medicine, it is now extended to include psychological and social processes as well, e.g., speech disturbances, DOUBLE BINDs and other COMMUNICATION disorders, families with self-recognized problems, perpetual poverty in society.

PERCEPTION: Alternatively, (1) an observer's awareness or appreciation of objects, processes or situations in his environment mediated through his sensory organs, and (2) an observer's descriptions, hypotheses or CONSTRUCTs of the world of which he becomes thereby a part.

PERCEPTRON: A mechanical device developed in the 1950's by Rosenblatt for deciding (->DECISION) among, and to a limited degree for the RECOGNITION and LEARNING of patterns which are defined by RELATIONs among a multitude of stimuli in its INPUT.

PERFORMANCE: ->COMPETENCE and PERFORMANCE

PERIODICITY: A measure indicating the time or number of OPERATIONs after which a process repeats itself (->ITERATION).

PERT: An acronym of Program, Evaluation and Review Technique denoting a form of NETWORK ANALYSIS in which the duration of processes required to complete a complex task or project is used to calculate the range of possible completion times and to aid informed DECISIONs on the scheduling of these processes.

PHENOTYPE: The overt features of living organisms including the interactions between them and their environments as identifiable by an observer. The phenotype of an organism is contrasted with its GENOTYPE on grounds that the former concerns its CONCRETE physical existance in an observer's DOMAIN whereas the latter concerns the genetic make-up which that organism inherited and which accounted for its EMBRYOGENESIS and DEVELOPMENT.

PLANNING: (1) the process of generating (->GENERATIVE) descriptions of alternative courses of action and the deciding (->DECISION) among these before engaging in any of the actions described. (2) The process of allocating resources and scheduling processes so as to direct the future BEHAVIOR or DEVELOPMENT of a SYSTEM. Planning is always selective among the possible futures of a SYSTEM incorporating this activity and is therefore behaviorally manifest.

POLITICS: Processes involving STRUCTURal changes in a PUBLIC, e.g., the formation of cliques, coalitions and elites that compete for scarce resources in the public DOMAIN including for the CONTROL of GOVERNMENT, and processes through which collective DECISIONs come about as a consequence of COMMUNICATION among competing factions and individual interests in society.

POLLUTION: Originally, impurity in relation to morals and religion, now material ENTROPY, the dispersion of unusable particles of matter in an usable material resource, e.g., air pollution, chemical waste in rivers. It is generally costly and often impossible to separate the pollutants from the resource and an increase in pollution therefore decreases the usefulness of the resource.

POLYSTABILITY: A STABILITY involving many alternative and sometimes only temporary equilibria (->EQUILIBRIUM) and is characteristic of SYSTEMs involving many weakly interacting components. When systems are joined to form larger WHOLEs, COMMUNICATION among them tends to have the effect of disturbing each other's individual equilibria. The equilibrium of the whole is not merely selective of and may not even coincide with the equilibria of its parts. Polystable systems may come to a temporary rest which disturbs some of its parts and forces the system to another temporary rest, etc., until it reaches a final and often DYNAMIC equilibrium. E.g., an economy can typically operate at different configurations of unemployment, GNP, capital investements, etc., and is hence polystable with each major participant

trying to move it away from what they consider less advantageous individually.

POPULATION: Generally, a collection of individuals with common characteristics. In statistics, a potentially infinite collection of independent (->INDEPENDENCE) units that include all units of a specified type with attention paid only to the agggregate (->AGGREGATION) property of the collection. A sample of DATA drawn from this population is a subset of the units constituting this population and scientific generalizations from such samples are limited by the size of the population originally specified (->MODEL, ->REPRESENTATION).

POSSIBILSTIC: Attribute of SYSTEMs whose BEHAVIOR includes options without specification of probabilities (->PROBABILITY) within that system. In contrast to DETERMINISTIC systems, possibilistic systems leave some UNCERTAINTY in the specification of future STATEs and BEHAVIOR, even if all relevant conditions are known. Possibilistic systems are also called NON-DETERMINISTIC.

PREDICTION: Literally knowing something outside the range of an observer's experiences. Minimally, prediction is a mere extrapolation of given DATA into the future (forecasting) or into the past (retrodiction) (->ESTIMATION). It is usually justified by reference to general theories or MODELs which serve as the basis for drawing inferences from available data to phenomena outside their range. Thus, predictions are the conclusions drawn from the premise of available data using theories and models as a kind of syllogistic device (->SIMULATION).

PREFERENCE: An ordering of alternatives according to likes and dislikes, generally without requiring explanations as to why. Consistent preference orderings are all transitive (e.g., if A>B and B>C then A>C). Inconsistent preference orderings contain circularities (e.g., A>B, B>C and C>A).

PRINCIPLE OF LEAST EFFORT: The proposition that an adaptive SYSTEM will try either adapt to its environment or adapt that environment to its needs, whichever is easier (Umpleby) (->ADAPTATION).

PRINCIPLE OF RELATIVITY: "A CONSTRUCTion that holds for two observers separately should hold for both" and must be rejected otherwise. E.g., Earthlings and Venusians may be consistent in claiming to be the center of the universe, but their claims fall to pieces if they should ever get together. SOLIPSISM is similarly not maintainable when an observer invents another autonomous (->AUTONOMY, ->AUTOPOIESIS) organism besides himself. The principle is neither logically necessary nor provable. In rejecting it, an observer is the

center of the universe and COMMUNICATION is essentially monologue. In accepting it an observer becomes part of a larger SYSTEM constituted by his RELATIONs with others (after v.Foerster). The principle leads to epistemological (->EPISTEMOLOGY) CONSTRUCTIVISM.

PROBABILISTIC: Attribute of NON-DETERMINISTIC SYSTEMs whose transitions between STATEs follow known or ascertainable probabilities (->PROBABILITY). The ERGODIC BEHAVIOR of probabilistic systems is describable as a MARKOV CHAIN.

PROBABILITY: A number between and inclusive of zero and one indicating the likelihood of an event. Two kinds of probabilities are distinguished. (1) The logical interpretation of probability indicates how easy it would be to select one designated or preferred alternative out of a given set of possible alternatives (->DEGREE OF FREEDOM). (2) The freqency interpretation of probability indicates how often a particular event is observed relative to all observed events. Whereas (1) is concerned with possibilities and makes no references to actual observations, (2) is concerned only with what was observed, not with what could be but wasn't. Despite the fundamental differences between the two, both conform to the same LAWs of probability theory. Let M be a set of elements (possibilities or observations). With 0 as the empty set. The probabilities of subsets A of M range between:

$$0 < P(A) < 1$$

For any set A and its complement A in M:

$$P(A \text{ and not } A) = P(0)=0$$
$$P(A \text{ or not } A) = P(M)=1$$

and for mutually exclusive sets A_i:

$$P(A_1 \text{ or } A_2 \text{ or...}) = P(A_1) + P(A_2) +...$$

the space of possibilities on the one side and the sample size of observations on the other assure that probabilities add up to 1.

