

Feedback and Cybernetics: Reimagining the Body in the Age of the Cyborg

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Words have frightening power. (Colin Cherry, 1980: 68)

The *cyborg* or 'cybernetic organism' represents a radical vision of what it means to be human in the western world in the late 20th century. Although the word has an official history that dates from 1964, when it was coined to describe a special union of human organism and machine system, over the last decade it has gained a certain notoriety in both popular film culture and specialized academic circles. Films such as *Blade Runner* (1982), the *Alien* trilogy, the *Terminator* series (1984, 1991), the *RoboCop* series (1987, 1990) and the British cult classic *Hardware* (1990) present a vision of the cyborg that ranges from pure machine-based military model to genetically tailored human simulation. These models and simulations are often designed to function in hostile, dystopic, futuristic worlds governed by various kinds of renegade military/industrial or corporate activity, or the consequences of such activity. More benign protocyborg models of a less imaginary, but no less militarized form, are to be found prefigured in the kinds of revisions of masculinity that were explored in the context of the American space program's shift in emphasis from test pilot to astronaut in Tom Wolfe's 1979 bestseller *The Right Stuff* and the film of the same name. On the other hand, alternative cyborg models have been explored in a more speculative vein, and from a more cloistered academic viewpoint, in 'A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century', Donna Haraway's seminal 1985 meditation on oppositional uses of the cyborg concept.

The success of cyborg-based films and the influence of Haraway's cyborg manifesto suggest that the word 'cyborg' has functioned throughout the 1980s, in one form or another, as a keyword in Raymond Williams's sense of 'significant binding words in certain activities and their interpretation' (Williams, 1983: 15).¹

There are, however, a number of other words that paved the way for 'cyborg' and its particular 'hybrid' mode of reimagining the human body under the sign of the machine. These words, some of which have existed for decades, others for a number of centuries, include 'automaton', 'automation' and 'automatic', 'android' and 'robot'; while others like 'bionic' appeared at about the same time cyborg was coined.

Lately, we have been introduced to another word, *cyberspace*, also known as 'virtual reality', which has also begun to circulate in popular and academic discourses on the future of the human body, often in the company of the word 'cyborg' or its images. Whether in the guise of 'cyberspace', a word first coined by William Gibson in his award winning science fiction novel *Neuromancer* (1984), or in the form of 'virtual reality', the idea of a new computer-based digital mode of articulating and, indeed, of reimagining the human body has been explored in novels, including Gibson's own *Count Zero* (1986) and *Mona Lisa Overdrive* (1988), films (such as *Brainstorm* [1983] and *The Lawnmower Man* [1992]), as well as in a host of academic and popular texts.²

It is not hard to imagine, therefore, that words such as 'automaton', 'automation', 'automatic', 'android', 'robot', 'bionic', 'cyborg' and 'cyberspace' might constitute a Williamsian *cluster* of keywords inasmuch as they form a 'set of . . . interrelated words and references' (1983: 22) that plot ever-changing thresholds in the history of the human body. With the appearance of each new word, a new threshold is crossed in the perception and social construction of the human body, between conceptions of the organic and inorganic, the body and technology, the human and non-human; and, indeed, of machines themselves insofar as they can also 'be considered as organs of the human species' (Canguilhem, 1992: 55, emphasis in the original).

There are two principal ways to explore the most recent cyborg and virtual reality thresholds in the history of the body/machine interface. The first is through the word *cybernetics*. Although it was not a new word when it was introduced in 1947, 'cybernetics' was considered to be a neologism that best described a new interdisciplinary science of control and communication. Reconceptualization can, in this case, be traced through the reasons given for the choice of this particular word, its attributed meanings and, finally, its evocative powers as an analogical tool.

The second way to explore the human body's reconceptualization is to trace cybernetics' subsequent history and, in particular, its impact on how researchers reimagined the human/machine interface in the early 1960s when the word 'cyborg' was coined. From there, one can trace the reverberations of cybernetics' initial impact as *word* and 'universal' discipline (Bowker, 1993) to the mid-to-late 1980s and Haraway's socialist-feminist oppositional cyborg. Finally, there is the question of virtual reality technology or cyberspace, which must be addressed, however

briefly, since it represents the potential site and, as such, the promise, as most recent and perhaps quintessential of cyborg interfaces, for new or more developed kinds of human organism/machine system interactions.³

Identity into Pattern: Norbert Wiener, Cybernetics and the 20th-century Automaton

Norbert Wiener, a founding figure of the science of cybernetics, provides a useful overview of different phases in the development of automata. His periodization is of interest because of its focus on shifts in motive force and the way that these shifts are related to a parallel history of the body. In his classic 1948 manifesto on a new science of cybernetics, *Cybernetics: or Control and Communication in the Animal and the Machine*, Wiener presented a history of automata that was divided into four stages: a mythic Golemic age; the age of clocks (17th and 18th centuries); the age of steam, originator of the governor mechanism itself (late 18th and 19th centuries); and, finally, the age of communication and control, an age marked by a shift from power engineering to communication engineering, from, in other words, an 'economy of energy' to an economy rooted in 'the accurate reproduction of a signal' (Wiener, 1948a: 51, 50).

Wiener noted, on the other hand, that these stages generated four models of the human body: the body as a malleable, magical, clay figure; the body as a clockwork mechanism; the body as a 'glorified heat engine, burning some combustible fuel instead of the glycogen of the human muscles'; and, most recently, the body as an electronic system (Wiener, 1948a: 51). Wiener's two-fold periodization is significant because it reveals an awareness, by one of the principal founders of cybernetics, of important disciplinary phases in a machine-based history of the western body. It is also significant because it draws attention to *parallel phases* in the body's functional reimagining as a fundamental element in a machine culture.

While the 19th century was characterized by an *engineered* body, a body considered 'to be a branch of power engineering', a model whose influence had extended well into the 20th century, Wiener argued (1948b: 15) 'we are now coming to realize that the body is very far from a conservative system, and that the power available to it is much less limited than was formerly believed'. In place of a 19th-century model, he suggested that

we are beginning to see that such important elements as the neurones – the units of the nervous complex of our bodies – do their work under much the same conditions as vacuum tubes, their relatively small power being supplied from outside by the body's circulation, and that the bookkeeping which is most essential to describe their function is not one of energy. (1948b: 15)

In its place, cybernetics proposed that the body be conceived as a communications network whose successful operation was based on 'the accurate reproduction of a signal' (1948b: 15).

