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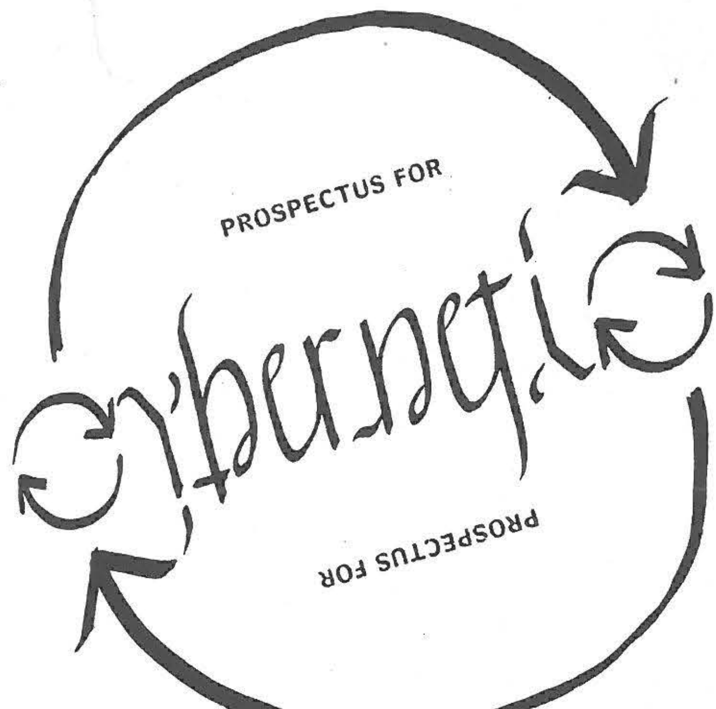

The magazine that is described in this prospectus would revive an interdisciplinary approach to science given the name cybernetics more than 40 years ago. It is an approach that appeared almost to have expired in recent decades, with the increasing specialization of disciplines, but whose vitality is becoming apparent again in many fields. The prospectus, itself a product of extensive interdisciplinary exchanges, is written in two parts.

I. A NEW FORM OF MAGAZINE. The first section gives a brief overview, describing the basic character and approach of the magazine, the background and original concepts of cybernetics, the topics for early issues of the magazine, and the editorial policy guiding its operation.

II. CYBERNETICS, COMPUTERS AND COGNITIVE SCIENCES. The second part of the prospectus gives a broader reassessment of cybernetic concepts as a framework for current developments in the sciences and in society, especially with respect to the study of computers and cognition.

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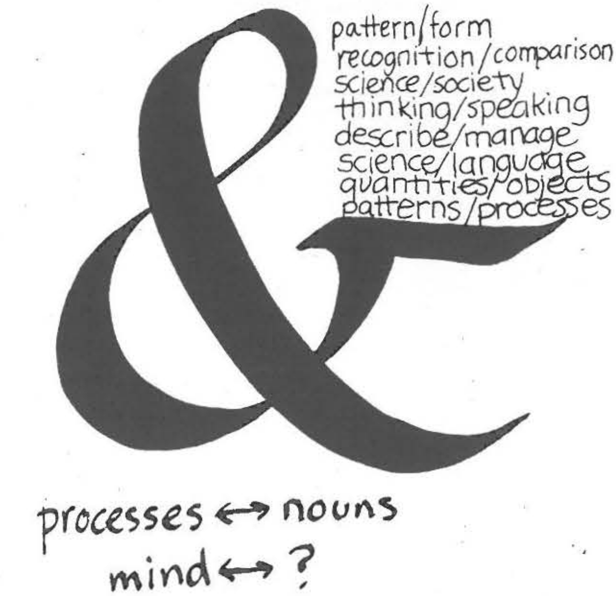
I. A NEW FORM OF MAGAZINE

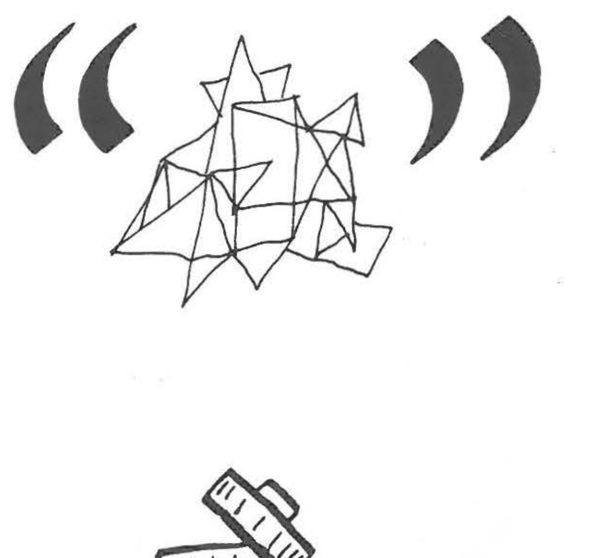
CYBERNETIC is a new form of magazine, to be published by the American Society for Cybernetics in cooperation with the Smithsonian Institution; more precisely, it is a magazine in formation but not yet information.



It is a magazine about pattern and form, about pattern recognition and the comparison of related forms. And it will address a critical issue in contemporary science and society; i.e., that our ways of thinking and speaking about the changes we perceive, and our models of how change occurs, are frequently not rich enough to describe and manage the complexity of the world we experience.

Our science, and language, seem better fitted for understanding quantities and objects, than for accounting for patterns and processes. The tendency, in our language, to identify dynamic processes with nouns, as if they were objects, contributes to this problem (for example, when we use the word "mind", we cannot point to any corresponding object; but the noun implies that there is one, which tends to obscure the nature of mental processes). William Blake addressed this type of confusion in his poetic dictum: "May God us keep, From Single vision and Newton's sleep."

A cybernetic approach to complexity has many roots and many possible descriptions; but a few brief quotes, from different points of view, may serve as an epigraph, setting forth the style of the new magazine.



William Kingdom Clifford, a 19th Century mathematician, turned to art for an image of mind as a process: "Just as a sculptor clears away from a block of marble now this piece and now that, making every time a separation between what is to be kept and what is to be chipped off, till at last all these chippings manifest the connection that ran through them, and the finished statue stands out as a complete whole, a positive thing made up of contradictory negations; so is a conception formed in the mind."

The morphologist D'Arcy Thompson urged a similar design principle on fellow biologists early in this century: "We must learn from the mathematician to eliminate and discard; to keep the type in mind and leave the single case, with all its accidents, alone."

And the early cybernetician and psychiatrist, Ross Ashby, put these ideas into an aphorism: "Pattern recognition is a throwing away of information. Any Device that can lose information can generalize." CYBERNETIC is designed to be such a device: a magazine that assists its readers in losing information.

The Meaning of "Information"

For example, readers are invited to lose the noun "information" (as in "bits" of information that can be "processed", "stored", and "retrieved") and replace it with the concept of informing, a cognitive activity. At present, a semantic confusion about information is perpetuated in terms like information processing, information society, information technology, and information revolution. This confusion can be traced back to World War II when Norbert Wiener, Claude Shannon and their colleagues, studying the reliability of signal processing systems used to transmit commands, were formulating information theory. They developed an expression equating the uncertainty removed from a system with the information gained; but, while they could measure the probabilities of the symbols to be transmitted, they did not make a critical distinction between these signals and the behavior of the recipient.

information
↓
informing

Since, in a wartime context, the command *is* the information because it is to be obeyed, if a recipient had thumbed his nose at the system, it might have been obvious that the "information" was in his understanding, not in the signals. In the context of an emerging information society, it is necessary to have a language and a logic that make this semantic distinction apparent, and that bring out the implications of treating information as commodity rather than as a cognitive process. If language obscures what we mean by "information", we may not know what kind of society we are making.

