What ever happened to cybernetics?
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The 1940s saw the rise of the science of cybernetics. A science seemingly bent on universalism, aimed at refiguring all of the other sciences in its own image, cybernetics followed in the heritage of 19th century Victorian dreams of the perfectly regulated political economy managed by a perfectly regulated science. The dream of the previous century was for science to provide the means to regulate all spheres of productive life. In the 20th century, science itself was to be brought under a more careful and precise regulation, that offered by cybernetics.

But what was cybernetics? What were the scope and extent of its dreams of regulation? Was it merely a good-willed inter-disciplinary movement that saw real metaphorical resemblances between problems in different domains? Did it aspire to supplant and displace the other sciences with its own epistemology and metaphysics? Was it the heir-apparent to the throne of science, or a mere pretender, seeking devious ways to undermine specialized knowledge well beyond its legitimate means? Was it a revolution in science, the science of the dawning age of information, or was it merely a clever narrative about a fictional past that led to a rosy cybernetic future? In short, what *was* cybernetics? And what happened to it? Did it disappear because it failed in its revolutionary goals, or did it disappear because it was so successful that it is now merely taken for granted. Indeed, did it disappear at all? These are some of the questions I hope to provide some insights upon today.

What is, or was, cybernetics?

So much of the problem of saying what happened to cybernetics depends upon what we think cybernetics *was*.

When I tell people that I study the history of cybernetics, they usually say "wow that's interesting, so what is cybernetics?" When talking to people of various backgrounds who have already thought about the history of cybernetics, I find that there are at least three distinct things that they have in mind. For your convenience today, I'll call these the broad view, the narrow view, and the internal view. For those of you who have read the program statement for this year's Roboexotica, you will already be introduced to the main ideas of the broad view, and some hints of the narrow view.

But why don't we start by looking at the etymology of cybernetics:

The word "cybernetics" was coined by MIT mathematician Norbert Wiener in the summer of 1947 to refer to the new science of command and control in animals and machines which he helped to establish and develop. The word was derived from the Greek *kubernētēs* meaning "steersman" or "ship pilot." Unknown to Wiener at the time, Plato had used the adjective *kubernetiken* in the *Gorgias* to refer to the “science of piloting,” and the French physicist André Marie Ampére had derived the French word *Cybernétique* directly from the Greek to refer to the science of government in his classification of sciences, the *Essai sur la Philosophie des Sciences*.

And so the root “*kuber*” leads us straight to “governor,” the regulator, guide and pilot of steam engines and states. It thus lies at a powerful metaphorical intersection of political economy and technology, social and material order, and the regulation of animals and machines.

The basic idea of Cybernetics is that complex systems–such as living organisms, societies and brains–are self-regulated by the feedback of information. By systematically analyzing the feedback mechanisms which regulate complex systems, cybernetics hopes to discover the means of controlling these systems technologically, and to develop the capability of synthesizing artificial systems with similar capacities.

The Narrow View

The narrow view of cybernetics is that the mechanism of negative feedback control is metaphysically central to the order and organization of the universe. This was the theme of the original Macy conferences, which were actually called symposia on “Circular Causal and Feedback Mechanisms in Biological and Social Systems.” The idea was to find these mechanisms in every science, and to thereby translate knowledge produced about them in one discipline to the problems of understanding them in another discipline.

For those less familiar with the concept, a brief sketch is in order. Negative feedback is the ability of a mechanism to receive information about the result of its own action, to calculate a correction based on the distance of that result from a pre-specified goal, and to act so as to reduce that distance. Negative feedback thus creates a circular causal loop whereby an action **A** causes an effect **B**, which in turn causes a new action **A'** which has been calculated to reduce the error of the next effect **B'**, and so on. The challenge of designing a useful machine for solving a given problem thus lies in determining how to perform the error-reducing calculation.

Negative feedback can be realized by a very simple mechanism. A common example is the thermostat which regulates the temperature of a room by turning the heat on when the temperature falls too low, and switches it off again when the temperature rises. Another is James Watt's governor which regulates a steam engine by opening a valve when it spins too fast and closing the valve again as it slows down.