For Wiener, writing in the late 1940s, the 'newer study of automata, whether in metal or in the flesh, [was] a branch of communication engineering, and its cardinal notions [were] those of message, amount of disturbance or «noise» . . . quantity of information, coding technique, and so on' (1948a: 54). He went on to argue, 'in such a theory, we deal with automata effectively coupled to the external world, not merely by their energy flow, their metabolism, but also by a flow of impressions, of incoming messages, and of the actions of outgoing messages' (1948a: 54). This new way of conceiving of automata was, in theory and practice, coupled to a new kind of feedback mechanism: the servomechanism.⁴ Wiener went so far as to argue that 'the present age is as truly the age of servo-mechanisms as the nineteenth century was the age of the steam engine or the eighteenth century the age of the clock' (Wiener 1948a: 55).

The difference between servomechanisms and earlier forms of clockwork-based automata, or even systems of automatic machinery which were governed by a steam engine's governor, did not reside in their fundamental operational logic (since the earlier automata were also governed by a feedback-based logic) but rather in their ability to penetrate, through a wide variety of forms, the *social* as opposed to the industrial fabric of a nation.⁵ Instead of being limited to clockwork mechanisms or prime movers such as steam engines, the new servomechanisms were designed for a wide range of applications. These included 'thermostats, automatic gyro-compass ship-steering systems, self-propelled missiles – especially such as seek their target – anti-aircraft fire-control systems, automatically controlled oil-cracking stills, ultra-rapid computing machines, and the like' (1948a: 55). Although Wiener conceded that 'they had begun to be used long before the war – indeed, the very old steam-engine governor belongs among them', he nevertheless pointed out that 'the great mechanization of the second world war brought them into their own, and', he prophesied, 'the need of handling the extremely dangerous energy of the atom will probably bring them to a still higher point of development' (1948a: 55). Thus, what feedback and other inventions such as the vacuum tube 'made possible [was] not the sporadic design of individual automatic mechanisms, but a general policy for the construction of automatic mechanisms of the most varied type'. Wiener went on to argue that such developments, in conjunction with a 'new theoretical treatment of communication, which takes full cognizance of the possibilities of communication between the machine and machine . . . now renders possible the new automatic age' (Wiener, 1954: 153).

As Wiener pointed out, the new study of automata was emerging in tandem with

a new science of communications and control – Cybernetics – a science that proposed a completely new vision of the human body, its relationship to the organic world and the world of machines. A new set of analogies was not only establishing connections, through a series of formal correspondences, between the human body conceived as a nervous system and the machine conceived as a communicating organism, but it was also mapping out the means for the automatic linking of machine to machine by way of a common communications language.

As usual, Wiener gives us a good picture of the power and austere elegance of cybernetics' logic of analogies and its new brand of anthropomorphism when he argued:

While it is impossible to make any universal statements concerning life-imitating automata in a field which is growing as rapidly as that of automatization, there are some general features of these machines as they actually exist that I should like to emphasize. One is that they are machines to perform some definite-task or tasks, and therefore must possess effector organs (analogous to arms and legs in human beings) with which such tasks can be performed. The second point is that they must be *en rapport* with the outer world by sense organs, such as photoelectric cells and thermometers, which not only tell them what the existing circumstances are, but enable them to record the performance or nonperformance of their own tasks. This last function . . . is called *feedback*, the property of being able to adjust future conduct by past performance. Feedback may be as simple as that of the common reflex, or it may be a higher order feedback, in which past experience is used not only to regulate specific movements, but also whole policies of behavior. Such a policy-feedback may, and often does, appear to be what we know under one aspect as a conditioned reflex, and under another as learning.

For all these forms of behavior, and particularly for the more complicated ones, we must have the central decision organs which determine what the machine is to do next on the basis of information fed back to it, which it stores by means analogous to the memory of a living organism. (Wiener, 1954: 32–3)

Wiener's cybernetic automaton was conceived as an active, hierarchically governed, self-regulated and goal-oriented machine, which was bound through a particular time/space logic – the adjustment of future conduct through a comparative assessment of past actions – to its environment. This automaton marked a new threshold of intelligence, which extended beyond that which had been previously established on the basis of automated, factory based machine systems.

The particular power of cybernetics' analogical logic resided in the fact that it was able to redefine the concept of 'life' itself in order to bring it in line with a *cybernetic* automaton's operational characteristics. As Wiener noted in its connection: 'now that certain analogies of behavior are being observed between the machine and the living organism, the problem as to whether the machine is alive or not is, for our purposes, semantic and we are at liberty to answer it one way or another as best suits our convenience' (1954: 32).

If we wish to use the word 'life' to cover all phenomena which locally swim upstream against the current of increasing entropy, we are at liberty to do so. However, we shall then include many astronomical phenomena which have only the shadiest resemblance to life as we ordinarily know it. (Wiener, 1954: 32)

Instead, Wiener championed a different and far more radical point of view when he argued that it was

best to avoid all question-begging epithets such as 'life', 'soul', 'vitalism', and the like, and say merely in connection with machines that there is no reason why they may not resemble human beings in representing pockets of decreasing entropy in a framework in which the large entropy tends to increase. (1954: 32)

The claim to have side-stepped the thorny issue of 'life' went well beyond the abstract level at which it was proposed. It implied a new systemic model for the structure of organisms that was in keeping with a demise, in the 20th century, of a simple mechanistic or taxonomic view of plant or animal organization. In their place, an organism was conceived as 'a multilevel system of elaborate complexity, buffered in several dimensions so as to maintain its metabolic stability in the face of changes in its environment, and equipped with a repertoire of behaviours to ensure necessary intake of energy, materials, etc.' (Pratt, 1987: 180). In other words, an organism was now conceived as if structured according to 'sophisticated systems of control' with its brain serving as a 'top-level co-ordinator' (Pratt, 1987: 180).

The model of an organism structured according to a nest of control mechanisms was also embraced by cyberneticians (Pratt, 1987: 190, 194-6). In fact, one might argue that cybernetics operationalized the question of 'life' by displacing the concept of organism from biology to engineering, thus effectively transforming it into a hardware problem. According to its new existential parameters, Wiener's cybernetic automaton was 'organic' and 'alive' precisely because it was *operationally* active, that is, it was 'effectively coupled to the external world, not merely by [its] energy flow, [its] metabolism, but also by a flow of impressions, of incoming messages, and of the actions of outgoing messages'. A logic of cybernetic analogies ensured, in other words, that functional equivalence was established at the level of the sense-organs (Wiener, 1948a: 54), since these were the principal means by which an organism could maintain a stable, that is systemic, existence in a given environment through an exchange of information.