PROBLEM: Literally, something thrown foreward (in time). Specifically, a cognitive inSTABILITY or disposition which demands of an organism that something be done to change its current BEHAVIOR or that it away from an existing undesirious and problematic STATE. Problems need not be caused by disturbances from the organisms environment (->ADAPTATION) but may also be the product of cognition itself, particularily when the brain is complex and self-organizing (->SELF-ORGANIZATION, ->PROBLEM-FORMULATION, ->PROBLEM-SOLVING).

PROBLEM-FORMULATION: An activity aimed at identifying (->IDENTIFICATION) a problem by specifying (a) the undesirious and problematic state currently occupied, (b) the resources currently

available to move away from that problematic state, particularly the available courses of actions, the combinatorial CONSTRAINTs on using them, etc., and (c) the criteria that need to be satisfied to say that a problem no longer exists or is solved. This activity defines the cognitive gap between what is and what is desirable and deliniates the resources for closing it. Problem formulation is the creative and probably the more important step towards overcoming a problematic state than PROBLEM-SOLVING (->INTELLIGENCE). A good definition of what the problem is is believed to be more than half of the way towards its eventual elimination.

PROBLEM-SOLVING: An activity aimed at closing the cognitive gap en route to a goal by employing acts or processes neither immediately nor obviously suitable towards this end. Problem solving has been studied in psychology in the form of puzzles, overcoming obstacles and inventing CONSTRUCTs or devices. Problem solving underlines nearly all means-ends DECISIONs whether in GOVERNMENT, the MANAGEMENT of enterprises or the design of equipment in engineering. The contemporary emphasis on finding technological solutions to human PROBLEMs is the principal motor for the GROWTH of TECHNOLOGY but also the principal source of ecological disequilibria (->EQUILIBRIUM, ->ECOLOGY) and of many human problems and social instabilities (->STABILITY).

PRODUCTION: Any process of synthesis, TRANSFORMATION or destruction realized in a space of interacting components that results not merely in the emission of signals or arrangement of CHARACTERS, but as in a computer or a clockwork in material entities which are capable of interacting with other entities possibly including with the components that produced them. (->AUTOPOIESIS, ->ALLOPOIESIS)

PROGRAM: A list of statements or instructions in a special purpose programming LANGUAGE that directs a COMPUTER to undertake a certain COMPUTING task (->ALGORITHM). Programs are needed because modern computers are essentially general purpose MACHINEs whose STRUCTURE must be specified from the outside.

PROGRAMMED INSTRUCTION: A technique for presenting a subject matter to a student who can work through it at his own learning speed. It consists of a NETWORK of statements and tests, which direct the student to new statements depending on his pattern of errors.

PROGRESS: A change of not necessarily toward some VARIABLE or the movement of a SYSTEM in a desired direction, not towards a specifice future goal but along a path of increasing value (->EMBRYOGENESIS, ->DEVELOPMENT, ->GROWTH).

PUBLIC: A SYSTEM involving individuals whose COMMUNICATIONS have

no specific receiver and are (ideally) accessable to all members of a community or society, e.g., a public debate, the mass MEDIA (to the extent it reflects public opinion and sentiments).

PUNCTUATION: The particular characterization of a process as a succession of states (->BEHAVIOR). As is true for all descriptions, punctuations are observer dependent. So the sequence ...abababa... can be variously described as a repetition of "ab" or as a repetition of "ba." Such a difference becomes significant in RELATIONs between individuals or between nations where it matters a great deal whether an event is taken to be an action or a response, e.g., whether a husband withdraws because the wife nags or the wife nags because a husband withdraws. Differences in punctuation underly many COMMUNICATION pathologies (->PATHOLOGY), and many international CONFLICTs.

PURPOSE: The attribute of a UNITY indicating that it might be used to further someone's aims. Purpose is not an inherent FUNCTION of the STRUCTURE or ORGANIZATION of that unity. But the property of a SYSTEM involving that unity and some user which converges towards an EQUILIBRIUM (->GOAL ORIENTED), maintains a steady state (->HOMEOSTASIS), survives certain threats from its surroundings (->ADAPTION), etc. E.g., the purpose of a hammer is for a craftsman to drive nails into something, the purpose of a computer is to solve someone's PROBLEM.

RADIATION: The dissipation of ENERGY from a source into its surroundings by the emission of waves or particles.

RADICAL: Literally, finding the roots (source or origin) of something.

RAM = Random Acess Memory: A MEMORY from which INFORMATION can be recalled selectively by the use of appropriate addresses or pointers to its storage location.

RANDOM: Attribute of a process that is entirely or largely governed by CHANCE, e.g., a roulette wheel, dice, the BROWNIAN MOVEMENT, but also the pattern on the screen of a television set receiving atmospheric NOISE only. Perfect randomness rarely exists in nature and is difficult to simulate. In practice, randomness is confined by particular PARAMETERs, e.g., a roulette wheel is expected to be random only within a range of numbers, not regarding how long the wheel takes to pick one, and it may even deviate from the ideal of uniform probabilities (->PROBABILITY), e.g., when the roulett wheel is biased. The SIMULATION of randomness by COMPUTERs utilizes so-called pseudo random generators whose BEHAVIOR is nearly impossible to predict without knowledge of the starting number and its ALGORITHM (->GENERATIVE).

RANGE of a TRANSFORMATION: The set of STATEs onto which transitions are defined or the transforms of an OPERATION.

REALIZATION: The PRODUCTION of an object or SYSTEM according to specific instructions, plans or PROGRAMs (->INFORMATION), e.g., building a house according to blueprints, replicating a scientific experiment published previously, cooking by recipe, realizing an artistic idea.

RECOGNITION: Literally, knowing again. Here, (a) an EQUIVOCATION of signals or messags sent at different times, (b) an equivalence relation established by an observer between a current observation and a class of previous observations, (c) the representation of a current state, condition or property by terms previously used for representing similar states, conditions or properties. Pattern recognition involves the application of DECISION procedures to determine whether two patterns are the same, different or of what kind each is. From an observer's perspective (b) is accomplished by the use of identical terms or names for categories as in (c). The definitions differ merely in emphasis on the consequence or the process of PERCEPTION respectively.