Getting Control of Language

A language of quantities cannot reveal the patterns of change, Gregory Bateson warned. "What we need is a language of relations and not a language of 'its'. We should get language into a place where we can use it, and not be steered by it."

its
↓
relations

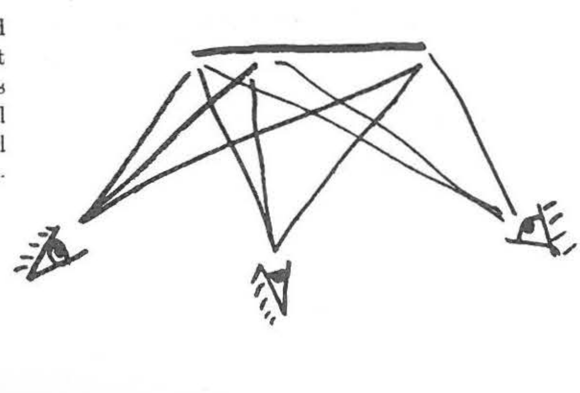
CYBERNETIC is designed to bring forward the original issues of cybernetics that arose in connection with the language of observing, describing and explaining purposeful systems (e.g., systems that can observe their own behavior). Observing a system that is observing itself entails a nesting of problems of self-reference that language may obscure; e.g., the purpose *of* a system, the purpose *for* it, and the purpose *of observing* it. Such distinctions become useful when the purpose of observing is to see the relationship between instructions and the embodiments of those instructions, or goals and the achievement of those goals. To this end, the magazine will embody an original notion of cybernetics: circular causality.

reason
↓
purpose

↻ circular causality

The First Issues of CYBERNETIC

The first issues of CYBERNETIC are in preparation, and are devoted to topics that can be viewed from different perspectives in the sciences, humanities and arts. This prospectus will form the spine of the first issue, augmented by the work of contributing designers, artists, poets, and scientists: informal reports on new research taking direc-



tions described in the prospectus will range from work on computers, the nervous system and cognition, to the fields of animation, music synthesis, multivalued logic, and disorders of language.

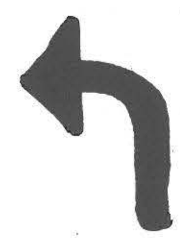
Future issues will include:

The Conversation Theory of Gordon Pask: including an account of Pask's machines and methods, and his theory's relevance to decision theory, expert systems, artificial intelligence, computer-aided learning, and the understanding of language.

"My own criteria are unashamedly aesthetic," Pask observes. "Conversation Theory (or any equivalent rival) sets the arid particularity of traditional studies into a more beautiful context. Either it transforms the meaning of 'scientific activity,' or (as you prefer it), ushers in an age when 'science' subsumes art and politics, without degrading either personality or the quality of creative action."

The Translation of Poetry and Problems in Semantic Computing: including a transcript of a conference of poets, linguists, critics, and computer scientists; with metacommentaries from researchers in fields of semantic computing and knowledge representation.

"Poetry," one critic has observed, "is what gets out of the translation." The problems that arise in mapping of meaning from one natural language to another throw light on the nature of language, and on attempts to develop computers with an ability to "understand" natural language.



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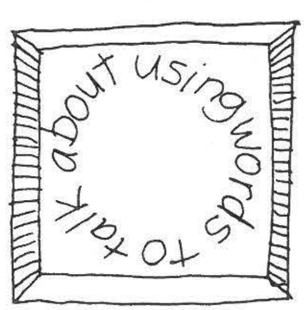
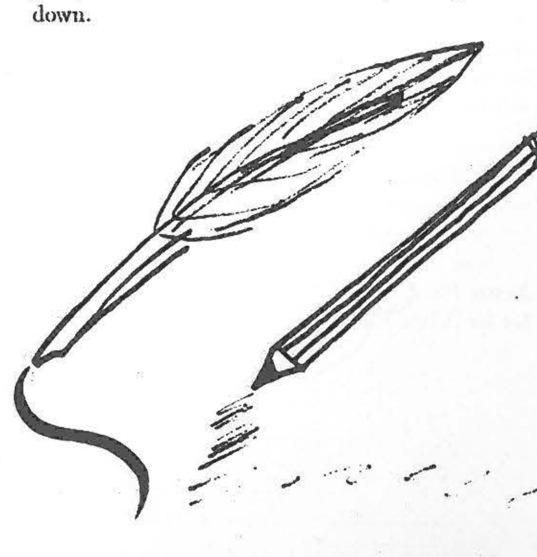
Visual Language Issue: an overview of the full range of visual symbol systems, including the written word, scientific diagrams, informal sketches, interactive computer graphics, subway maps, mathematical notation, and musical scores.



Sometimes the written word is not the best way to communicate an idea. For instance, words can *talk about* circularity, but they cannot *be* circular, at least not within conventional typography. Unfortunately, we often use words to talk about the limitations of using words, and thus end up writing in circles. The visual language issue will gain perspective on the written word by seeing where it breaks down.

New Perspectives and the Scientific Method. "Discoveries," Ramon y Cajal observed, "are largely a function of the method used." This issue will include contributions from scientists in many disciplines on the evolution of the "scientific method" and current models that account for observers and what they observe; with metacommentaries from the humanities and arts. A complementary section on "new perspectives and the artistic method" will explore other methods of discovery, with metacommentaries from the sciences.



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Editorial Policy

CYBERNETIC will be an occasional publication, becoming quarterly as the level of financing permits. Sometimes, tape will augment print to present new ideas in music, interviews and conversations among contributors. Throughout the past year, correspondents and critics from disciplines as diverse as computer science, linguistics, neurobiology, history, anthropology, architecture and design, and management (Appendix A) have actively contributed to drafting this prospectus—an interdisciplinary process that will continue in making the magazine.

CYBER
THE MA

In this process, the definitions of editor and reader are not the conventional ones. An editor's function is usually to obscure the processes of thought, correction and revision underlying the finished product that is published. However, in making CYBERNETIC a self-referential magazine in style and substance, form and content, the editors view their function as exposing the processes by which understandings develop and are arrived at, in order to stimulate differences that lead to continuing conversation, rather than agreements that end the discussion. As participants in this process, the readers can be defined, not as observers of what is published, but as the editors of the editors.

change to clarify

The editors adopt as their standard the expression of Ludwig Wittgenstein: "What can be said at all can be said clearly..."

The Role of Visual Language

In the quest for clarity, CYBERNETIC will draw on new concepts in visual language, adapting and applying research in computer graphics, animation, visual mathematics, and related fields of design science, as well as conceptual and cybernetic art. Designers are ordinarily brought into the magazine process to illustrate and decorate the already completed text. Magazines which are primarily concerned with design ideas frequently reverse the process, and are aimed at design professionals. CYBERNETIC has, from its inception, grown out of conversations that included designers and visual thinkers in different fields, and its pages will reflect a continuing interaction of contributors, editors and designers. Many of the problems addressed in the magazine present difficulties in visualizing complex relations in systems of more than two or three dimensions. The search for better visual representations of complex information will be a major goal of the magazine.

CYBERNETIC

TEXT decoration

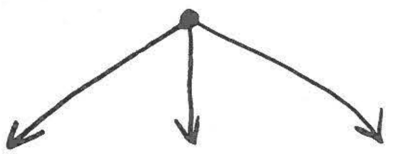
3D

Among the editors and contributors will be representatives of graphics laboratories concerned with extracting new information from raw visual data, as well as with new forms of display for what is already known (e.g., graphics labs at the JPL, Los Alamos, Lawrence Laboratories, Xerox Parc, MIT's Visual Language Workshop and Center for Advanced Visual Studies, Harvard's Design Science

show MIT picture

Group, Stanford's Digital Typography and visual thinking groups, and many other centers and individuals concerned with forms of visual language.