Yet another way of grasping the cybernetic automaton's organic nature was through the common temporality that it shared with the world of 'living' organisms. After noting that 'the relation of these mechanisms [the new automata] to time demands careful study', Wiener pointed out:

It is clear of course that the relation input-output is a consecutive one in time, and involves a definite past-future order. What is perhaps not so clear is that the theory of the sensitive automata

is a statistical one. We are scarcely ever interested in the performance of a communication-engineering machine for a single input. To function adequately it must give a satisfactory performance for a whole class of inputs, and this means a statistically satisfactory performance for the class of input which it is statistically expected to receive. Thus its theory belongs to the Gibbsian statistical mechanics rather than to the classical Newtonian mechanics. (Wiener, 1948a: 55)

It was on the basis of these observations that Wiener went on to argue that 'the modern automaton exists in the same sort of Bergsonian time as the living organism; and hence there is no reason in Bergson's considerations why the essential mode of functioning of the living organism should not be the same as that of the automaton of this type' (1948a: 56). As this argument suggests, it was no longer a question of machines functioning *as* organisms, or of organisms functioning *as* machines. Instead, the machine and organism were to be considered as two functionally equivalent states or stages of cybernetic organization.

Wiener's cybernetic automaton marks an important threshold in the history of the human body. By the late 1940s confusions arising from competing images of the human body as thinking organism were effectively exorcised through an anti-mimetic shift in the history of automata. Perhaps cybernetics' greatest achievement in this direction was to consummate the transformation which the Industrial Revolution had inaugurated in the case of automatic machinery. The cybernetic automaton's mirroring of the human body was not established on the basis of conventional mimicry, as in the case of androids and their internal parts, so much as on a common understanding of the similarities that existed between the control mechanisms and communicational organizations of machine systems and living organisms. As a result, the principle of cybernetic embodiment extended well beyond prime movers and factories to infiltrate into the sinews of the most humble piece of technology which could accommodate a servomechanism.

Previously, mimetic automata had provided visually based mechanical models for reflection on the nature of the human organism and its social, political and cultural identities. With the appearance of the cybernetic automaton, the sociology of human identity was transformed into an abstract product of cybernetic organization. In the case of Čapek's pre-cybernetic 1920s robots, for example, identity was ultimately predicated on traditional categories for the representation of difference in the products of social and industrial organizations, categories such as factory marks, color and language. In short, it was a question of National & Ethnic Robots (Čapek and Čapek, 1961: 57). Cybernetics, on the other hand, proposed a radically different solution to the fundamental nature of the human organism by proposing that its Being be reduced to an organizational *pattern*⁶ whose operational logic was also coextensive with other organisms and types of

machine systems. As Wiener emphasized at the beginning of his penultimate chapter on 'Organization as the Message' in *The Human Use of Human Beings*:

The metaphor to which I devote this chapter is one in which the organism is seen as message. Organism is opposed to chaos, to disintegration, to death, as message is to noise. To describe an organism, we do not try to specify each molecule in it, and catalogue it bit by bit, but rather to answer certain questions about it which reveal its pattern: a pattern which is more significant and less probable as the organism becomes, so to speak, more fully an organism. (Wiener, 1954: 95)

Machine and human organism exhibited the signs of life insofar as each managed to increase their level of organization. The process of functional equivalence or analogy would know no bounds since it too was defined in terms of an abstraction: organization (based on feedback) and pattern (a consequence of negentropy). By the early 1960s, the influence of this cybernetic model would reach mystic proportions in Marshall McLuhan's writings when he proposed that a 'current translation of our entire lives into the spiritual form of information' might 'make of the entire globe, and of the human family, a single consciousness' (McLuhan, 1964: 67). As an introductory text on cybernetics would later claim: 'Feedback is Universal' (Porter, 1969: 8).

Cybernetics: A Word to Bind Space and Time, a Word to Render Equivalent Living Organisms and Machine Systems

Communications theory provides one answer to the question of how words bind space and time in the service of new conceptions of the human and the human body. It does so inasmuch as it suggests that human organisms, but also human organisms and machine systems, are bound together through an exchange of 'signals in time, such as speech or music; and . . . signals in space, like print, stone inscriptions, punched cards, and pictures' (Cherry, 1980: 125; emphases in the original). But words, written and spoken, can bind time and space, human bodies and machines in other ways. They can, for example, bind bodies and machines by way of etymologically-based feedback loops that govern present and future actions according to a past set of meanings (i.e. a given field of learning). Hence words can serve, from this viewpoint, as media for instituting a history which is etymologically operationalized in a present, in a given physical (i.e. spatial) context. In fact, the word 'cybernetics' provides a good example of how words can function as feedback mechanisms and, moreover, how words might serve as powerful passageways between radically different images of the human organism.

The word 'cybernetics' was coined in 1947 to describe a new science that united communications theory, control theory and statistical mechanics under the auspices of a clear set of disciplinary objectives. Its myth of origins was presented in

a famous passage in *Cybernetics: or Control and Communication in the Animal and Machine*:

Thus as far back as four years ago [1943], the group of scientists about Dr. Rosenblueth and myself had already become aware of the essential unity of the set of problems centering about communication, control, and statistical mechanics, whether in the machine or in living tissue. On the other hand, we were seriously hampered by the lack of unity of the literature concerning these problems, and by the absence of any common terminology, or even of a single name for the field. After much consideration, we have come to the conclusion that all the existing terminology has too heavy a bias to one side or another to serve the future development of the field as well as it should: and as happens so often to scientists, we have been forced to coin at least one artificial neo-Greek expression to fill the gap. We have decided to call the entire field of control and communication theory, whether in the machine or in the animal, by the name *Cybernetics*, which we form from the Greek κυβερνήτης or *steersman*. In choosing this term, we wish to recognize that the first significant paper on feed-back mechanisms is an article on governors, which was published by Clerk Maxwell in 1868, and that *governor* is derived from a Latin corruption of κυβερνήτης. We also wish to refer to the fact that the steering engines of a ship are indeed one of the earliest and best developed forms of feed-back mechanisms. (Wiener, 1948a: 19; emphases in the original)