RECONSTRUCTABILITY: Property of a SYSTEM whose MODEL is composed of simpler parts. In reconstructability analysis, the analyst obtains DATA from a system to be analysed for its reconstructability, he hypothesises a GENERATIVE model and compares the data obtained from both. If the artificial data match those actually observed or if their difference is statistically insignificant, he is justified in saying that the STRUCTURally simpler model explains, accounts for, simulates (->SIMULATION), replicates or reconstructs the system which gave rise to the original data. The idea stems from Ashby's CONSTRAINT ANALYSIS. Klir is associated with its formalization and name.

RECURSION or RECURSIVENESS: The attribute of a PROGRAM or RULE which can be applied on its results indefinitely often. E.g., in linguistics the rule which introduces an adjective before a noun. Unlike in ITERATION, recursion need not converge towards a state. It rather tends to make a STRUCTURE grow.

RECYCLING: Feeding the waste material of one process of PRODUCTION into the same or another process so as to make further use of it. Cycles exist only if initially distributed matter is condensed and used again for the original PURPOSEs. Such circular flows of matter are rarely ever closed, ultimately yielding unusable POLLUTION.

REDUCTIONISM: The practice of reducing CONCEPTs, hypotheses or

theories that apply to one type of entity to concepts, hypotheses or theories of another, espistemologically more basic kind. E.g., Socio-biology seeks to explain social events in biological terms and biophysics seeks to understand biological phenomena with the instrumentarium of physics. More subtle is the use by some political scientist of psychological CONSTRUCTs, such as personality, in the description of nations (->ATOMISM).

REDUNDANCY: The VARIETY in a CHANNEL that exceeds the amount of INFORMATION actually transmitted. Its most common forms: (1) repetitive transmission of the same message over one channel, (2) duplication of channels, of which each could handle the transmission by itself, (3) restrictions on the use of CHARACTERs or on the combinations of characters from an ALPHABET to form proper words or expressions (->LANGUAGE), (4) communicating something already known to its addressee. In the process of COMMUNICATION redundancy is essential to combat NOISE, to assure RELIABILITY and to maintain a communication channel. English writing is estimated to be 50% redundant which accounts for the ability of native speakers to detect and correct typing errors. Parity checks, which are common in communication within COMPUTERs, enhance reliability but only at the expense of using additional channel capacity. The amount of information actually transmitted is not increased by this device. Similarly, Indian GOVERNMENTs of the Mogul period are known to have used at least 3 parallel reporting channels to survey their provinces with some degree of reliability, notwithstanding the additional efforts.

REFERENT: Something pointed to or singled out for attention, a designated object, real or imaginary or any class of such objects.

REGULATION: Any systematic (RULE-like or determinate) BEHAVIOR of one part of a SYSTEM that tends to restrict the fluctuations in behavior of another part of that system. While both parts must lie in the same FEEDBACK loop, regulation involves this basic asymmetry: the regulator detects and responds to discrepancies from some expectation (->CRITERION, ->GOAL), which is of an ORDINALITY higher than the behavior so assessed, and it computes (->COMPUTING) the actions appropriate to keep the behavior to be regulated within desirable limits. The regulated part merely responds to the source of fluctuations and to the regulating actions without INFORMATION about the regulator's expectations. The behavior of the regulator is often hard-wired, as in a thermostat, or rule-like, as in a bureaucracy. Regulation does not imply LEARNING, ADAPTATION (->ULTRA-STABILITY, ->CONTROL) or intelligence.

REIFICATION: The process of regarding something abstract as a material entity, Whitehead's "fallacy of misplaced concreteness," e.g., the mistake of confusing a SYSTEM, which is a CONSTRUCT, with the physical entity described in its terms (->GENERAL SYSTEMS THEORY). In

SOCIAL SYSTEMs reification is encouraged by the use of LANGUAGE and underlies many proceses of constructing social reality.

RELATION: (1) A statement with one or more ARGUMENTs implying a CONSTRAINT among coocurring values of these arguments. E.g., a mathematical FUNCTION such as the LOGARITHM, an ordering such as "is greater than" or "causes," a statement of association such as "is married to," a correspondence, a CODE. Equivialently (2), a subset of elements of a CARTESIAN PRODUCT set (Wiener). When that subset contains observed or permissible coocurrences, its complement in the same product set is called a CONSTRAINT and contains conceivable coocurrances that did not occur or are excluded. Relations are of different ORDINALITY. Unary relations or properties are of order one. BINARY relations are of order two, etc. Relations may be combined to form new relations, e.g., the simple ternary relation of "off-spring" which relates a father, a mother and a child can be used recursively (->RECURSION) to generate a whole family tree. More than one relation may be defined in the same Cartesian product set as the relations "talked to," "is married to" "exchanged goods with" all of which are subsets of the product of two sets of people.

RELATIVITY: ->PRINCIPLE OF RELATIVITY

REPRODUCTION: ->COPYING, ->SELF-REPRODUCTION

RELIABILITY: Generally, invulnerability to potentially corrupting influences. Specifically: (a) stability in the face of component failure or partial destruction, e.g., in case of death of a U.S. president a predestined successor is assigned presidential powers; when a flat worm is cut both pieces grow the missing parts, head or tail; when a highway is repaired the other routes take over the traffic. (b) stability in the presence of NOISE (->COMMUNICATION, ->REDUNDANCY), e.g., reliable measurements are expected to be replicable in varying circumstances yielding the same results. In the social sciences much effort is spent to avoid measuring artifacts and observer biases all of which reduce the reliable transmission of DATA or FACTs.

REPLICATION: Repetitive production of unities (->UNITY) that occupy different physical spaces but share the same ORGANIZATION. Replication implies neither an original unity (->COPYING) nor that the SYSTEM replicating these unities bears a resemblance to them (->SELF-REPRODUCTION).

REPRESENTATION: If something stands in place of or is chosen to substitute for something else, the former is considered a representation of the latter. E.g., representation of constituencies in GOVERNMENT, linguistic representation of an event (->SYMBOL). The

belief that all knowledge is a representation of the properties of the real world is as unacceptable as the insistence that all descriptions or messages are about something else.

REQUISITE VARIETY: ->LAW OF REQUISITE VARIETY

RESEARCH AND DEVELOPMENT (R&D): The practical application of scientific and engineering knowledge for enhancing TECHNOLOGY, military developments, MANAGEMENT techniques and social practices.