What we intend is to develop a language that may be useful to a wide range of readers in understanding each other's problems. Visual language will be an indispensable aspect of this process. In dealing with complexity, designer Aaron Marcus notes much of what we want to understand is represented in the form of networks, in systems of nodes and links, and in higher levels of nodes and links about these nodes and links. "The problem of creating images of networks" Marcus observes, "is a fundamental visible language problem which hasn't been solved. We can't keep communicating it all through words because the relationships are too complex, and we may not have names for those relationships." A similar formulation of this problem was offered by the 18th Century Swiss botanist, Albrecht von Haller: "Nature knits up her kinds in networks rather than chains, but we follow her in chains because our language can't handle more than one thing at a time." The editors see the design of CYBERNETIC as a part of this problem and hope to make it a part of the solution.



II. CYBERNETICS, COMPUTERS AND COGNITIVE SCIENCES

A History of Schisms and Reconvergence

In recent years, cybernetics has not been widely perceived as a solution to anything, and the field has seemed to lack its original coherence and purpose. Those who describe themselves as cyberneticians will come up with different definitions of what the discipline means to them; indeed, rarely has a word meant so many things to so few people. Why, then, should cybernetics be the appropriate core concept, and this new magazine an effective heuristic device, for making connections among the sciences and other disciplines in a society that sometimes feels threatened by its scientific achievements? The editors believe that the answer lies in the history of the split between cybernetics and those disciplines concerned with computers and cognitive processes that branched off from a cybernetic background. What was lost in these schisms was what Gregory Bateson called "the pattern which connects."

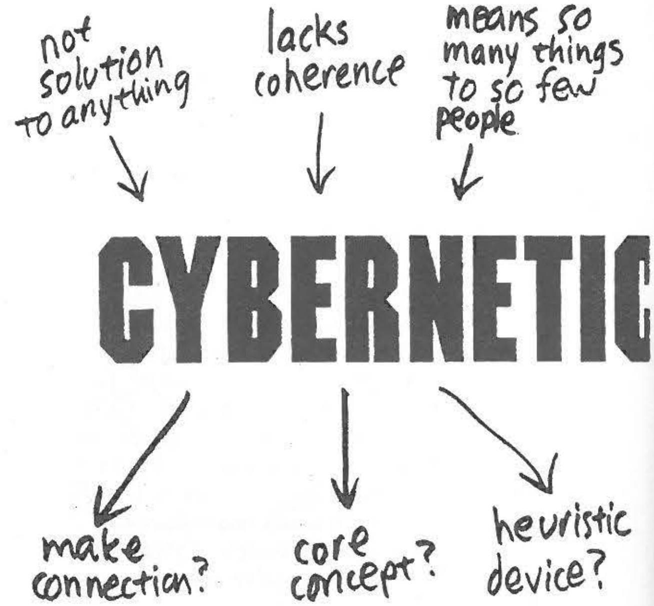
The informal account that follows is aimed at answering the question: "Why CYBERNETIC?" The trajectory of the answer will also describe the editorial domain of the magazine, and its goals.

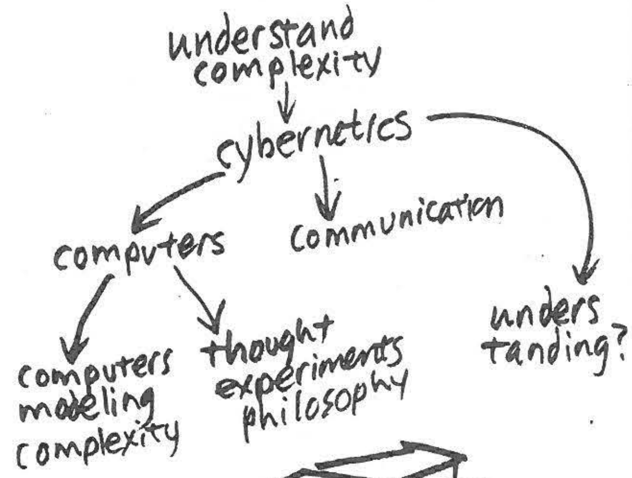
The original appeal of cybernetics to scientists, and to humanists interested in technology, was its value as an approach to understanding complexity. But cybernetics laid the groundwork for new computer and communications mechanisms that have vastly increased the world's complexity, while the development and understanding of underlying concepts have not kept pace.

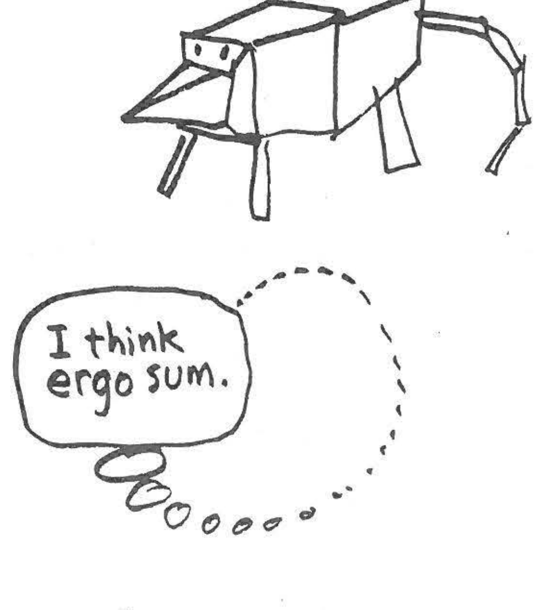
When general purpose computers became available in the 1950's, a split occurred between scientists who made these machines their models and simulators of intelligence, and the cyberneticians who preferred using conceptual tools of formal logic and mathematics to perform their "thought experiments." This split might thus be viewed as a schism between philosophy and machinery, a state of affairs unfortunate to both sides.

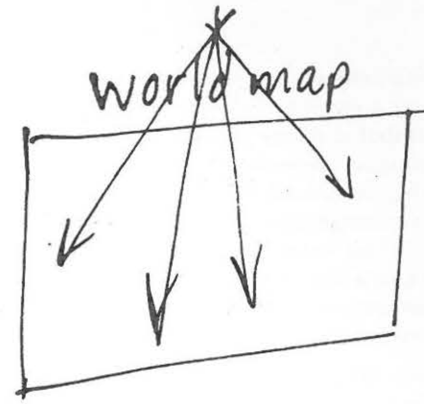
Currently, in disciplines like computer science, artificial intelligence, neurobiology and cognitive sciences, the old cybernetics is remembered mainly for producing a curious array of mechanical mice, rats, and turtles that could be conditioned to exhibit simple adaptive behaviors, and has acquired a bad reputation for concepts that have not yet been fully developed or understood. Common responses dismiss cybernetics for its early emphasis on feedback as the solution to all problems, or its too tight analogies between digital computers and brains, or its too rigid concepts of control.