While Wiener acknowledged that 'the term *cybernetics* does not date further back than the summer of 1947', he argued that 'we shall find it convenient to use in referring to earlier epochs of the development of the field' (1948a: 19).⁷

Wiener presented the *raison d'être* of a new universal science, in this celebrated passage, a science whose *interdisciplinary* coherence resided in its ability to bind different fields of knowledge associated with machine systems and living organisms according to a shared textual frame (a common body of texts); a uniform terminological frame of reference; and, finally, a unique *name* that could be used to unify the field in terms of a single genealogy (Maxwell) and metaphor (the feedback mechanism and its readily accessible image of the steersman). One notes, furthermore, that 'cybernetics' and the new interdisciplinary science to which it referred were considered to be modern western creations both in terms of their founding figures (whether Maxwell or Wiener and his colleagues) and their common New World frame of reference (North America), if not in its subsequent influence.⁸

As Wiener clearly acknowledged, the choice of the word 'cybernetics' was the result of a carefully orchestrated etymological exercise. It was not surprising, therefore, that the word embodied a coherent notion of space and time, knowledge and disciplinary identity, for it encompassed a past history of feedback mechanisms, rendered coherent a given set of problems and interrelationships, and projected a future path of development under the auspices of a phantom steersman. The progressive unfolding of this path, and moreover of society (insofar as it too was conceived as a cybernetic organism),⁹ was guaranteed by its *own* root metaphor

(the feedback mechanism) and its ability to 'adjust future conduct by past performance' (Wiener, 1954: 33). But words can also operate in a different register beyond a particular threshold of comprehension and control. They can function as perceptual thresholds insofar as they unlock and reveal a whole parallel world which gives sense to their roles and functions of *binding space and time*. In the case of cybernetics, this other world was created in a two-fold manner.

In the first place, 'cybernetics' ascribed meaning and etymology could function as both map and vehicle to reproduce and propagate a new interdisciplinary science's universalist world-view. Twenty years after the publication of *Cybernetics: or Control and Communication in the Animal and the Machine*, one finds, for example, on the contents page of a 1968 special issue of *Studio International* devoted to the exhibition 'Cybernetic Serendipity' at the Institute of Contemporary Arts, London, a simple and elegant definition of Wiener's interdisciplinary science: Cybernetic – 'adj. of cybernetics – a science of control and communication in complex electronic machines like computers and the human nervous system'. It was a definition which, as was later acknowledged (p. 9), was derived from the subtitle to Wiener's first book on cybernetics.

Both word and definition served as introductions to a new kind of interdisciplinary technology-based artistic practice whose all-encompassing powers of vision and creation were displayed for all to see in an exhibition and catalogue, the culminations of a three-year project which encompassed 'computers, cybernetics, electronics, music, art, poetry, machines, as well as the problem of how to present this hybrid mixture'. The project also chronicled the effects of opening the domain of art to other practices and practitioners such as those of the 'engineer, mathematician, or architect' whose products were no longer distinguishable on individual disciplinary grounds (Reichardt, 1968a: 5). 'Cybernetic Serendipity' was, as such, a worthy offspring of a cybernetic world-view.

However, the definition can also be viewed as functioning from a slightly different perspective. If the exhibition and its catalogue succeeded in their attempts to 'present an area of activity which manifests artists' involvement with science, and the scientists' involvement with the arts', and if they succeeded in showing 'the links between the random systems employed by artists, composers and poets, and those involved with the making and the use of cybernetic devices' (Reichardt, 1968a: 5), then they did so under the auspices of a definition which was resolutely binary in its spatial and temporal logics. Not only were control *and* communication linked to computers *and* the human nervous systems according to a doubly articulated binary logic, but the set of relationships was presented in a form that mirrored, in a universalist and transhistorical manner, the articulated point of view first presented in the subtitle of Wiener's 1948 book on cybernetics: *Control and Communication*

in the *Animal and the Machine* (my emphases). In other words, while the definition bound together the separate spaces of computer and human nervous system, it also bound a 1968 British art exhibition to a 1948 founding text on cybernetics in a manner that suggests the presence of a ghostly feedback loop – and this in spite of conceptual transformations produced by cybernetics' migration across geographical boundaries.¹⁰ Thus Wienerian cybernetics' authoritative presence as a 'text' of origins and universal blueprint in the context of an important British art exhibition, points to its ongoing powers to unlock, as if by magic (but, in fact, according to a logic of feedback), a set of passageways between disciplinary domains, machine and biological systems, and, perhaps most significantly, consciousness and creativity.

The second way that a word might reveal a whole parallel world which can give sense to its role and function of binding space and time is through an interconnected series of analogies and metaphors *which are authorized in its name*. In this case, the word operates at a distance, so to speak, as in the case of Wiener's metaphor of the organism as message (1954: 95), or his exploration of the functional analogy between 'automatic machines and ... the human nervous system' (1948b: 14), which were authorized by a founding name and the conceptual domain and interdisciplinary practice to which it referred. Inasmuch as cybernetics was conceived as an interdisciplinary practice which linked a past (Maxwell) to a future articulated through the fictive actions of a steersman (Wiener's phantom double?), whose operating logic was that of a feedback mechanism, and insofar as cybernetics linked systems of control *and* communications in animals *and* machines according to the same logic and practice, it set the stage for an exceptionally powerful process of remapping and reimagining the boundaries of the human body.

A series of correspondences, analogies and metaphors were used to bridge different domains of knowledge according to a new universal world-view or a 'new economy of the sciences' whose apex was no longer to be found, as in the past, in physics (Bowker, 1993: 117, 118–19).¹¹ New terms of reference such as feedback, message and noise functioned to reduce heterogeneous fields such as telephone engineering and the body's nervous system, the analogue computer and the human brain to a common viewpoint originating in control and communications theory and their engineering practices. As one commentator later noted: 'the ideas of feedback and information provide a frame of reference for viewing a wide range of situations, just as do the ideas of evolution, of relativism, of axiomatic method, and of operationalism' (Simon, 1981: 194). Indeed, the explosion of cyborg or human/machine images in recent American science fiction films is testimony to the continued influence of a cybernetic model, albeit a looser and more speculative *visual* model, on patterns of human development.¹²

On the other hand, there was no obvious guarantee that the adoption of a given

metaphor or analogy would automatically lead to a revolution in human thought and perception. If feedback and information could provide a common frame of reference, then this correspondence might have been achieved through a radical and ultimately damaging simplification of existing complexities. As Herbert A. Simon has pointed out, 'metaphor and analogy can be helpful, or they can be misleading. All depends on whether the similarities the metaphor captures are significant or superficial' (Simon, 1981: 193). Moreover, Colin Cherry, another leading figure in the field of communications theory, has suggested, in his critique of the brain/computer analogy and similar kinds of analogies (Cherry, 1980: 301-4), that the fruitful use of analogies is also determined by an appropriate focus and threshold of visualization. An analogy or metaphor that is pushed too far could prove to be as damaging as a false or superficial analogy.