RESPONSIBILITY: Accountability of an individual for DECISIONs and BEHAVIOR under his CONTROL by virtue of his PUBLIC role, office, charge or duty and to the public which endowed him with that role, office, charge or duty. Responsibility is CONSTITUTIONally embedded within an autonomous (->AUTONOMY) SYSTEM, e.g., in the public.

REWRITE RULES: RULEs which apply to a string of CHARACTERs and replace some of these characters by another string. Chomsky's proposal for linguistics entailed that a grammer be described in terms of a FINITE number of rewrite rules capable of generating (->GENERATIVE) all and only gramatical sentences of a given LANGUAGE.

RISK: The PROBABILITY of failure. In DECISION making under UNCERTAINTY, risk analysis aims at minimising the failure to achieve a desired result, particularly when that result is influenced by factors not entirely under the decision maker's CONTROL (->GAME THEORY).

RITUAL: A MECHANISM existing within a social SYSTEM that (a) engages a set of individual members in coordinated and complementary activities which are (b) cognized by these members in terms of purpose, often supernatural, ideological or ritual but have (c) certain regulatory consequences in the sense of affecting or keeping constant variables within or outside (in the ENVIRONMENT of) that social system. Sometimes cognizised purposes and regulatory consequences are the same, as may be the case in technical discourses among experts, but mostly it is not. For example the Maring in New Guinea fear illness caused by the spirits who do not like people to reside in the lower areas whereas the lower area is in fact infected with malaria carrying mosquitoes.

RNA: Ribonucleic Acid ->GENETIC INFORMATION

ROBOT: Derived from the Czech word for work, a MACHINE built to resemble a human in BEHAVIOR, INTELLIGENCE and sometimes also in appearance. Successful robots tend to be limited to particular FUNCTIONs, like automatic pilots for routine flights of an airplane or machines on an assembly line replacing human operators.

ROM = Read Only Memory: A MEMORY, particularly in small COMPUTERS, from which INFORMATION is recalled in the same (or the reverse) order in which it was entered, e.g., from the left to right, line by line like removing beads from a necklace or in terms of whole chips. Random access is not possible (->RAM).

RULE: A statement specifying what is permissible under given circumstances. E.g., the rules of chess spell out how a piece can move, the rules of grammar state which linguistic TRANSFORMATIONs (e.g., from active into passive sentence construction) are possible (->REWRITE RULES). Unlike LAWs, which are inevitably deterministic rules tend to leave a user, whether he be a chess player or a native speaker, alternatives and specify CONSTRAINTs within which he may chose. Rules do not imply obligation to act. The search for rules rather than laws distinguishes two schools in COMMUNICATION research, the CYBERNETICS of observing SYSTEMs from the cybernetics of observed systems and perhaps the social sciences from the natural sciences.

RUNAWAY: The increasing loss of stability in a SYSTEM with unCONTROLed DEVIATION AMPLIFYING FEEDBACK, e.g., an armsrace, the GROWTH of cancer,

SATISFICING: By evaluating all possible alternatives, the COMPUTATION of an optimum STRATEGY (->OPTIMIZATION THEORY) may not be feasable when the number of alternatives is very large (->COMBINATORIAL EXPLOSION). E.g., in chess, the number of available plays exceeds computational limits not just for humans (->BREMERMANN'S LIMIT). A DECISION maker who settles for a less amibitious result and obtains the optimum he can compute under given time or resource CONSTRAINTs is said to satisfice.

SECOND-ORDER CYBERNETICS: The CYBERNETICS of SYSTEMs involving their observers as opposed to the cybernetics of systems that are observed from the outside (v.Foerster). Second-order cybernetics is a more recent development, involves the observer as a constituitive (->CONSTITUTION) part of a circular ORGANIZATION and is concerned with SELF-REFERENCE, EPISTEMOLOGY, AUTONOMY, self-GOVERNMENT, AUTOPOIESIS to name just a few phenomena.

SECOND LAW OF THERMODYNAMICS: The LAW of the necessary degradation of ENERGY or the ENTROPY LAW (->THERMODYNAMICS).

SELECTIVE INFORMATION: ->INFORMATION

SELF-CORRECTING CODE: ->ERROR CORRECTING CODE

SELF-DEFINITION: ->CONSTITUTION

SELF-DESCRIPTION: A self-referential (->SELF-REFERENCE) statement or proposition about an observer's identity which is stable under iterative (->ITERATION) COMMUNICATION between him and his environment.

SELF-FULFILLING HYPOTHESIS: An initially provisionary statement that guides a scientist's effort to observe, to set up experiments and to collect DATA, all of which are more likely to lend support to rather than reject the statement, thereby making it more true than it would have been had that effort not been so guided. Self-fulfilling hypotheses are known in the social sciences since the recognition of the HAWTHORNE EFFECT but are difficult to identify since the hypothesis' CONTROL of the observer's actions is largely unconcious and often denied (->SELF-REFERENCE, ->SELF-FULFILLING PROPHESY).

SELF-FULFILLING PROPHESY: A forecast (->PREDICTION) which, by the very FACT that it is stated, has the effect of bringing about what it claims and thereby making it more "true" than it would have been without publication. The implicit SELF-REFERENCE includes the acts of individuals who believe in the TRUTH of the prophesy and are capable of either influencing or interpreting the course of events in the prophesy's DOMAIN. The self-referential loop is rarely cognized by the believer. Besides many religious examples, such as miraculous healings, many phenomena, such as ethnic prejudices, teacher's evaluation of student's capabilities, etc. are largely self-fulfilling in this sense (->SELF-FULFILLING HYPOTHESIS).

SELF-ORGANIZATION: Attribute of a SYSTEM that changes its internal ORGANIZATION on its own account, neither in response to conditions in another system with which it may interact (->ADAPTATION, ULTRA-STABILITY) nor as a consequence of its membership in a larger METASYSTEM (->CONTROL, ->ALGEDONIC REGULATION). Self-organizing systems can only be explained from within and are in this regard autonomous (->CLOSED SYSTEM, ->AUTONOMY).