Concurrently, later research in cybernetics of potential interest to people engaged in computer and cognitive re-







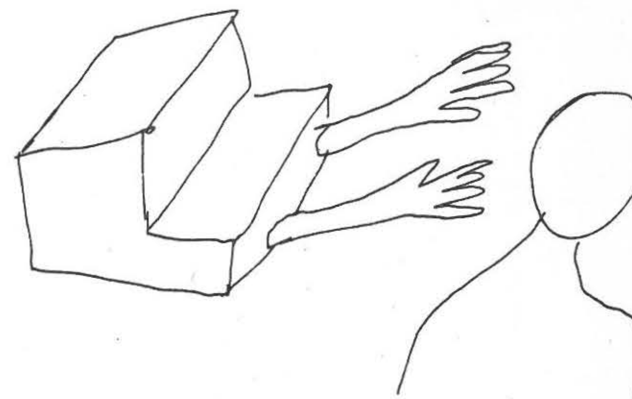


search has been largely overlooked, at least in the U.S.A. In this category are studies of relational structures for semantic computing (Biological Computer Laboratory, University of Illinois) now being expanded in the Japanese Fifth Generation Computer Project; and expert systems and data bases mapped onto recursive nets (Gordon Pask) being implemented in research for the U.S. Army Research Institute and the British Admiralty. At least as significant is the body of cybernetic research in mathematics and logic (e.g., Ron Atkin in England, Eduardo Cianiello in Italy, Gotthard Gunther in Germany, Lars Lofgren in Sweden, Carl Adam Petri in Germany) that could lead to new designs for computing in concurrent or parallel rather than serial computer architectures.

while

While it is a commonly held viewpoint among computer scientists that computer scientists have access to the best machines available and are in the best position for testing new ideas, from a cybernetic point of view the rapid development of powerful computers, for all their benefits, appears to have had an unfortunate consequence. As is apparent in the history of science, once instruments are developed to help answer a question, and as they are improved, the research may become driven by the logic of the instruments rather than by the logic that led to the question. To the extent that this has occurred, cyberneticians see computer science as influencing cognitive research with serial-processor-based linear models of brain function and behavior.

unfortunate



increasing

The increasing interest in computer science research in new models using semantic nets, context-setting frames, non-von Neumann and parallel processor architectures, as well as the recent interest in non-linear models of the nervous system, indicates that the early schism may be disappearing, and a process of mutual re-cognition may be useful.

indicates

re-cognition

E.g.

For example, many cyberneticians would agree that Norbert Wiener's original concept of control is too rigid. In his last years, Wiener came to regret the emphasis on and use of his control languge: he perceived there was a deep need for distributed control models with no identifiable locus of control. Wiener's close colleague, neurophysiologist Warren McCulloch, extended this concept with an analogy in which the first element to receive information was the commander. A shifting locus of control was suggested in McCulloch's "Principle of [redacted] of potential command where information constitutes authority." He cited the example of the [redacted] where the Japanese were defeated partly *because* they destroyed [redacted] U.S. flagship early in the battle. [redacted] result, wherever the Japanese attacked, the local commander who [redacted] first assumed authority [redacted] the [redacted] fleet had hundreds of [redacted] comma[redacted]sions were [redacted] without going through [redacted] big decision hier[redacted] applied this [redacted] the nervous sys[redacted]

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8

Distributed control models are now beginning to appear in many areas of neurobiology, for example in Leon Cooper's distributed theory of memory, in Terrence Sejnowski's information processing model, and in David Marr's research on vision. Gerald Edelman's current research with a pair of unprogrammed automata (named Wallace and Darwin) which can exhibit associative memory, moves away from all instruction or information processing models of the nervous system, pointing toward a heterarchical rather than a hierarchical structure.

Leon Cooper
Terrence Sejnowski
David Marr
Gerald Edelman

hierarchical
↓
heterarchical

There is an emerging view of the brain, Sejnowski observes, "that is probabalistic rather than deterministic, inherently distributed rather than local, and dynamic rather than static. Unfortunately, our experience with probabalistic, distributed, dynamic systems is limited. Even simple examples and models would help us grasp the brain's complexity." Despite the brain's formidable complexity, Sejnowski adds, "its design principles need not be complicated." But there are less than adequate means and media available for comparing new models with analogous models in other disciplines, even as closely related as artificial intelligence.

Deterministic
↓
Probabilistic

Distributed control models have arisen in artificial intelligence research at least since Oliver Selfridge's 1958 Pandemonium program of distributed demons fighting for attention. Marvin Minsky's and Seymour Papert's society of minds concept, Carl Hewitt's actor models and Alan Newell's production models are among the other, more recent approaches to linguistics, motivation, pattern recognition, learning and memory, and other problems of cognition being studied by artificial intelligence research.

Oliver Selfridge
Minsky & Papert
Alan Newell

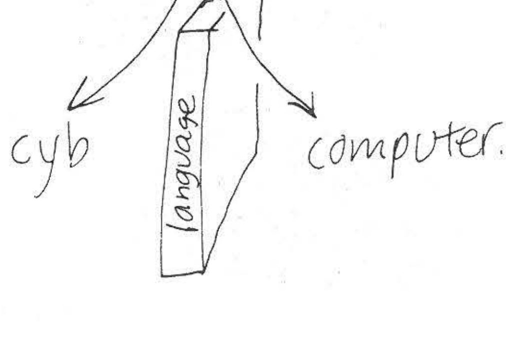
Gordon Pask's cybernetic approach to these problems abandons the conventional T/F truth value logic implicit in all these efforts, and adopts a multi-value logic for modeling "agreement" and "consensus," which cannot be implemented with a simple true-false logic. Even the asynchronous data-flow models and non-von Neumann architectures now being developed do not address the issue of the computing circuitry at this fundamental level of logic design.

Gordon Pask

T-False
↓
consensus

The developers of these advanced models in neurobiology and artificial intelligence (as well as their cybernetic counterparts) have less discourse with each other than they would like, and should have, and there are few available media for looking at the more general design principles involved, or their potential application to the complexity of social systems. This appears to be an area where CYBERNETIC could make a contribution by creating new opportunities for discourse.

If history has divided the disciplines, however, more than that history now keeps them apart. The differences that caused the split between cybernetics and other computer-oriented sciences are now deeply embedded in language.



Much of the cybernetic research that appears relevant is presented in idiosyncratic vocabularies and formalisms which create barriers to understanding even among cyberneticians. On the other side, cyberneticians see a persistent semantic confusion of symbols with objects (which otherwise would be termed superstition) in the language of artificial intelligence; for example, the confusion of signal with information mentioned earlier, also the confusion of input with perception, record with memory, change with learning. The term "artificial intelligence" itself can be seen as a semantic trap. A cybernetic definition of artificial intelligence would be "an artifact that can make *us* more intelligent." (This view is also reflected in the Japanese Fifth Generation Computer Report, 1979–1980: "Fifth Generation computers can play an important role in amplifying an intelligent ability which only mankind can have.")

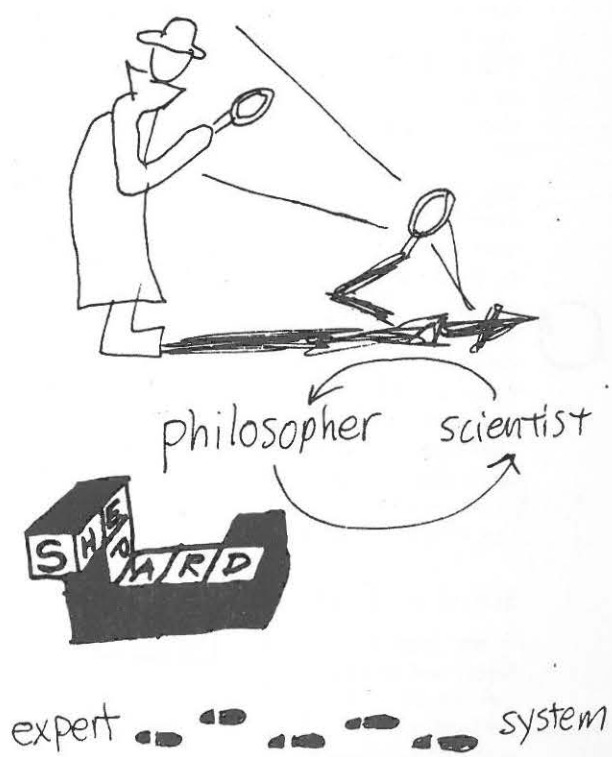
artificial intelligence
↓
amplifying intelligence

Subjectivity and Science

The editors of CYBERNETIC believe that such differences in point of view and language could now become a valuable resource, and should be developed rather than overlooked. A comparison of concepts and procedures in other disciplines with related problems might give readers a useful tool for re-examining their assumptions. Scientists traditionally have left the philosophy of science to philosophers, but cybernetics reverses the traditional relationship between science and philosophy.

overlooked (differences)
↓
developed !