Indeed, the ultimate success of cybernetics' analogical system was based on the point of view adopted in regard to mechanical structure. Cherry has argued, for example, that 'early invention was greatly hampered by [an] inability to disassociate mechanical structure from animal form' (Cherry, 1980: 59). Thus, in the case of the brain, 'it is not the machine which is mechanistically analogous to the brain but rather the *operation* of the machine plus the instructions fed into it' (Cherry, 1980: 57; emphasis in the original). What was at issue, as Cherry noted with approval in connection with Wiener's use of analogical thought, was a *fundamental* distinction between mimetic and functional analogies (Cherry, 1980: 57, 58) – a distinction which had been sharpened when the 'newer study of automata' had been reduced to a 'branch of communications engineering' (Wiener, 1948b: 15). Thus Cherry's objections to popular extensions of the brain/computer analogy (with their propensity to encourage 'animistic' models), and his charges that they obscured and simplified the working of the brain (to the extent of generating pseudo-questions such as 'Can a machine think?' [Cherry, 1980: 246]), was the product of a particular disciplinary perspective which sought to cleanse scientific practice of anthropomorphic residues.

The binding powers of metaphors and analogies could, as these criticisms suggest, work in both directions. They could create fields for investigation or they could just as easily curb investigation through seduction, the spells cast by simple, clear and elegant images or relationships, as in the case of the computer as mind/mind as computer analogy.

By opening up a whole range of investigations under its semantic auspices, cybernetics not only functioned as a keyword in Williams's sense of the term, but it also served as a powerful feedback-based chronotope¹³ that could operate between the human body and world of machines. The traffic of ideas across this chronotopic interface was facilitated by the use of a cluster of technical words that mapped an

architecture of communication within, across and between the worlds of machines and living organisms. For example, if homeostasis regulated an inner cybernetic environment, then feedback regulated the relationship between 'inner' and 'outer' environments (Simon, 1981: 9) according to information which was itself conceived as simply 'a name for the content of what is exchanged with the outer world as we adjust to it, and make our adjustment felt upon it' (Wiener, 1954: 17).

Thus, if, as Wiener observed, 'where a man's word goes, and where his power of perception goes, to that point his control and in a sense his physical existence is extended' (Wiener, 1954: 97), then the word 'cybernetics' not only extended Wiener's presence as (co-)founder of this new field but, more importantly, it extended a temporal logic (through the principle of feedback) as well as a system of analogies across the many disciplines which absorbed cybernetics' name as a prerequisite for access to its vocabulary and methodology. In this sense, as one historian has recently pointed out (Bowker, 1993: 122), 'cybernetics could operate either as the primary discipline, directing others on their search for truth, or as a discipline providing analytic tools indispensable to the development and progress of others'.

Moreover, as cybernetics extended its powers over diverse fields or adherents, it extended its temporal hold over them in such a way as to bind them according to a common perceptual space, since perception was, in cybernetic terms, simply a medium for the regulation of active feedback,¹⁴ and the principle of feedback was what allowed cybernetics as a discipline to survive in the world of ideas. Thus, in a specific Williamsian sense, the word 'cybernetics' encapsulated the special transformations it was created to describe; and, of course, included among these was a new model of the human organism and its identity.

From Cybernetic Automaton to Cyborg: Shifting Thresholds in the Human/Machine Interface

Wiener would state, as the opening sentence in a 1948 *Scientific American* article, that 'cybernetics is a word invented to define a new field in science' (1948b: 14). His optimism was based, as we have seen, on this field's potential range and depth of interpretation. For the word and field to which it referred was designed to encompass the human mind, the human body and the world of automatic machines and reduced all three to a common denominator: 'control and communication' (1948b: 14).

As we have also seen, the root metaphor for this enterprise was the feedback mechanism, a mechanism, moreover, which 'governed' the traffic in ideas between the domain of communications theory, with its concrete parallel world of

mechanical or electronic switches and circuits, the human body's neural pathways and, ultimately, its brain. In short, cybernetics theory and its system of analogies was in a position to inject a new type of engineering language into the living human body's nervous system, a language that could pave the way for the human body's reimagining in relation to a history of automata.

It was the concept of feedback, in particular, that provided the means for a more extended process of reimagining since it opened the way for the electrical and, ultimately, the electronic *collectivization* of the human body – a collectivization that would reach planetary proportions in McLuhan's metaphor of a global village and its information-based consciousness. Access to this extended model of a cybernetic body was guaranteed by the 'ubiquity of feedback' – an ubiquity that signified that 'interaction [was] everywhere'. For it was this kind of ubiquity that could inaugurate a shift of 'attention away from an individualism that had highlighted [a] noncircular cause-and-effect [world-view] and from the individual person – as if he or she could be independent of others and even independent of chance events occurring in the environment' (Heims, 1993: 271–2). Translated into McLuhanesque terms, feedback was a privileged gateway to a collective electrically-based global consciousness (McLuhan, 1964: 64, 311), not only because it erased the distinction between automated machines and living organisms, but also because it marked, from a communications point of view, 'the end of the lineality that came into the Western world with the alphabet and the continuous forms of Euclidean space' (McLuhan, 1964: 307). It was on the basis of such a logic and world-view that cybernetics and its attendant vocabulary could disseminate the image of a new kind of body to a wider disciplinary field and, further, to a non-specialized general public.