SELF-PRODUCTION: ->AUTOPOIESIS

SELF-REFERENCE: In the CONTEXT of LANGUAGE, a statement that refers to itself or contains its own referent (->REFRENCE). Self-referential statements may be redundant, e.g., "this is an English sentence," in the sense that the statement informs (->INFORMATION) what a speaker of the English language already presumes in order to interprete it (->REDUNDANCY). They may also be manifestly false or contradictory, e.g., "this is a French sentence" or "this sentence contains four words." Self-referential statements may also be

paradoxical, e.g., "this sentence is false." Paradoxical self-reference is said to exhibit a vicious cycle (->PARADOX). In the more general sense, self-reference is involved in a description which refers to something that affects, CONTROLs or has the power to modify the form or the validity of that description. The circularity which the statement implies involves non-linguistic contexts as well. E.g., a SELF-FULFILLING PROPHESY, DOUBLE BIND, the description of a SYSTEM by an observer who is part of the system observed, the cognitive ORGANIZATION of biological organisms. In this general sense, self-reference establishes a circularity that may involve not only referential but also causal, interpersonal or instrumental RELATIONs and thereby constitute (->CONSTITUTION) a UNITY of its own.

SELF-REGULATION: ->HOMEOSTASIS.

SELF-REPRODUCTION: The PRODUCTION of a UNITY with an ORGANIZATION similar to that which produced it, each occupying different physical spaces, e.g., the production of biological offsprings. Inasmuch as organisms produce offsprings, whose materiality differs from that of their parent organism, a better term would be self-COPYING.

SELF-SIMILARITY: A geometrical resemblance or physical correspondence between the parts of a SYSTEM and the system as a WHOLE. For example, each part of a hollographic image represents INFORMATION about the whole so that a significant portion of that image may be lost with only insignificant loss of the information provided by that whole. In fractal geometry, the composition of wholes and of the parts participating in such wholes follow the same principles of construction except on a smaller scale. The magnification of a fractal universe apparently reveals nothing new yet this universe generates extremely complex forms.

SEMANTICS: Variously located in logic, linguistics, philosophy and COMMUNICATION research, the study of how and what a sign, SYMBOL, message or SYSTEM means to an observer. For some, semantics is that branch of semiotics (the study of human BEHAVIOR in the process of communication) which is concerned with the relationship between signs and REFERENTs or with the CONSTRAINT imposed by non-linguistic phenomena on choices among linguistic expressions.

SERVOMECHANISM: An engineering term for an automatically operating device for the REGULATION of a SYSTEM's VARIABLE(s) actuated by the difference between the actual and a desired value of such a variable (->FEEDBACK).

SHANNON'S TENTH THEOREM: ->TENTH THEOREM OF INFORMATION THEORY

SIMULATION: An unobtrusive scientific method of inquiry involving experiments with a MODEL rather than with the portion of reality this model represents (->REPRESENTATION). Simulation is unobtrusive because it does not disturb the object of inquiry (except perhaps when an actor applies its results). Inasmuch as all INFORMATION provided by a simulation is already contained in the model, simulation is useful primarily when the model is no longer tractable by algebraical techniques. This becomes particularly important with large numbers of equations built into the model, with large numbers of parts interacting within the model, with large numbers of paths that need to be traced simultaneously and with large numbers of iterations required to approximate the results.

SOCIAL ENTROPY: A measure of the natural decay of the STRUCTURE or of the disappearance of distinctions within a SOCIAL SYSTEM. Much of the ENERGY consummed by a social organization is spent to maintain its structure, counteracting social entropy, e.g., through legal institutions, education, the normative consequences of television. ANOMIE is the maximum state of social entropy.

SOCIAL MOBILITY: The movement of individuals, families or groups within a social space constituted by status, occupation, income and similar VARIABLEs through which members of a society may be described.

SOCIAL SYSTEM: In CYBERNETICS, a SYSTEM involving its observers. Such a system is constituted (->CONSTITUTION) by COMMUNICATION among observers who participate within that system by drawing distinctions and creating RELATIONS within it (->ANALYSIS, ->SECOND-ORDER CYBERNETICS). This contrasts sharply with the use of the same term in the structural-functional school of sociology, where it denotes a pattern of social acts in pursuit of individual and collective goals and governed by the need of the "social system" to maintain its own STRUCTURE.

SOCIALIZATION: A mutually adaptive process (->ADAPTATION) which is realized (->REALIZATIION) in interaction among members of a social group and results in the elimination of individual BEHAVIORs of which the group collectively disapproves. (Not to be confused with INTERNALIZATION which effects conformity through SYMBOLic means).

SOFTWARE: The PROGRAMs and instructions required to operate a COMPUTER as opposed to HARDWARE which refers to the machine itself.

SOLIPSISM: The theory that locates reality entirely in the mind of the beholder. It specifically denies the existence of involuntary experiences with an outside world be it through direct PERCEPTION of something or through vicarious experiences created in the process of COMMUNICATION. For contrast see EPISTEMOLOGY and CONSTRUCTIVISM in

CYBERNETICS.

STABILITY: A property of a SYSTEM's BEHAVIOR when its EQUILIBRIUM is disturbed. Equilibria may be unstable, neutral or stable. An illustration of the three types is provided by a ball respectively balanced on a ridge, placed on a flat and level surface and in a concave hole. The three types differ in response to displacements. An unstable equilibrium requires hardly any disturbance to be lost, typically forever, e.g., the state of a volatile fluid, the beginning of a competitive game, equality among human interactors. A neutral equilibrium is arbitrary or non-preferential, whereas a stable equilibrium is such that a system returns to it after the displacing disturbance is removed. E.g., In wartime, civil liberties, PRODUCTION of consumer goods and COMMUNICATIONS may be restricted only to be restored after hostilities cease. This marks a stable equilibrium. However, if these restrictions persist despite the absence of war this would indicate that the equilibrium was neutral. Equilibria are stable only relative to the magnitude of the disturbance. If a disturbance exceeds the threshold of a stable equilibrium, it may bring the system to another (unstable, neutral or stable) equilibrium (->POLYSTABILITY, ->ULTRASTABILITY). ADAPTATION is a higher form of stability in which a stable equilibrium is maintained or regained in the face of disturbances that attempt or temporarily displace the equilibrium.

STATE: Any well defined condition or property which can be recognized if it occurs again (Ashby) (->RECOGNITION). States may be described in terms of the set of instantaneous values of all the VARIABLEs of the SYSTEM (Klir). States are mutually exclusive. Sequential machines occupy only one state at a time, others may have more than one (->COMPUTERS).

STATE DETERMINED: An attribute of SYSTEMs whose BEHAVIOR is specified, can be predicted or understood, from the STATE it occupies currently. In contrast to HISTORY DETERMINED systems, state determined systems can be described in terms of transitions from states at one point in time to states at the next point in time, e.g., as first-order MARKOV CHAINs. Looking further back into the history of such a system does not add to understanding or predictability.