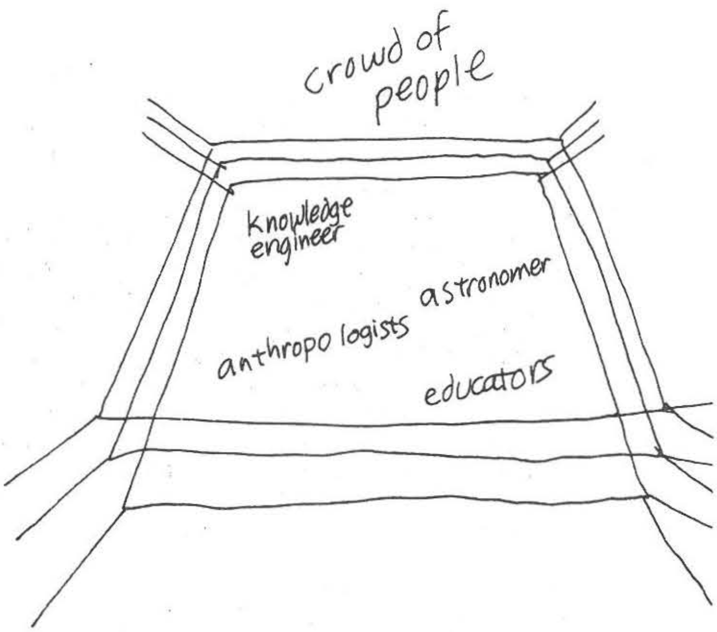
The usual mode of correction has been for philosophers to correct scientists when their work is in some way faulty or clumsy. Now cyberneticians are beginning to tell philosophers when their work has shortcomings that have caused problems for science. The philosophers may be nervous about this new circular relationship, but the widespread epistemological ferment in many fields of natural and social science, and in humanistic disciplines including the arts, invites a fresh look at the basic assumptions currently considered "scientific."



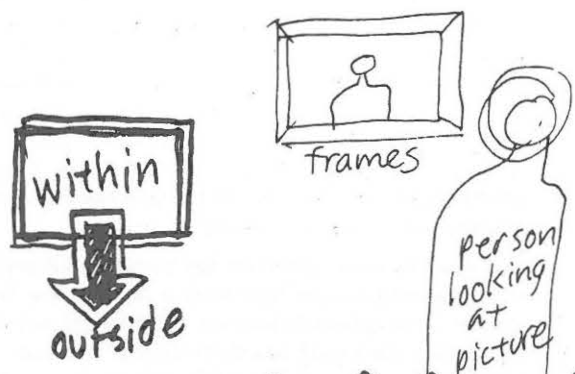
Some researchers in psychology are using introspection as a source of ideas about mental activity (e.g., Shepard and Cooper's work on mental transformation of images). In artificial intelligence, many researchers have abandoned the notion of the objectivity of knowledge, and are searching for ways of handling the judgmental, uncertain, noise-ridden, humanly devised mass of data that they desire to see as information or knowledge.

What might be termed the first law of knowledge engineering, for example, is Edward Feigenbaum's 1977 observation that the critical problem in designing expert systems in the bridge between the computer scientist and the expert who often cannot even approximately describe his inference processes, heuristics, or data, and who often colors and biases his description of his expertise. A cybernetic second law of knowledge engineering would state that Feigenbaum's first law of subjectivity applies to the computer scientist also, not only to the expert.

The editors of CYBERNETIC see the magazine as a space for comparing problems of subjectivity that are arising in many disciplines. The knowledge engineers are not alone: anthropologists consciously adopt an "externalist" or "internalist" stance to account for their role as observers; educators discover that their assumptions may bias their students' achievements; even astronomers have trouble with "observer bias" (in a classic example, Percival Lowell discovered the canals on Mars that astronomers who "knew better" did not see). Those who accompany us into this briar patch of thorny issues, however, must be warned to carry their own first aid. Obviously, cybernetics cannot alone answer the need for a new scientific method that accounts for the subjectivity of the observer, although it has made a start in exposing the questions.



The German logician Gotthard Gunther, a leading investigator of many-valued logics, sees the problem clearly in the light of history: "When the Greeks developed their scientific methods—which, as far as the basic assumptions are concerned, are still ours—they did so with a conceptual ontological frame which radically excluded subjectivity. And they were well aware that their methods were only meaningful within this frame. The modern cybernetician uses these very same methods but outside their legitimate frame. The result is that if analogues of subjective processes are designed into computer hardware the cybernetician is consciously or unconsciously trying to make them as lifeless as possible."

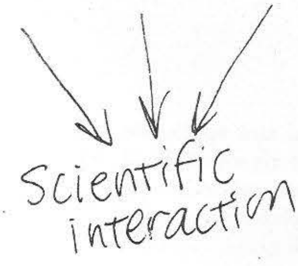


This is more than a cybernetician's dilemma. Without a means of accounting for themselves in science, scientists often find difficulty in relating what they do as scientists to the problems of society and human behavior. As a result, science threatens to become one of the problems of society and human behavior, while humanists and educators retreat from the learning and teaching of science (currently, for example, one-half of U.S. high school students take no math or science course after 10th grade). This cultural problem is not obviously susceptible to the application of formal tools and methodologies (cybernetic, or otherwise) but a cybernetic perspective offers a useful way of approaching social systems.

Science and Society

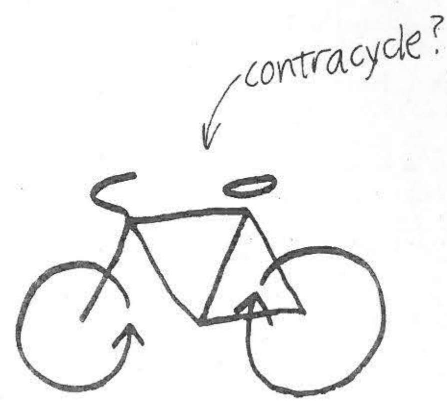
It was from comparisons of purposeful behavior in machines and organisms that concepts like feedback, control, and regulation were developed and applied to social and political problems. The interaction of natural and social scientists envisioned by Norbert Wiener when he adopted the word cybernetics, however, after an initial period of successful interdisciplinary conferences and collaborations,

feedback control regulation

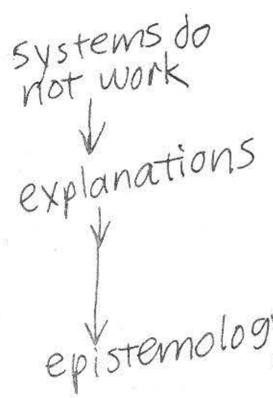


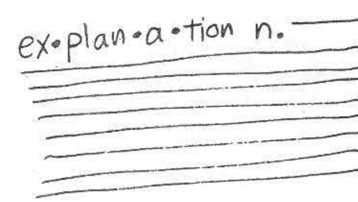
is now a relatively rare occurrence. It is in reviving this spirit of interaction that the editors of CYBERNETIC feel the most important work needs to be done.