The basic concept of feedback was first developed seriously in 1932 by the engineer Nyquist in his Regeneration Theory, and reached maturity with the general theory of servomechanisms published by MacColl in 1945. Information was given a precise mathematical definition by the Bell Telephone Labs engineer Claude Shannon in his “Mathematical Theory of Communication” published in 1948, though his work was circulated in secret for nearly a decade before that. He defined information as a measure of the reduction in uncertainty caused by receiving a particular message from the whole set of possible messages. His formalism drew upon Boolean logic and probability theory to derive a purely mathematical definition of information, and this was only means to his ultimate goal, which took the form of the "error-correcting channel" for sending messages. His equations tell you how much noise can be allowed on a given channel, which tells you how many signals can be transmitted on it in a given period of time. This is the fundamental mathematical theory which let engineers pile thousands of telephone calls onto a single wire, and now millions upon microwaves.

Wiener began thinking about negative feedback when he was trying, along with Julian Bigelow and Arturo Rosenblueth to design an anti-aircraft gun that would follow a moving target, called the AA-Predictor. When they wrote their landmark paper in 1943 on "Behavior, Purpose and Teleology," they drew on both the servomechanical and information theoretic conceptions of feedback. The other landmark paper in 1943, McCulloch and Pitts paper on the "Logical Calculus of Neural Nets" used a radically different formalism drawn from Rudolph Carnap's positivist logic, but was soon simplified to the Boolean logics of Shannon's formalisms. In it, they demonstrated mathematically that a cyclic neural network, one that fed-back upon itself, could instantiate a Universal Turing Machine, and thus implicitly argued that the brain was a universal computer.

In the long run, most of the cyberneticians would follow the information formalism rather than the original servomechanical one. The reason is probaly that the concept of information was itself far more universalizable than the concept of error-correction alone. Being able to calculate the correction to the voltage in an electric motor was not very intellectually inspiring all on its own. And with the development of the stored-program digital computer over the next few years, the use of Boolean logic, its formalisation as information, and the potential of universal computation would all conspire to form a uniquely powerful concept for cybernetics to lay its claims to being a universal science with computation as its universal technology.

If we accept this narrow view of cybernetics as being the science of feedback control mechanisms, then cybernetics is alive and well. Of course, nobody calls it cybernetics anymore, they simply call it control theory, or information theory. There are still plenty of conferences on these topics every year. Mostly this work exists in hardcore engineering disciplines, servomechanical control systems and the border of electrical and mechanical engineering, their application in robotic systems and manufacturing processes, the design of control systems for planes and rockets and increasingly in automobiles with such things as electronic fuel injection systems, anti-lock brakes and traction control systems, and countless other industrial and consumer applications.

As the basis of information theory and signal processing, it is central to the hardware that makes cell phones, ethernet, and wireless networks actually work. In each case the basic theories which enable these technologies is the self-regulated mechanism, negative feedback, or error-correcting signal processor. Again in each case, there is a rich history of technological advancement, much of it conducted without much concern for "cybernetics" *per se*, its universal ambitions or world vision. It would be impossible to say what percentage of these technologies depend upon cybernetics. Indeed, one could probably make a convincing case that cybernetics itself merely appropriated servo-mechanical control theory and information theory as its first disciplinary conquest, from which it began telling stories of its historical inevitability and impending conquest of the other sciences, which it then pursued in earnest.

If the narrow view is thus drawn from a close reading of the underlying mathematical theories, and the technological products of these theories, then it appears to be not so universalizing. While it has enabled many of the significant technologies of the information age–computers, guided missiles, mobile phones, robots, and the internet–it has not re-written our basic understanding of science and society. In the end it is just one important and useful part of engineering among many.

The Broad View

The broad view starts from taking the rhetoric of cybernetics seriously. This is the view promoted in the introductory statement of this year's Roboexotica Symposia–"Dreams of Regulation." In its self-centered retellings of the history of science and human civilization as leading ultimately and inevitably to the science of cybernetics, it created its own mythology. The age of matter was passing away, and the age of form was coming. The age of industry, symbolized by the steam engine, was giving way to the age of information, symbolized by the computer. And where physics had promised to give humanity domination over matter and energy, cybernetics now promised to give humanity domination over information and organization. This was how cybernetics saw itself as replacing physics as the science upon which all others would be based. Cybernetics was thereby nothing if not radical and revolutionary. It sought to overthrow the entire scientific order as handed down from Newton, and with it the social and political order.