In fact, it was a short step from invoking a functional analogy between machine and human organism in the 1940s to the 1960s and Marshall McLuhan's influential notion of a technology that functioned as 'an extension or self-amputation of our physical bodies', a technology that produced 'new ratios or equilibriums among the other organs and extensions of the body' (McLuhan, 1964: 54). Since they were clearly based on a cybernetic model, McLuhan's ideas were a belated acknowledgement of the fact that the human body had already been irrevocably transformed in the context of cybernetics. Even McLuhan's evocation of an extended nervous system (1964: 64) retains a metaphoric resonance which is lacking in the cybernetic concept of organism as 'local enclave in the general stream of increasing entropy' (Wiener, 1954: 95). Hence, it is no wonder that by the time these ideas had reached a wider public through McLuhan's writings, consciousness had long since taken the radical form of a ratio between the senses (McLuhan, 1964: 67). Wiener's first book, *Cybernetic: or Control and Communication in the*

Animal and the Machine, had been published in 1948, and his popular account of cybernetics, *The Human Use of Human Being*, in 1950. These books had already proposed to a general public that the human body be radically reimagined, its identity to become an organizational singularity and its intelligence simply a pattern among many such patterns.

In 1962, two years before the publication of *Understanding Media*, McLuhan's influential introduction to the post-war world of Western media, and 14 years after the introduction of the word 'cybernetics', two American scientists introduced an important corruption of that word. They did so in order to identify a new kind of human/machine interface, a new type of 'organism'. Since that time, this organism has had a powerful hold on the way the body is imaged, imagined and constructed at the outer limits of western science, technology and industry, as well as at the outer limits of its military and aerospace industries. This hold has even extended to university-based as well as non-university-based intellectual and artistic speculations on the future of the human body. Moreover, this organism's fundamental impact on the construction of a Western Imaginary can, one suspects, be traced to the fact that it reintroduces mimesis in the shape of anthropomorphism back into the history of automata.

The neologism 'cyborg' (from cybernetic organism) was proposed by Manfred E. Clynes and Nathan S. Kline in 1960 to describe 'self-regulating man-machine systems' and in particular an 'exogenously extended organizational complex functioning as an integrated homeostatic system unconsciously' (Clynes and Kline, 1960: 27). The technical density of the definition was a function of its proposed sphere of operations: the application of cybernetic controls theory to the problems of space travel as they impinged on the neurophysiology of the human body. In fact, a special kind of 'artifact organism' – the cyborg – was posited as a solution to the question of 'the altering of bodily functions to suit different environments' (Clynes and Kline, 1960: 26). For these researchers, alteration of the body's ecology was to be effected primarily by way of sophisticated instrumental control systems and pharmaceuticals. Thus, 'the purpose of the Cyborg, as well as his own homeostatic systems' was, according to these early pioneers, 'to provide an organizational system in which such robot-like problems [as the body's "autonomous homeostatic controls"] are taken care of automatically and unconsciously, leaving man free to explore, to create, to think, and to feel' (Clynes and Kline, 1960: 27). And as the references to 'his' and 'man' indicate, this problematic was gender specific.

In its most extreme form, Wiener's cybernetic organism could take the form of pure information – 'human information' (Wiener, 1954: 104) – nothing more than a given 'pattern maintained by . . . homeostasis, which [was] the touchstone of [a]

personal identity' to be transmitted as a message because it was in the first place a message (1954:96). In contrast, the Clynes/Kline cyborg represented a different, more immediate and practical solution to the one that was envisioned by the early cyberneticians inasmuch as it was designed to withstand the rigors of space travel, while nevertheless adopting cybernetics' fundamental principles, in particular feedback and homeostasis.

Although initially designed for space travel, the transformative implications of this new type of cybernetic organism were far-reaching. As Clynes subsequently pointed out in a Foreword to *Cyborg – Evolution of the Superman*, a popular account of the cyborg phenomenon published by D.S. Halacy in 1965: 'a new frontier is opening which ... is not merely space, but more profoundly the relationship of "inner space" to "outer space" – a bridge being built between mind and matter, beginning in our time and extending into the future'. He went on to argue that the cyborg was more flexible than the human organism because it was not bound throughout a lifetime by heredity. Indeed, the cyborg was a reversible entity precisely because it was a 'man-machine combination' (Halacy, 1965:7). This reversibility, combined with the fact that 'man-made devices' could 'be incorporated into the [human body's] regulatory feedback chains', produced a stage of evolution that was *participatory* (Halacy, 1965:8). Hence, if automatic machines held the promise of another form of human intelligence, then cybernetics redefined that intelligence in such a way that the Clynes/Kline cyborg could become its most perfect embodiment: 'a new and ... better being' (Halacy, 1965:8).

In 1985, 'cyborg' was appropriated, as a consequence of its polysemic resonances, by a socialist-feminist historian of biology, Donna Haraway. It was used in this case for a different social purpose, 'rhetorical strategy and ... political method' (Haraway, 1991:149). For Haraway the cyborg was not only a 'hybrid of machine and organism', it was also a 'creature of social reality as well as a creature of fiction' (Haraway, 1991:149). Within a new semantic context provided by socialist-feminist discourses on the gendered body, she argued that this word could function as 'a fiction mapping ... social and bodily reality and as an imaginative resource suggesting some very fruitful couplings' (Haraway, 1991:150).

In contrast to the Clynes/Kline cyborg, which was conceived as a 'superman' capable of surviving hostile non-earth environments, Haraway's cyborg was a product of late-capitalist earth. In keeping with its traditional ecology, it was re-fashioned along the lines of an entity that could transgress earth-bound social/symbolic boundaries between human and animal, animal-human (organism) and machine, and the physical and non-physical (Haraway, 1991:151–3). Transgression was, moreover, negotiated (in keeping with its late 20th-century context)

both in terms of science fiction and the everyday cultural worlds of postmodernism and post-colonial multinational capitalism.

Haraway's cyborg exhibited two other characteristics which distinguished it from the Clynes/Kline cyborg and more recent popular cyborg images, such as those presented in the *RoboCop* and *Terminator* series. As an offspring of *feminist science fiction*, Haraway's cyborg was conceived to be 'a creature in a post-gender world', and inasmuch as it was conceived as a social and political mentor, it was pictured (in keeping with its 'illegitimate' origins) as 'oppositional, utopian, and completely without innocence' in the sense that it was 'resolutely committed to partiality, irony, intimacy, and perversity' (Haraway, 1991:150, 151). It was in these multiple senses that Haraway suggested that the cyborg could become 'our ontology' and that it could give 'us our politics' (Haraway, 1991:150). For its transgressive ontology and politics ensured that it was able to effectively circumvent, in spirit if not in name, its military/industrial origins (Haraway, 1991:150).