The generality of the feedback concept was Wiener's first cybernetic insight: too much feedback caused oscillations in machines, and a similar cause could explain "purpose tremor" in people with cerebellar injuries. Since then, the concept has been so widely applied that it is part of our vernacular. Rock and roll musicians now play feedback, playing amplified instruments in front of an amplifier so that the pick-ups pick up the amplification to generate sounds the instruments do not make (an effect termed "infinite sustain").



Feedback is now so familiar a concept that its limitations have become clear, and many other early cybernetic concepts of control and regulation now seem inadequate to the complexity of our current crises. Asked for feedback on a draft of this prospectus, Robert Knisely, Deputy Chairman of the National Endowment of the Arts, responded: "I am most concerned that late 20th Century life, in both the developed and undeveloped worlds, is no longer responding to traditional cybernetic cues, and is therefore quite literally 'out of control.' Feedback has provided us with evolution, market economics, and the ability to ride bicycles. It seems ineffective, at a macro level anyway, againt the depletion of natural resources, the slow degradation of mixed economies, and thermonuclear war."





The problem is not so much with the principles that we know, but how to acquire the principles we do not yet know. The problem of late 20th Century life is not only that many of our social systems do not work, but that many of our explanations do not work, and a society cannot correct what it cannot understand. A growing awareness that current explanations are a part of the problem has revived interest in subjectivity, relativism, and the nature of knowing throughout the sciences, humanities, and also in discussions of artistic perspective.

The increasing complexity of social systems is making epistemology, the explanation of explanation, an immediate concern of society rather than an esoteric interest of philosophers. The implications for scientists can be seen in statements such as the following:

"We know enough, today, about societal problems and cognitive processes, to realize that the two are profoundly interconnected. Anyone who attempts to study and to answer the questions posed by one, sooner or later finds himself involved with the study of questions raised by the other.

"It is necessary to recognize that he who sets out to study and to act upon cognitive processes and societal problems is himself a member of the set of his objectives. The time-honored distinctions, therefore, between theory, practice, fundamental and applicable research, development, etc., no longer so rigorously hold, when the subjects are cognitive processes and societal problems. In fact, all active attitudes available to scientific and creative man must move simultaneously and together, none emphasized at the expense of the other, each emphatically appropriate to a given observation or purpose." (From a National Science Foundation proposal on "Cognitive Technology," submitted by the Committee on Cognitive Technology, Biological Computer Laboratory, University of Illinois, 1972.)

"In psychological and social investigations, the systems being studied are both the source and the product of their own understanding. The understanding an individual has of how the mind works is an integral part of how his mind works. The theories that guide action in a society are themselves a major constitutive organization of the society. In gaining knowledge of ourselves and our interactions with other people, we are engaged in a recursive process of changing the very things we are in the process of understanding." (From "Understanding Computers and Cognition"—an unpublished draft—by Terry Winograd and Fernando Flores, 1983.)

The essential problem in such situations is that those who act as scientists find themselves without rigorous methods for knowing how to proceed. As Winograd points out, "Today, there are many people looking at questions like how computer systems (and other technologies) should be developed and evaluated, what the design process is, and how it relates to human goals. They are grappling with deep problems of circularity; e.g., a new technology changes the social structure whose goals it was intended to achieve."

A Choice of Explanation

In such situations, however, circularity is not the problem; it is the chosen methods of explanation that make circularity a problem. This was the fundamental insight of the early cyberneticians when they invented the original notion of cybernetics, "circular causal and feedback mechanisms." At the time, this was a new idea in scientific thought, and its implications have not yet been fully explored. To develop the concept of circular causality required a shift in the choice of explanation, from (in Aristotle's terms) the efficient cause to the formal cause; from the use of "because" to the use of "in order." It was making this conscious shift that allowed the early cyberneticians to come to grips with problems of purposeful behavior in machines, living organisms and societies. Where the traditional scientific method of reductionism seeks to specify a system in terms of components, the use of circular causality is aimed at identifying the formal relations in a system as a whole. The reductionist method isolates components in order to analyze them as objects: invoking circular causality shifts one's attention and language to the relations among the components that

cart → horse

because
↓
in order

components
↓
wholes

objects
↓
relations

define the unity of a system, and the function or processes that are needed to maintain the defining relations.

The early cyberneticians made the switch from "because" to "in order" as a form of explanation so that they could stipulate the equifinality of systems in which the final state of affairs is equal for all ways of approaching it. For example, an observer studying the birds migrating to a certain island may not care about the particular trajectory of every individual bird at each moment; what he wants to know is where they are all heading.

The purpose of "purpose" as a mode of explanation is to get rid of the trajectories that are of no concern, and make a direct approach to the "homeostatic" place that is invariant for the system. This does not diminish the value of the other viewpoint, i.e., of looking at the trajectories; it makes it equally defensible. It depends on what the observer wants to know. In adopting one form of explanation, cyberneticians were not rejecting the other, but attempting to make clear the appropriate use of each. Even more significant was their realization that the choice of explanation, by efficient cause or formal cause, was just that: a choice.

Reductionism is one way of a scientist's understanding of some aspects of the world, but it has limitations, as modern physicists realized when their experiments led them into a dilemma. The problem of reductionism, Gordon Pask observes, is that it eventually leads to a bad question: the bad question is the one where the more accurately you answer it, the less sense it makes.

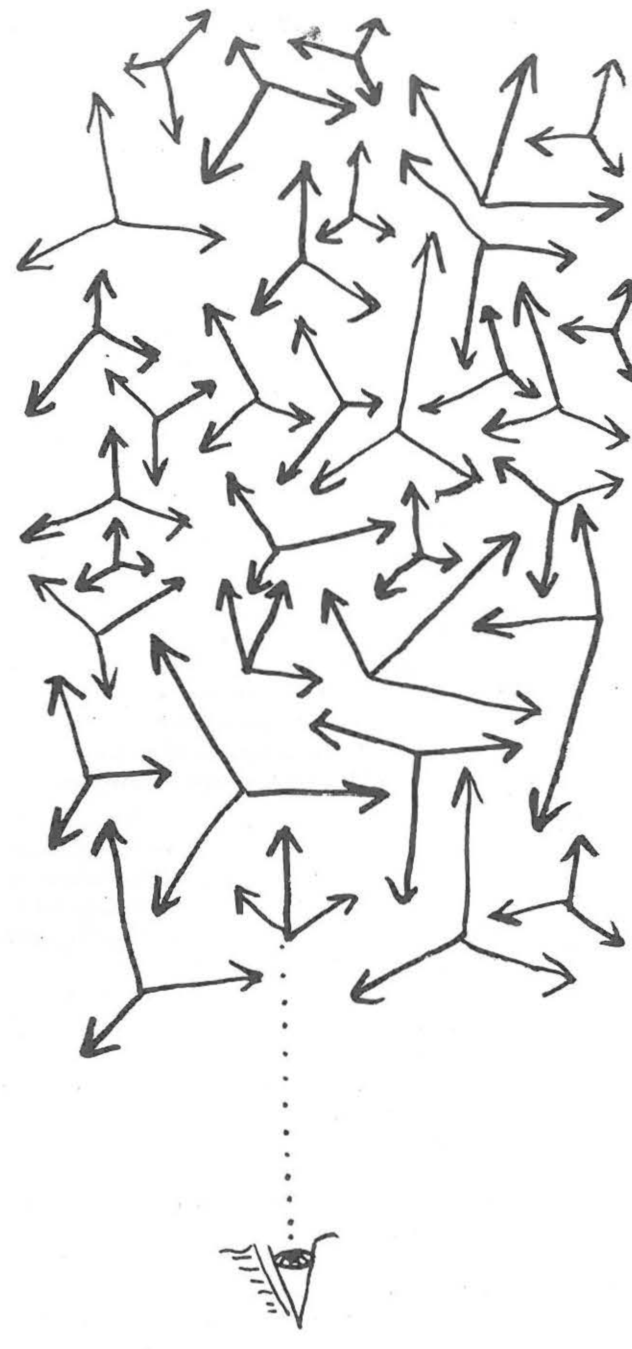
The shift in perspective adopted in cybernetics closely parallels the point of view adopted by Heisenberg and Bohr in physics. Heisenberg's insight was that the more accurately the position of an elementary particle is observed, the more elusive becomes its velocity (and vice versa), because measuring one aspect affects the other; while Bohr pointed out first that it is the observer's choice of instrumentation that determines the "nature" of light to appear either as a stream of particles or else as a progression of electromagnetic waves. In both cases, the reductionist dilemma was avoided by changing the form of explanation, viewing each system as composed of duals instead of dualities, pairs of aspects whose relations defined the system as a whole.