It should be noted that most of the people involved in the design and construction of the first stored-program digital computers, most notably Alan Turing, John von Neumann, and Julian Bigelow, were all involved in cybernetic groups before they built the first computers. They also explicitly drew on cybernetic concepts of feedback and information, and especially McCulloch and Pitts' neural nets paper in the actual designs for the first computers: von Neumann's Institute for Advanced Study machine, and Turing's ACE. Moreover, their explicit aim in designing these machines was to automate the calculation of scientific models, and draw the whole of science into the practice of representing knowledge *as* mathematical models. In short, the digital computer is the quintessential cybernetic device.

The strategy for the cybernetic revolution was ambitious and multi-faceted. But it was also comprehensive and organic. Indeed much of the compelling nature of its rhetoric derived from the consistency and elegance of its theology–all the parts fit together and reinforced one another.

At the center of its rhetorical strength was the double-move of establishing itself as the providing a universal language for science, and promoting this language through interdisciplinary projects and conferences, and the use of the computer and computational models. By the early 1940s, Nicholas Rashevsky was leading a weekly discussion group at the University of Chicago which sought to turn biological knowledge into a mathematical models. It was here that the young Viennese physicist Heinz von Foerster was first introduced to Warren McCulloch, and where a few years earlier Walter Pitts had done the same. By the late 1940s the Macy conferences established the paradigm of the new interdisciplinarity that cybernetics sought. It brought together leading researchers in engineering, mathematics, physics, chemistry, biology, psychology, psychiatry, medicine, anthropology, economics, sociology and philosophy. The goal was to co-opt the other sciences by getting them to speak the same language, the language of cybernetics. The strategy was to bring them together to talk about their own problems, to find the shared metaphors, to apply new metaphors and encourage the use of the new cybernetic language. Less than two years later in England, a group calling itself the Ratio Club began meeting monthly for cybernetic discussions. They had emerged from a conference on mathematical biology, and set themselves the purpose of determining to what extent the human mind could be understood and simulated mathematically. All of these early cybernetic groups were alike in that they brought together different disciplines to discuss their problems with the shared metaphors and language of information and feedback.

Again, the rhetoric of this strategy was remarkably powerful. Many scientists, not only those who attended the cybernetic meetings, were impressed by the new language and the promise of finding insights into their problems from other disciplines. And there was a genuine energy unleashed in the interdisciplinary collaborations which ensued–mathematicians working with medical doctors, electrical engineers working with psychiatrists, etc.

Cybernetics cannot however, claim to be the original author of interdisciplinary science. Rather, that credit goes to World War II. The great powers fighting that war recognized early on that science could provide the advantages necessary to win. They brought together scientists from many disciplines to solve the practical problems of war-fighting. Operations Research was one such product of this effort, in which mathematics was brought to bear on nearly every aspect of war strategy and tactics, from the search patterns of planes looking for U-boats, to the ideal size of a supply convoy, and ultimately the prototype for "big science" itself, the Manhattan project and its world-shattering atomic bomb. Indeed, it was the development of an intelligent anti-aircraft gun that had brought the Wiener team together, and the British and American teams that built the first digital computers, as well as Shannon and Weaver. Thus, at its birth cybernetics, inter-disciplinarity and World War II are bound up in a tight, circular causal loop that would be difficult to untangle.

The mythological power that surrounded cybernetics was also tied up in the historical moment it found itself in, and was extrapolated directly from Christian mythology of creation and destruction. The world had grown wary of war, and longed for more rational political controls. It had seen in new and godlike-powers put in human hands, the atomic bomb presented both the image and the reality of a new kind of apocalypse. DNA presented a key to a new kind of origin. And it was Cybernetics which wrote the narrative which connected these together, presented a scientific history of an evolving universe that would lead inevitably to intelligent human civilization, and place in its hands the means to its own destruction. Cybernetics offered not only a way to understand this history, but to manage and control it. It offered Game Theory as the means to managing the political crisis of nuclear arms. It offered technological control as the means of providing a better life. And it offered information as the metaphysical and economic basis of this brave new world. Cybernetics is, in this view, simply equated with a technological utopia, enabled by and articulated through information, communication and computation.

If we accept this broad view, the we are already living in the Age of Cybernetics, though maybe we just call it the Age of Information. It does not matter that nobody practices anything called 'cybernetics' because everybody is always already cybernetic, everywhere and all the time. While it is not without some appeal, perhaps this is too broad a view. What else might cybernetics be? It is too narrow to say it is just feedback mechanisms. It is too broad to say that it is techno-utopianism. Rather, the truth must lie somewhere in between.