The immediate origins of the word 'cybernetics' can be traced, as Wiener suggested, to military research coupled with a specific post-war interdisciplinary university-based research programme (Heims, 1993; Bowker, 1993). 'Cyborg' exhibited a similar genealogy with, however, a different inflection since it was the hybrid product of the United States' space programme and a medical research laboratory (both Clynes and Kline were at the time [1960] researchers at Rockland State Hospital, Orangeburg, New York). On the other hand, Haraway's socialist-feminist cyborg was the joint creation of mid-1980s political activism and academic radicalism. The distinction between the two categories of cyborg can be traced to their authors' respective backgrounds. While the body's physiological ecology ('the body-environment problem' (Clynes and Kline, 1960:26) determined its early semantic field, Haraway's academic socialist-feminist background was the determining factor in her rearticulation of the cyborg's politics and gender.

Haraway's cyborg was, as such, a perfectly crafted image for a 1980s vision of a late 20th-century oppositional consciousness, especially since it embodied all of the contradictory characteristics of a decade which defined its cultural and political practices, in the context of radical academic theory, in terms of postmodernist and post-colonial criteria of partiality, hybridity, pastiche and playful irony. As one cultural theorist would later note in its connection, 'transgressed boundaries, in fact, define the cyborg, making it the consummate postmodern concept' – or, from a reverse perspective, 'uncertainty is a central characteristic of postmodernism and the essence of the cyborg' (Springer, 1991:306, 310). Indeed, as an oppositional cyborg's multiple articulations suggested, and as Clynes had already suggested in 1965, this most recent of reconceptualizations in the domain of automata was symptomatic of the body's uncertain future in the mid to late 20th century.

A hardware-based cyborg integrates or interfaces, in its most extreme and evocative form, a human body with a pure technological environment (machine elements, electronic components, advanced imaging systems). Clearly, under such circumstances technology becomes the determining factor in the definition of the body's physical rearticulation, the material foundations for its sense of performed identity. Although traditional domains of bodily differences such as those that are subsumed under the rubrics of ethnicity and gender are still operating in the case of popular cyborg imagery (Springer, 1991), one can imagine, as Haraway has done, that these differences might eventually be eclipsed by a technologically-based system of similarities and differences. Instead of describing this body primarily in terms of age, ethnicity or gender, or even in Haraway's hybrid post-ethnic or post-gendered terms, a more accurate description is perhaps to be obtained by treating a reimagined cyborg body as a *technological* entity whose definitive characteristics are to be plotted according to a system of technicity (Tomas, 1989). Such a system would not only have to take account of the plasticity of the cyborg's politics and identity, it would also have to account for its operating principles, such as those of speed, manoeuvrability and force, as well as its participatory logic, rooted as it is in a trinity of cybernetic adaptability: communication, information and feedback.

Postface: Virtual Reality and the Cyborg as Pure Data Construct

Wiener's evocation of the human body conceived as pure information brings to mind virtual reality technology with its promise of a common global digital space – a kind of second atmosphere, whether one models it after McLuhan's extended consciousness whose embodiment was to be found in the 'spiritual form of information' (1964: 67), or William Gibson's often quoted definition of cyberspace: a 'consensual hallucination' experienced by 'billions' of computer operators (Gibson, 1984: 51).

The bridge of cybernetics and its living organism-as-pure-information paradigm links the worlds of cyborgs and virtual reality. In doing so it also serves as a juncture that marks an important division or, more accurately, a branching in the history of automata. One path from this juncture leads into outer space, while the other route leads into a kind of meta-atmosphere composed of a pure digitalized electronic information. The human body is, in this latter context, reimagined and reimagined to be an inconsequential historical residue, a kind of chimera, or puppet (Walser, 1991), an *automatonic* image which is subject to almost infinite manipulation. Thus the 'basic job of cyberspace technology, besides simulating a world, is', as one researcher has noted, 'to supply a tight feedback loop between patron and puppet,

to give the patron the illusion of being literally embodied by the puppet (i.e., the puppet gives the patron a virtual body, and the patron gives the puppet a personality)' (Walser, 1991: 35).

It is therefore not surprising, given the possibility for an almost perfectly transparent sense of manipulation, that 'the possibilities of virtual realities' are considered by some to be 'as limitless as the possibilities of reality' – a distinction and conjunction which is founded on this technology's potential power to provide a 'doorway to other worlds' which is based on a 'human interface that disappears' (Fisher, 1991: 109). As these comments and those on the role of feedback in binding a human patron and cybernetic puppet suggest, virtual reality is, in fact, a manifestation of a cybernetician's ultimate dream: a pure information space which can be populated by a host of pure cybernetic automata or, in Gibson's more precise and less anthropomorphic terms, data constructs.

It is in the context of this seamless boundary between the body and technology that we now return to the figure of the automaton and note, as one researcher has recently pointed out, that:

the craftsman of the last century shaping the motion of the elaborate clockwork characters by painstakingly filing cams is much like the programmer iterating toward an algorithm for animating computer graphic human motion, or defining plastic deformations of facial expression. (Lasko-Harvill, 1992: 226)

If the Clynes/Kline cyborg offered a participatory solution to the problem of survival in hostile environments, then it did so through a radical fusion of the human/machine interface as first proposed in the context of classical mimetic automata. The astronaut/cyborg and later science fiction models were and are conceived as post-Industrial Revolution androids that embody the power of prime movers coupled with sophisticated sensory and control systems. These hardware-based cyborgs exhibit android form, robot power and cybernetic intelligence and are designed to function in extremely hostile environments. At one point in *The Human Use of Human Beings*, for example, Wiener had suggested that 'we have modified our environment so radically that we must now modify ourselves in order to exist in this new environment' (1954: 46). In retrospect, it is easy to see that the Clynes/Kline cyborg was a hardware-based solution to this kind of problem. While the first cyborg was initially designed for space travel, modification and adaptation can take as many forms as are needed for the conquering and colonization of non- or anti-human environments. Indeed, Haraway's post-gendered oppositional cyborg suggests that such environments extend to the conflicting and hostile worlds of ideas.

Perhaps conquest provides the most appropriate frame of reference through which to view the cyborg's most recent computer-based transformations since its

new form is the product of a special problem in human adaptation: namely, how to exist in an environment that consists of pure information. The answer is, as Wiener first pointed out, provided by cybernetics: one transforms the human organism into a pattern of pure digital information. Adaptation is, as a result, perfect and complete since organism and environment are conceived in similar terms.