dualities
↓
duals

This shift in description, however, began to undermine the traditional scientific concept of an objective reality. An explanation of, say, the photon, or the electron, was now unavoidably given in terms of an interaction between the observer and the phenomenon being observed. As psychiatrist James Durkin observes, "The champions of objectivity in physics pushed their investigations to the limit and discovered subjectivity there."

objectivity
↓
subjectivity

Einstein's principle of relativity, stipulating that there is no unique coordiate system in nature, also contributed to a growing insight into objectivity and its limitations. Cybernetics, Warren McCulloch explained, was an attempt to make clear "the bearing of relativity, not only on our physical frames of reference, in the sense of space, time and movement, but also on any other set of axes appropriate to an observer coping by measurement and perception with his own changes in a changing world."



An Emerging New Perspective

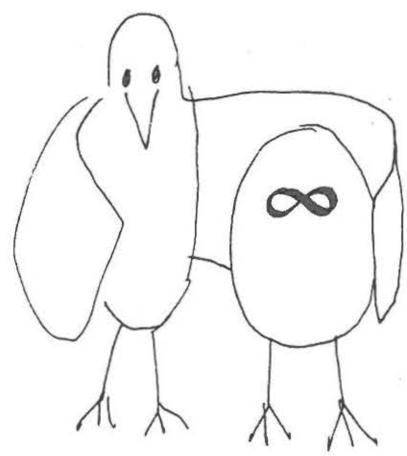
As cyberneticians began turning their attention from observed systems to observing systems, the early interest in feedback and control mechanisms shifted to concepts of self-organization, self-reference, and circular causality in mathematics, logic, language, and the formal aspects of living and cognitive systems. Similar approaches are emerging in other disciplines as well, and have found popular expression in works such as Douglas Hofstadter's *Gödel, Escher, Bach.*

In their research, cyberneticians began to see new aspects of phenomena that were obscured by using traditional methods of explanation. An example is Heinz von Foerster's use of recursive function theory (functions that produce themselves) to describe behaviors of living systems. From these investigations came such statements as: "The nervous system is organized (or organizes itself) to compute a stable reality. Cognition is the computation of computation." Or: "There is no information in the environment; the environment is as it is."

Humberto Maturana's research on vision provides a similar example. In "What the Frog's Eye Tells the Frog's Brain," Maturana, McCulloch, Lettvin and Pitts produced evidence that the retina did not simply transmit signals about intensities, but about patterns of variation of intensities; i.e., the retina was computing differences that make a difference.

Maturana later recognized the assumption in this research that "we were handling a clearly defined cognitive situation: there was an objective (absolute) reality, external to the animal, and independent of it (not determined by it), which it could perceive..." In his later research on color vision, however, Maturana's perception of the situation changed; he understood his purpose "not as the study of a mapping of a colorful world on the nervous system, but...understanding of the participation of the retina (or nervous system) in the generation of the color space of the observer."

This shift led to an entirely different understanding of cognition; Maturana and fellow biologist Francisco Varela applied the peculiar logic of autology- of concepts that can be applied to themselves- to an understanding of the self-organization and autonomy of living systems, leading to Maturana's unconventional proposition that "Living systems are cognitive systems, and living, as a process, is a process of cognition. This statement is valid for all organisms, with and without a nervous system."



Such propositions are inversions of the traditional scientific point of view, and provide a basis for science that keeps in mind issues of goal, end, purpose or *telos*. The new attention to circular causal mechanisms—i.e., to processes that both constitute and maintain a system's defining relations—brought into focus the unity of systems that require all of their components in order to have all of their components (in the barnyard conundrum, you need both the chicken and egg to have them both).

In terms of traditional causality, attempts to explain such systems lead to paradox. A current example is the problem of pre-biotic chemistry: you need DNA in order to direct the building of proteins, and proteins to get DNA. The paradox arises from a reductionist explanation that uses the replication of DNA to explain life. An alternative would be to look at formal causes (defining relations) and to use life as an autonomous whole to explain the replication of DNA. Similar problems arise in many fields of medical research: following the recent identification of "oncogenes" as a cause of cancer, the editors of *Nature* posed the question whether a single point mutation in a gene coding for a specific protein could "explain" a biological phenomenon as complex as cancer? Or was this naive reductionism? (They were not ready to call it naive.) Physiologists constantly confront circular problems in control theory (e.g., does the fibrillation cause the low blood pressure, or conversely, does the low blood pressure cause the fibrillation?). The same class of problems can be easily identified in the social sciences (does the arms race cause international tension, or vice versa?).

One approach to such issues of causality is to view them as problems, like pattern recognition, "that we will piecemeal to death over the years with brute computer strength." However, where such paradoxes arise, an observer also has the opportunity to reflect on the questions being asked; the paradox may simply be an erroneous statement of the problem.

Toward an Understanding of Understanding

The editors see CYBERNETIC as a space for raising questions that might otherwise go unnoticed. We do not expect that readers will seek cybernetic solutions to their research problems in the magazine, but that reading it will contribute to their understanding of what the problems are.

solutions
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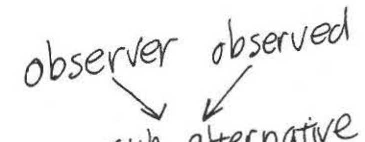
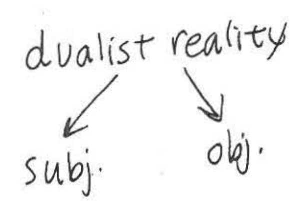
problems

The traditional scientific perspective of objectivity is among the questions that are not ordinarily raised. A cybernetic perspective brings with it an alternative to the objective underpinnings of traditional scientific thought. "Objectivity," von Foerster observes, "is the delusion that it is not a delusion. It is the cognitive version of the physiological blindspot: we do not see that we do not see. Also, objectivity is the subject's delusion that observing can be done without him. Invoking objectivity is abrogating responsibility; whence comes its popularity."