The Internal View

The practitioners of Cybernetics seem to have been aware of the untenability of the grand universalizing project. On the one hand, they all believed that the world was essentially cybernetic. And while the wished to reform the sciences with the universal language of systems and mathematical models, they realized that this language was easily appropriate, misused and abused. Everywhere scientists were popping up and laying claim to these terms, and doing some rather uninteresting things with them.

In particular there was the new field of Artificial Intelligence. While its pioneers had been trained by the cyberneticians, and its aims of achieving human intelligence in machines was deeply cybernetic, by the 1960s political rifts had formed around it. McCulloch saw AI as being little more than the construction of toys and the solving of logical puzzles. He did not see that it could offer any insights into the human mind, because it failed at a fundamental level to address the structure and operation of the brain. From the other side, Marvin Minsky and Seymour Papert had published a logical critique of neural networks in their book *Perceptrons*. This had the effect of killing funding for neural network research for a decade, and forced AI researchers to distance themselves from the cyberneticians. The cyberneticians regrouped around new research themes, such as Bionics and Self-Organizing Systems, but by the end of the 1960s they found it hard to get funding.

The choice to regroup around Bionics and Self-Organizing Systems was one aspect of a movement internal to cybernetics, and so I will call it the internal view of what happened to cybernetics.

With the rise of a new generation of cybernetics researchers in the mid-1950s, a decade after cybernetics had first come together, came an even more radical vision of what cybernetics was. It would come to call itself 2nd order Cybernetics, and its mythology was based upon distancing itself from the 1st order cybernetics of Wiener and McCulloch. This time the basic thrust was epistemic rather than metaphysical. Cybernetics would again be defined by a feedback, but now it was between a system and its observer, rather than merely being within the system being observed. What made this radical was that the observer was part of the system being observed. This is also what made it epistemic, rather than metaphysical–observation was the central concern.

The movement to 2nd order cybernetics was led by Heinz von Foerster. Though he had served as the editor to the original Macy Conferences, he was a generation younger than all of the other participants. Indeed, it was not until 1958 that he was allowed to run a lab dedicated to cybernetics research, the Biological Computer Laboratory at the University of Illinois. We can see in the history of this lab the rise and fall of 2nd order cybernetics, and perhaps cybernetics more generally.

As a physicist, von Foerster was captivated by the advances in atomic physics, and in particular the Uncertainty Principle. What intrigued him about this was that the observer was inherently part of the system being observed–it was not possible to measure the position and spin of an electron without disturbing the system in such a way that one these bits of information was lost. In subsequent investigations into the nature of time and observation, von Foerster convinced himself that this relation held for all systems, and therefore all scientific knowledge. This insight held several implications, most notably ethical and aesthetic ones about how one chose one's system, and how one treated a system under observation.

That the BCL was the birthplace of 2nd order cybernetics is also born out by the fact that the other major figures in the area were all early visitors and frequent guests. The first visiting scientist was a young Gordon Pask, who came to the BCL to grow ears and neurons in electrolyzed chemical solutions. He was followed by Stafford Beer, who would go on to reorganize the Chilean economy around a cybernetic vision with a centralized computer, all under the direction of Allende, at least until a CIA-supported *coup* put an end to it.

Two other young Chilean cyberneticians were brought to the BCL to escape the reprisals of Pinochet, Humberto Maturana and Franciso Varela. Heinz von Foerster himself worked to help them flee the country, and arranged for visiting positions for them at the BCL. While they were there, they completed and published their notorious tract on *Autopoesis*, the power of a self-organizing system to bring itself into existence. It stood at once as a theory of how life could come into being, and how a mind could become conscious. In each case the essential thing was reflexivity, that the observer observed itself, and observed itself observing itself, and so forth. This idea became central to, among other things, the *Gaia* theory in which the earth is an autopoetic system breathing life into itself–literally.

With all its good intentions to insert a critical and ethical reflexivity into the most fundamental aspects of science, namely empirical observation, it was soon caught up in the radical politics of the late 1960s. This made for some exciting scientific, artistic and political work at the BCL in the early 1970s, much of it summarized in the 1974 publication, the *Cybernetics of Cybernetics*.