STATISTICAL ENTROPY: A measure of VARIATION or diversity defined on the PROBABILITY DISTRIBUTION of observed events. Specifically, if p_a is the probability of an event a, the ENTROPY H(A) for all events a in A is:

$$H(A) = -SUM_a \; p_a \log_2 p_a$$

The quantity is zero when all events are of the same kind, $p_a = 1$ for any one a of A and is positive otherwise. Its upper limit is $\log_2 N$ where N is the number of categories available (->DEGREES OF FREEDOM) and the distribution is uniform over these, $p_a = 1/N$ for all a of A

(->VARIETY, ->UNCERTAINTY, ->NEGENTROPY). The statistical entropy measure is the most basic measure of INFORMATION THEORY.

STOCHASTIC PROCESS: A process of change governed by probabilities (->PROBABILITY) at each step. E.g., flipping a coin, epidemic expansion, mass traffic flow, the BROWNIAN MOVEMENT, RANDOM walk, SOCIAL MOBILITY. For such, and a great many other phenomena, stochastic processes provide suitable MODELs.

STRATEGY: Originally contrasted with "tactics," now the detailed description of a method for deciding among plans that cover all conceivable contingencies (->DECISION, ->GAME THEORY).

STRUCTURE: There are at least three near synonymous definitions. (1) The complex of concurrent RELATIONS among a set of objects with the number of objects more numerous than the ORDINALITY of the relations connecting them, e.g. a GRAPH, a NETWORK. (2) A multitude of coocurrances of values, n-tuples, that deviate from CHANCE in some but not all respects. Here structure is manifest in the PROBABILTIY DISTRIBUTION that a SYSTEM with a structure as defined in (1) is capable of generating. (3) A pattern that connects the components of a MACHINE or organism, e.g., the command structure of a military unit ->(3), the distribution of obligations and responsibilities in a formal organization ->(2), the wiring in a piece of electronic equipment ->(1). The components which are connected within a CONCRETE SYSTEM, machine, organism or SOCIETY, enter the description of that system's structure but not that system's ORGANIZATION.

SUBSYSTEM: Part of a larger SYSTEM and defined within a subset of VARIABLEs of that larger system. Subsystems may be delineated by an observer but they may also maintain their own identity and boundary (->AUTOPOIESIS) independent of the distinctions drawn by an observer. Subsystems may overlap in some variables and give rise to a STRUCTURE representing interdependencies, e.g., between an economy, the educational system and GOVERNMENT as three subsystems of society.

SUPERSYSTEM: The larger SYSTEM that contains the system of interest within a subset of its VARIABLEs. It provides the CONTEXT of a system. System and supersystem as well as SUBSYSTEM and system are related by a part-whole RELATION. A supersystem must not be confused with a METASYSTEM which is about a system, represents or refers to or operates on a logical level (->THEORY OF LOGICAL TYPES, ->ORDINALITY) higher than the latter.

SURVIVAL: The continuance of a SYSTEM's ORGANIZATION after the circumstances in which it originated or which could have caused its destruction have passed. In EVOLUTION, the process of natural selection is the ultimate DECISION maker for whether something survives

or disintegrats into its components. To survive, a system must not possess disadvantageous or non-viable characteristics (which does not imply survival of the fittest, a common misconception).

SYMBIOTIC: Attribute of a complementary RELATION between two essentially different SYSTEMs in which both benefit from that dependency (contrasted with a COMMENSAL relation).

SYMBOL: A sign that informs by CONVENTION. Symbols need not have a REFERENT as in ceremonies and rituals. When they do have a referent, its connection with the sign is not one of necessity.

SYMPTOM: An INDEX used largely in medicine to identify a PATHOLOGY.

SYNCHRONIC: Attribute of descriptions or of theories that focus on the static aspects of a SYSTEM's STRUCTURE or ORGANIZATION as opposed to DIACHRONIC descriptions.

SYNCHRONICITY: Jung's term for an acausal connection between events that renders them meaningful to an observer, e.g., precognition, coincidences of dreams with independently (->INDEPENDENCE) occuring events, the frequent coocurrance of particular numerals within a short time period of a longer sequence.

SYNERGY: It derives from the holist (->HOLISM) conviction that the WHOLE is more than the sum of its parts and, because the ENERGY in a whole cannot exceed the sume of the energies invested in each of its parts (->FIRST LAW OF THERMODYNAMICS), that there must therefore be some quanitity with respect to which the whole differs from the mere aggregate (->AGGREGATION). This quantity is called synergy. In practice, synergy is mostly a negative quantity owing to the fact that all complex organisms consume energy merely for maintaining its own STRUCTURE. More loosely, synergy refers to the benefits of collaborative as opposed to individual efforts.

SYSTEM: (1) A set of VARIABLEs selected by an observer (Ashby) together with the CONSTRAINTs across variables he either discovers, hypothesises or prefers. Inasmuch as the variables of a system may represent (->REPRESENTATION) the components of a complex MACHINE, an organism or a social institution and a constraint is the logical complement of a RELATION, an equivalent definition of system is that (2) it represents a set of components together with the relations connecting them to form a WHOLE UNITY. Unlike in GENERAL SYSTEMS THEORY, in CYBERNETICS, a system is an observer's CONSTRUCT. If it describes, simulates or predicts a portion of his environment, it may be regarded as a MODEL of that portion (->RECONSTRUCTABILITY). The

model and the modelled "world" share the same ORGANIZATION but because of their different material REALIZATIONs they are likely to differ in STRUCTURE. Cybernetics starts with investigating all possible systems and then inquires why certain systems are not materially realized, or it asks why certain conceivable BEHAVIORs are not followed. Systems neither exist independent of an observer nor imply a PURPOSE.

SYSTEMS ANALYSIS: The diagnosis, formulation, and solution of PROBLEMs that arise out of the complex forms of interaction in SYSTEMs, from hardware to corporations, that exist or are conceived to accomplish one or more specific OBJECTIVEs. Systems analysis provides a variety of analytical tools, design methods and evaluative techniques to aid in DECISION making regarding such systems.

TEACHING: Any process that facilitiates LEARNING how to learn or deuterolearning (Bateson).