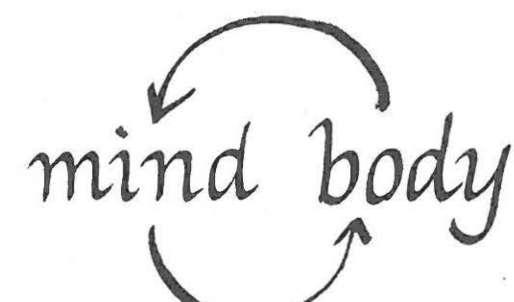
The cybernetic alternative to objectivity is not solipsism; it is a subjectivity that moves in the opposite direction, a perspective in which reality is to be understood in terms of the observer and the observed together. This is a point of view expressed in Wittgenstein's proposition that "Objects may be real, but they are not reality."



The emergence of cybernetics and the more recent interest in "experimental epistemology" in other disciplines may be symptoms of change in the traditional scientific world view—a view that divides reality into irreconcilable dualities of subject and object, mind and body, meaningful information and physical energy, reason and will, form and function. This dualist viewpoint, which was shared by both vitalists and mechanists in the 19th Century, produced a biology and psychology which isolated and explained objects and functions as "natural" phenomena, while treating formal cause and explanations in terms of design or purpose as "supernatural."

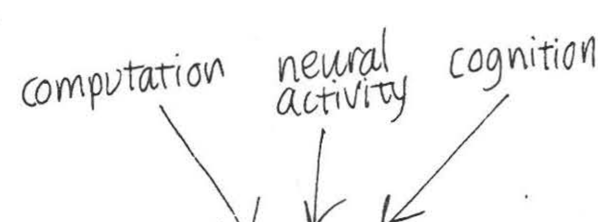


The great accomplishments of modern scientific endeavor eclipsed the lack of any scientific methods for understanding purpose in nature. In the mid 20th Century, however, the development of machines that could embody aspects of what were previously considered "mind" (and thus beyond reach of reductionist science) required a new understanding of mind and body as aspects complementary to each other: In McCulloch's term, *embodiments of mind.*



This new understanding, accounting for the observer and the observed as duals, required a logic of circular causality to make clear that whether the observer sees one aspect of a system or another (form or function, information or energy, language or movement) depend on one's choice of explanation, and that the choice is always up to the observer.

This new understanding is far from complete, but it is visible in its outlines. It is concerned with the most ancient questions of cognition, and the most recent problems of technologies based on the high-speed transformation of symbolic representations, both numerical and semantic.

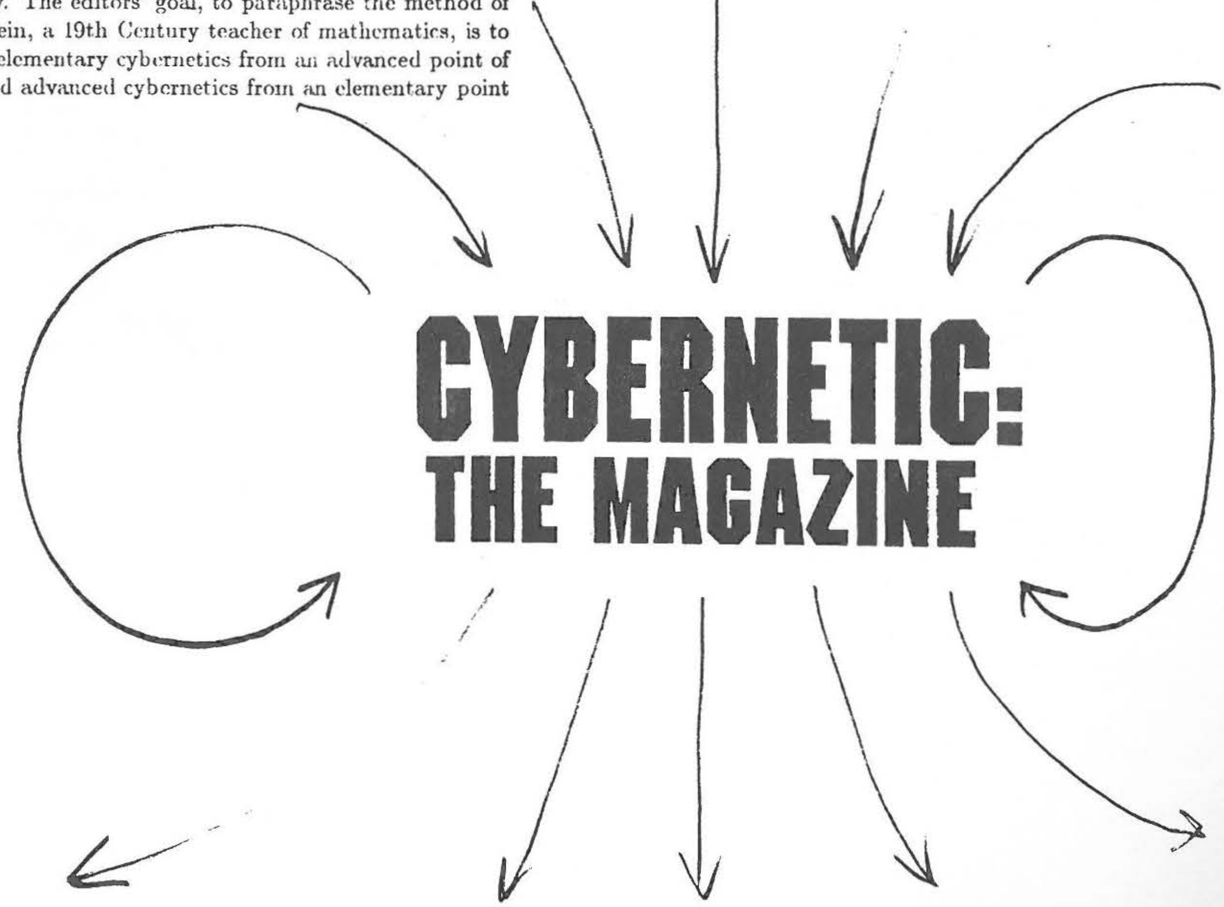


Historically, the new perspective can be seen as integrating ideas that developed from three directions: from Aristotle's calculus of propositions; from Leibnitz' foundation of computing in binary representations; and from Ramon y Cajal's demonstration of the synaptic termination of neurons onto each other, which opened the possibility of interpreting a neuron as an operator on its inputs (the activity of other neurons).

The convergence of these ideas into a unified perspective began in the minds and conversations of three men: Warren McCulloch, a neurophysiologist and logician; John von Neumann, a logician and mathematician; and Norbert Wiener, a mathematician and engineer. In 1953, at the last of ten interdisciplinary conferences on cybernetics sponsored by the Josiah Macy Foundation, McCulloch reported on an important shift in focus that had occurred, from a primary interest in the feedback concept to a growing awareness that every signal has two aspects: one physical, the other mental, formal, or logical. "This turned our attention to computing machinery," McCulloch observed, "to the storage of information as negative entropy. Here belong questions of coding, of languages and their structures, of how they are learned and how they are understood."

Although the participants did not immediately realize it, their shift in focus was leading them towards a deeper shift in perspective. The complementarity of the two aspects of a signal provided a new basis for understanding cognitive processes, in hardware, living organisms, or social organizations. In retrospect, it can be seen that they were developing an epistemology of computation (from *computare*, to consider things together and get something else out).

The purpose of publishing CYBERNETIC is to provide logical space for comparing the different perspectives and explanatory principles arising in different disciplines. To this end, and to this beginning, CYBERNETIC will focus attention on the elementary cybernetic concept of circular causality. The editors' goal, to paraphrase the method of Felix Klein, a 19th Century teacher of mathematics, is to present elementary cybernetics from an advanced point of view; and advanced cybernetics from an elementary point of view.



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