If anything marks the end of the cybernetic movement, it is the *Cybernetics of Cybernetics* (May 14, 1974). With DARPA and the ONR redirecting their funds to the MIT AI lab, the BCL had struggled to find funding for several years. In his final desperate act, von Foerster had developed a proposal in 1972 to the Department of Education which aimed to build a vast electronic on-line encyclopedia into the PLATO system that had been recently developed by the Coordinated Science Lab at Illinois. While von Foerster's fans see in this proposal an early vision of the internet, it was really something more like Wikipedia, in which a user could type any question and get access to the best available knowledge on the subject. Regardless of whether it was truly prescient of the World Wide Web, the proposal was nothing less that visionary and ambitious. It is therefore none too surprising that it failed even to receive funding for a pilot program. Von Foerster annouced his retirement and closed the BCL.

As its title suggests, *Cybernetics of Cybernetics* is a "hyperreflexive" work, it recapitulates the great texts of cybernetics, its lectures and pedagogy, and even the student projects of the BCL. But it is more archive than narrative history or textbook, almost a time capsule. A "Parabook" appears in the middle with indexes and acknowledgments, and it even includes a detachable "Metabook" with conceptual maps of the various contributors and key terms. Despite its radical structure and intent, the whole book resonates like the death knell for cybernetics, because its history is, in some sense, complete. There is no more cybernetics to be done, at least not any that requires the laborious recapitulation necessary to connect to this history. It is both an archeological memory trace, and the end of cybernetic history.

The cybernetic methodology did live on, in the sense that discourse in many diverse fields are still being broken down into systems, information, feedback and networks–all the more so since the advent of the Internet and "Cyberspace." But since 1974, nothing of great significance has been added to the cybernetic corpus.

And so I submit that what happened to Cybernetics is this:
It ate its own tail.

Just as 2^{nd} order cybernetics brought itself into existence autopoetically, it destroyed itself by failing to believe in itself any longer.

But it stands ready to rise from the ashes and be reborn–anywhere, anytime–through autopoetic love, or through a cocktail making robot who begins to question its own existence and motives.

Is Cybernetics dead?

Given that more and more people are spending more and more time in "cyberspace," it would be unfair to say it was dead. Perhaps like Obi Wan Kenobe in Star Wars, killing it has only made it stronger, for now it is everywhere. It stands ready to be reborn through autopeotic love anywhere, anytime. Whether it will take the form of a neo-cybernetic movement, or a 3rd order cybernetics is anyone's guess. Regardless, there is some value in thinking that

Today, while we might find judge it undesirable, we do not consider it impossible, or even unusual for someone to spend a great deal of their time in "cyberspace".

When Donna Haraway challenged feminists and leftists to embrace the language and metaphysics of cybernetics, what was she aiming at? Was the Cyborg just another metaphor for hybridity? If it was, then why was she so insistent on adopting not only the terminology of cybernetics, systems and information, but its whole ontology? No, this was not mere rhetoric. This was move was political, and
it was saavy, wise and insightful.

For Haraway shows us that it is not just the "world" the "environment" that is cybernetic. WE are cybernetic. WE are cyborgs, cybernetic organisms. We are hybrids made up of organic beings and mechanical parts. And the only thing that ties us all together, you and me, you and the other parts of you, is information.

Fundamentally, cybernetics is a new ontology. Andy Pickering has called it an ontology of becoming. The universe is not made up of matter, particles or energy. Nor is it made up of ideas, words, and symbols. It is not numerals, or universals, or plenum, or atoms, or monads. The world is made up to feedback loops of information. Not bits and numbers, calculations and data. This is the mistake of those who underestimate information, the delusion that information is static, stabile, capable of being captured and controlled. Information is dynamic, changing. Information *flows.* It bears reflecting on the fact that information is measured on expectation– and it is the message which is least is expected which carries the most information. The most predictable message is the least informative. And thus the goal of "control" in the cybernetic system is not the status quo, but rather the flexibility to handle the new an unexpected. Cybernetics in its most essential nature is a politically radical ontology. It is a point worth noting, even if the there are those who would have us believe that cybernetics aimed to turn us all into well behaved-robots.

Yes, cybernetics is the science of command and control. Yes, cybernetics has a yearning dream of regulation. But no, information itself cannot be controlled and regulated. It is *actions* that are to be controlled and regulated *because* of information. We need not fear that any database will ever rule the world, we must only fear the databases that regulate the actions of those who do control the world.