TECHNOLOGICAL DETERMINISM: The belief that TECHNOLOGY develops (->DEVELOPMENT) by its own LAWs, that it realizes its own potential, limited only by the material resources available, and must therefore be regarded as an autonomous (->AUTONOMY) SYSTEM CONTROLling and ultimately permeating all other SUBSYSTEMs of society. Evidence for the first proposition is largely taken from the natural history of technology, its PROGRESSive character and the coocurance of independent (->INDEPENDENCE) inventions. Evidence for the second proposition stems from the unwarranted generalization that everything that is invented is ultimately installed and ignores human playfulness, individual and collective interests and man's cognitive limitations. The conclusion is nevertheless supported by the FACT that technology has indeed penetrated all spheres of human existence from interpersonal COMMUNICATION, to definitions of the quality of life in technological terms.

TECHNOLOGY: The body of knowledge about, and the systematic study of, methods, techniques and hardware applied in the ADAPTATION of the physical environment to man's needs and wants. The application of scientific knowledge to build or improve the INFRASTRUCTURE of agriculture, industry government and daily life. (Technology must not be confused with the very infrastructure it generates). Technology has AUTOCATALYTIC properties. It favores the use of technical devices and processes even in solving social problems, e.g., by using fertilizers to enhance agricultural production rather than a different form of work ORGANIZATION, by using COMPUTERs for national planning rather than decentralized DECISION making processes.

TELEOLOGY: Originally, the study of ends, goals and PURPOSEs. In CYBERNETICS, the STRUCTURal and ORGANIZATIONal conditions for SYSTEMs to exhibit purposeful BEHAVIOR, reach goals (->GOAL ORIENTED), maintain steady states (->HOMEOSTASIS), survive threats from their environments

(->EVOLUTION, ->ADAPTION), etc.

TENTH THEOREM OF INFORMATION THEORY: "With the addition of a correction CHANNEL equal to or exceeding in capacity the amount of NOISE in the original channel, it is possible to so encode (->ENCODING) the correction DATA sent over this channel that all but an arbitrarily small fraction of the errors contributing to the noise are corrected. This is not possible if the capacity of the correction channel is less than the noise" (->REDUNDANCY). This theorem is an isomorph of the LAW OF REQUISITE VARIETY.

TEXT: Literally, the original written or printed form of a literary work considered as the authoritative source of interpretations. In CYBERNETICS, DATA with an inherent pattern, STRUCTURE or ORGANIZATION through which the meanings are revealed (->CONTEXT).

THEORY OF LOGICAL TYPES: A theory proposed by B.Russell that rules out SELF-REFERENCE in order to prevent the emergence of antinomies and PARADOXes in logic. It states that a class is of a logical type higher (->ORDINALITY) than its members and, because logical types must not be confused, no class can contain itself as a member. E.g., the LAW OF THE EXCLUDED MIDDLE which states that propositions can be either true or false is a proposition and should therefore be either true or false. But because it can only be true (else it would not be a LAW), it defies its own claim. Russell's solution is that the law is a proposition about propositions and must not be confused with the propositions to which it refers (->META-). According to the theory, self-referential statements are neither true nor false but meaningless. The theory has been influential in linguistics by recognizing the importance of logical as well as grammatical restrictions on the combinations of words (->LANGUAGE). It provided support on attacks on logical positivism, especially on its verification principle and has inspired inquiries into COMMUNICATION pathologies that arise from the confusion among logical types, e.g., of content and relationship aspects of COMMUNICATIONS (->DOUBLE BIND). However, by exorcising self-reference, the theory of logical types has retarded the development of theory, largely cognitive theory, in areas where self-reference is prevalent. With its focus on circularity CYBERNETICS has transcended the theory and essentially solved the problems self-reference originally posed.

THERMODYNAMIC ENTROPY: The quantity of ENERGY no longer available to do physical work. Every real process converts energy into both work or a condensed form of energy and waste. Some waste may be utilized in processes other than those generating it (->RECYCLING) but the ultimate waste which can no longer support any process is energy in the form of dispersed heat (->SECOND LAW OF THERMODYNAMICS). All physical processes, despite any local and temporal concentration of energy they may achieve, contribute to the increased overall dispersion of heat.

Entropy therefore irreversibly increases in the known universe.

THERMODYNAMICS: That branch of physics which is concerned with the storage, TRANSFORMATION and dissipation of ENERGY (including the flow of heat from which the term is derived). Its first LAW, or the conservation law, states that energy can neither be created nor destroyed. This law provides the basis for all quantitative accounts of energy, regardless of its form, and makes energy the most important concept in physics. Its second law, or the ENTROPY law, states that in all processes some of the energy involved irreversibly looses its ability to do work and is degraded in quality. The latter is called THERMODYNAMIC ENTROPY whose extreme form is dispersed heat and manifested in a uniform temperature distribution. Another statement of this second law is that in any process entropy never decreases. The irreversibility of physical processes implicit in this law makes the entropy law probably the most important law in understanding terrestrial processes including living organisms and social forms. The third law of thermodynamics, or the asymptotic law, states that all processes slow down as they operate closer to the thermodynamic equilibrium making it difficult to reach that equilibrium in practice. This law suggests that the powerful and fast changes which are typical of TECHNOLOGY and characteristic of living forms of organization are bound to occur only at levels far removed from thermodynamic equilibrium.

THIRD LAW OF THERODYNAMICS: The law of asymptotic decelleration (->THERMODYNAMICS).

TOLERANCE: One SYSTEM's non-reactivity to a range of INPUTs which would normally elicit responses in other systems of the same kind (->EQUIVOCATION).

TRANSCENDENCE: Being beyond the reach or apprehension of experience. Its opposite is immanence (Kant). A state of transcendence indicates that a COGNITIVE SYSTEM is not powerful enough (->THEORY OF LOGICAL TYPES) to cope with or represent the INFORMATION present, e.g., the experience of PARADOX.

TRANSDUCTION: A process embodied in an INPUT-OUTPUT device for converting or CODING without MEMORY one type of signal, motion, wave or sequence of CHARACTERs into another. E.g., a loudspeaker produces sound waves from electrical oscillations, the human eye converts patterns of light into nerve impulses. Such devices are called transducers and are describable by a TRANSFORMATION or FUNCTION.

TRANSFORMATION: A set of transitions (Ashby) from the possible STATEs of a SYSTEM to their respective successors. In whatever LANGUAGE a transformation is stated, it should spell out the set of

operands or states to which the transformation applies (->DOMAIN) and the set of transforms which result from applying that transformation (->RANGE). A mathematical FUNCTION, e.g., y=f(x), is one form of transformation, a CODE, a transition matrix, a causal network, a Petri-graph and a set of REWRITE RULES are others.