Has cybernetics given us more efficient systems of social control? Yes.
Has cybernetics given us more powerful forms of propaganda? Yes.
Has cybernetics given us more powerful, efficient and lethal military of man-machine systems? Yes.
But have we realized the radical political implications inherent in cybernetics, and inherent in the bureacarcies, messages, ideologies, and systems that it has spawned? NO. Cybernetics is a call to arms, not an ideology. It is an ontology for action, an ontology of becoming. It cannot tell us what should or shall become, it simply accepts whatever becomes. Rather, it provides us with a way of thinking about what a system it, how it comes to be, persists, organizes and reproduces.

What then is left of the historical narratives? Indeed, given the power of these rhetorical strategies, and the seeming success of cybernetics as a "universal science" whatever became of it? Geof gives us the dates 1943-1975 as the period of interest, but why does this period end in 1975? What ended? And how did Cybernetics close its chapter of history, which seemed to extend as far into the future as it did to the past?

In its purist forms, first-order cybernetics is still alive and well in several disciplines. That is, if we take "feedback-regulated mechanisms" as being definitive of first-order cybernetics. Of course, nobody calls it cybernetics anymore, they simply call it control theory, or information theory. Mostly this work exists in hardcore engineering disciplines, servomechanical control systems and the border of electrical and mechanical engineering, their application in robotic systems and manufacturing processes, the design of control systems for planes and rockets and increasingly in automobiles in such things as traction control systems. It is still the basis of information theory and signal processing, and is central to the hardware that makes cell phones, ethernet, and wireless networks actually work. In each case the basic theories which enable these technologies to work is the self-regulated mechanism, a feedback control, or error-correcting signal processor. Again in each case, there is a rich history of technological advancement, much of it conducted without much concern for "cybernetics", its universal ambitions or world vision. It would be impossible to say what percentage of these technologies depend upon cybernetics. Indeed, one could probably make a convincing case that cybernetics itself merely appropriated servo-mechanical control theory and information theory as its first disciplinary conquest, from which it began telling stories of its historical inevitability and impending conquest of the other sciences, which it then pursued in earnest.

[what is that story?]

We could take a broader view of cybernetics, that it was about the idea of the fundamental equivalence of the human and the machine, that information stood alongside matter and energy as the fundamental substances of the universe, and that society and the planet could be regulated by paying proper attention to the flows of information and energy. If we take this view, then cybernetics truly saw itself as theory of everything. And in some sense it succeeded in universalizing itself. That is, in such a view, any dream of technological control, social control, environmental control, etc., are all 'cybernetic' at some level.

Better yet, we could also consider the internal history of cybernetics itself, and its evolution into second-order cybernetics. This tale is more interesting for several reasons. First of all because it has a different metaphysical perspective. But also because the very fact of its evolution is in many respects a response to its own failure to conquer all of the sciences.

The bigger problem is that these perspectives are of a history of ideas, not of technologies. What then does it mean to say that a technology is cybernetic?

"Cyborg" is apparently a contraction of "cybernetic organism," but according to cybernetic theory this definition is redundant because all organisms are cybernetic. A popular definition of the term is that a cyborg is any natural organism whose biological composition has been complemented by artificial means, but not only does this admit any tool-user as a cyborg (and perhaps hermit crabs as well) it also depends on a distinction between natural and artificial which conflicts with cybernetic theory. A literal interpretation–with "cyber" coming from the Greek *kubernētēs* meaning "pilot" or "governor" and "org" from the Greek *organon* meaning "ordered system" and used by Aristotle as the title for his system of logic–leaves us with "a governed system" or "a system subjected to control." Since "cybernetics" is meant to be the science of control systems, the "cyborg" is probably best thought of as the system so brought under control. It seems to me that the term is most often used to refer to any organism which has been subjected to intentional engineering with respect to its organic functioning, and comes close to the original coining of the term: "What are some of the devices necessary for creating self-regulating man-machine systems? This self-regulation needs to function without the benefit of consciousness, in order to cooperate with the body's own autonomous homeostatic controls. For the artificially extended homeostatic control system functioning unconsciously, one of us (Manfred Clynes) has coined the term Cyborg." (from Clynes, Manfred & Kline, Nathan, "Cyborgs and Space," *Astronautics*, Sept., 1960, p. 27.) This would seem to cover not only augmentations such as artificial limbs and pacemakers, but also purely organic engineering techniques such as organ-transplants, genetic manipulation, and cloning. This definition can also be made to fit social networks and human-machine ensembles by considering the organism in question as the system constituted by one or more individual organisms and artifacts and the social and material relationships, structures, and dynamics which are relevant to its systemic organization.