TRANSIENT STATES: That set of a SYSTEM's STATEs which cannot be occupied again when that system reaches one of its EQUILIBRIUM STATES. BEHAVIOR involving transient states is basically irreversable, e.g., processes of EVOLUTION, biological GROWTH but also social and technological DEVELOPMENT. Behavior involving transient states is also NON-ERGODIC.

TRANSLATION: A CODE whose DOMAIN and RANGE consists of expressions of different LANGAUGEs (rather than of the unordered CHARACTERs of an ALPHABET) and whose aim is to bring INFORMATION equivalent expressions into correspondence. Translation usually focuses only on some, but not all, VARIABLEs of information, e.g., poetic equivalences, semantic equivalences, pragmatic equivalences.

TRUTH: A property implicitly ascribed to a proposition by belief in or assertion of it. The denial is "falsity." The verification theory of truth identifies it with a correspondence between the proposition and the events, properties or objects to which it refers (->REFERENCE) linguistically or operationally. The logical theory of truth identifies it with the coherence between that proposition and other propositions. The constructivist theory of truth identifies it with constructability (->CONSTRUCTIVISM) implying the absence of PARADOX and contradiction.

ULTRASTABILITY: The ability of a SYSTEM to change its internal ORGANIZATION or STRUCTURE in response to environmental conditions that threaten to disturb a desired BEHAVIOR or value of an essential VARIABLE. The changes such systems are capable of are qualitative in the sense of changing the mode of interaction with an environment in steps or jumps, not along a continuum, and they are purposeful because such systems seek a behavior that is disturbance defying. Ultrastability is stability of a logical level higher than the STABILITY to which a system converges without change of its internal organization or structure. Ashby's HOMEOSTAT was the first mechanical demonstration of this form of stability heretofore reserved to living organisms (->MORPHOGENESIS).

UNCERTAINTY: The (average) number of binary DECISIONs a decision maker has to make in order to select one out of a set of mutually exclusive alternatives, a measure of an observer's ignorance or lack of INFORMATION (->BIT). Since the categories within which events are observed are always specified by an observer, the notion of uncertainty emphasises the cognitive dimension of information processes,

specifically in the form of measures of VARIETY, STATISTICAL ENTROPY including NOISE and EQUIVOCATION.

UNCERTAINTY PRINCIPLE: A principle in quantum physics, formulated by Heisenberg: "It is impossible to simultaneously measure the position and the momentum of atomic particles with an arbitrary degree of accuracy." The principle recognizes the FACT that, on the atomic level, any measuring process involves ENERGY which by necessity interferes with the energy measured. BREMERMANN'S LIMIT on the amount of INFORMATION a material SYSTEM can process is an outgrowth of this principle. A less quantifiable uncertainty principle exists in the social sciences: "Any interaction between an observer and the observed changes both. The more an observer probes, the more difficult it is for him to obtain INFORMATION about the initial STATE of what he observes and the more are his observations contaminated by his own efforts" (->SELF-REFERENCE).

UNITY: Something distinguished against its background by an observer who considers it a WHOLE entity. Something describable as whole without the need to describe it in interaction with its environment (->INDEPENDENCE, ->FIGURE-GROUND).

UTILITY: Usefulness. Value. An attribute denoting the capacity to satisfy human desires, usually measured by the price someone is willing to pay. Marginal utility is the change in utility due to a one-unit change in the quantity consumed.

VARIABILITY: An attribute indicating the ability to vary or to take different STATEs. SYSTEMs are usually limited in variability and these limits are experienced or expressed either in terms of a CONSTRAINT on their VARIETY or in terms of the range of possible values between extremes (->DEGREE OF FREEDOM, ->UNCERTAINTY).

VARIABLE: Anything able to vary but taking no more than one value at a time: (1) A SYMBOL that stands for a class of two or more mutually exclusive alternatives (values, STATE descriptions, categories, qualities, ..), (2) Something that retains its own identity while capable of changing its state. Whereas (1) stresses its conceptual notion, e.g., temperature, frequency, SYSTEM, (2) stresses it material REALIZATION, e.g., in the form of a thermometer, a counter, a machine. An object measured or described in terms of several variables is represented by one and only one value in each variable, which is equivalent to occupying a point in a multi-DIMENSIONal space constituted by these variables.

VARIATION: An aggregate (->AGGREGATION) measure of a PROBABILITY DISTRIBUTION of observed events. Variation is small when probabilities are large and confined to few alternatives, ideally one. Variation is

large when probabilities are small and distributed over a great number of alternatives. STATISTICAL ENTROPY is a measure of variation. "Variation" is the qualitative analogue of "variance" as used in the statistics of ordered (interval scale) VARIABLEs.

VARIETY: That aggregate (->AGGREGATION) property of a set, collection or VARIABLE indicating the number of mutually exclusive alternatives available within it. Variety may be expressed either by the simple number of distinct elements (->DEGREE OF FREEDOM) or by the dual LOGARITHM thereof (->UNCERTAINTY, ->BIT).

WHOLE: Without recognition of its parts a whole is an essentially structureless and unanalysable UNITY. If its parts are INDEPENDENT or RANDOMly sampled by an observer, a whole has no outstanding quality RERother than that of being an observer's aggregate (->AGGREGATION). If a whole is qualitatively different from a mere aggregate of its parts, the difference lies in its STRUCTURE or ORGANIZATION. Thus any whole may be understood as, described in terms of, and considered equal to a structure or an organization of component parts (->GESTALT, ->HOLISM, ->SYSTEM). In some cases the properties of its parts may be ignored without appreciable loss of understanding a whole, particularly when parts are numerous, simple and the same as in the objects of COMPUTER SCIENCEs, MACRO-economics, and quantum physics all of which heavily rely on MATHEMATICS for their CONSTRUCTions. When the parts are few, complex, different, and tenuously related, as in a marriage, the properties of the parts figure more prominentally in the undertanding of a whole and can not be ignored in favor of such wholes' organization.

ZIPF'S LAW: In any culture, social group or organism, SYMBOLic repertoiries, like words consisting of a finite string of CHARACTERs, either are or converge toward a type/token DISTRIBUTION in which shorter symbols appear more frequent than longer symbols. E.g., compare the frequency of the word "do" with that of "symbol" and with that of "salubrious" in ordinary English. Considering that the length of a string of characters is an indication of the computational effort involved, the LAW suggests that in any SYSTEM of some complexity symbolic repertories are or converge toward a distribution of minimum INFORMATION processing efforts.