This most extreme of all cybernetic visions, a final and radical solution to the problem of environmental mutations and ensuing adaptation, provides a kind of 'terminal' answer to the question of the direction of the human organism's 'evolution' in the late 20th century. Insofar as 'the interface between the user and the computer may be the last frontier in computer design' (Foley, 1987: 127), then this interface may also be the last frontier in the design of human beings and, as such, the key to the diversity of cybernetic patterns that can colonize and populate virtual reality in the name of one of western modernity's root metaphors – the feedback mechanism – and in the name of one of its keywords: cybernetics.

Notes

This paper is part of book-length work that examines the relationships between the cyborg concept and late 20th-century imaging systems, including virtual reality. Its orientation is towards a critical investigation of current cultural practices and specifically oppositional practices in the arts. Earlier versions of this paper were presented at a conference on 'Body Images, Language & Physical Boundaries', University of Amsterdam, Amsterdam, in July 1993, and at the University of Windsor, Windsor, Ontario, in November 1993. A working version of this paper was published as a chapter in Murray (1994). I would like to thank all those who commented on the paper in its various versions.

1. For an extended discussion of this practice see Williams (1983: 15, 22–5).
2. A recent sampling would include the (Richards et al., 1991) collection of texts in *Bioapparatus*, Lasko-Harvill (1992), Balsamo (1992), Stone (1991, 1992). Balsamo (1993: 135 fn. 13) contains a list of recent publications in the popular press devoted to virtual reality.
3. In this connection, I stress my use of the word 'promise', since at each stage exclusions are as important as inclusions in the ongoing construction of actual and possible histories.
4. A servomechanism is a form of automatic feedback control system 'in which the motion of an output member . . . is constrained to follow closely the motion of an input member, and in which power amplification is incorporated' (Porter, 1969: 55).
5. I deal with earlier forms of automata more fully in an earlier version of this paper (Tomas, 1994).
6. 'It is the pattern maintained by this homeostasis, which is the touchstone of our personal identity' (Wiener, 1954: 96).
7. Although the word had an earlier historical currency, since the word 'cybernétique' was used by the French physicist André-Marie Ampère in 1843 to denote a 'science of government' (Ampère, 1843: 140–1), Wiener's reintroduction of the term stands as the origin for its contemporary use.
8. 'I am writing this book primarily for Americans in whose environment questions of information will be evaluated according to a standard American criterion: a thing is valuable as a commodity for what it will bring in the open market' (Wiener, 1954: 113).
9. See also Wiener (1954: 26–7): 'It is my thesis that the physical functioning of the living individual

and the operation of some of the newer communications machines are precisely parallel in their analogous attempts to control entropy through feedback. Both of them have sensory receptors as one stage in their cycle of operation: that is, in both of them there exists a special apparatus for collecting information from the outer world at low energy levels, and for making it available in the operation of the individual or of the machine. In both cases these external messages are not taken *neat*, but through the internal transforming powers of the apparatus, whether it be alive or dead. The information is then turned into a new form available for the further stages of performance. In both the animal and the machine this performance is made to be effective on the outer world. In both of them, their *performed* action on the outer world, and not merely their *intended* action, is reported back to the central regulatory apparatus.' Wiener went on to note that not only is 'this complex of behavior . . . ignored by the average man . . . [but it] does not play the role that it should in our habitual analysis of society; for just as individual physical responses may be seen from this point of view, so may the organic responses of society itself'. Communication was thus conceived from a cybernetic point of view to be 'the cement which binds' society's 'fabric together'.

10. As Cherry has noted, for example, 'the word "cybernetics" is little used in Britain, but rather the term "control systems" is employed', while 'the French often use "la cybernétique" to correspond with "information theory" in Britain', which, in turn, 'is unfortunately used elsewhere synonymously with communication theory', the latter being sometimes referred to, in France, by the word 'cybernetics' (Cherry, 1980: 58, 217).

11. For a detailed discussion of the strategies underlying cybernetics' universalism see Bowker (1993). Bowker's excellent discussion does not, however, focus on the universalist semantics of the word 'cybernetics' itself. For a discussion of cybernetics, its cluster of metaphors and powers of synthesis see Heims (1993: 248–72).

12. Note in this connection the spectacular narrative consequences of the whole problematic of controlling the future in terms of a past which is itself the basis for an already existing future in the *Terminator* series.

13. In his celebrated essay 'Forms of Time and of the Chronotope in the Novel', Mikhail Bakhtin proposed that similar processes of time/space binding, in the case of the novel, be identified by the word *chronotope*. In his words, 'we will give the name *chronotope* (literally, 'time space') to the intrinsic connectedness of temporal and spatial relationships that are artistically expressed in literature' (Bakhtin, 1981: 84). While he noted that the chronotope existed in other areas of culture he did not pursue its investigation in these domains. Instead, he suggested that 'in the literary artistic chronotope, spatial and temporal indicators are fused into one carefully thought-out, concrete whole', and continued: 'Time, as it were, thickens, takes on flesh, becomes artistically visible; likewise, space becomes charged and responsive to the movements of time, plot and history' (1981: 84). While Bakhtin remained sensitive to the metaphoric uses of the mathematical concept of space-time in the case of literary chronotopes ('The special meaning it has in relativity theory is not important for our purposes; we are borrowing it for literary criticism almost as a metaphor (almost, but not entirely)' [1981: 84]), in the 1973 conclusion to his extensive study he argued for its extension well beyond literary boundaries and concluded: 'For us the following is important: whatever these meanings turn out to be, in order to enter our experience (which is social experience) they must take on the *form of a sign* that is audible and visible for us (a hieroglyph, a mathematical formula, a verbal or linguistic expression, a sketch, etc.). Without such temporal-spatial expression, even abstract thought is impossible. Consequently, every entry into the sphere of meanings is accomplished only through the gates of the chronotope' (1981: 258).

14. 'Th[e] control of a machine [or organism since these modes of organization were by analogy interchangeable terms] on the basis of its *actual* performance [feedback] . . . involves sensory members which are actuated by motor members and perform the function of *tell-tales* or *monitors* – that is, of elements which indicate a performance. It is the function of these mechanisms to control the mechanical tendency toward disorganization; in other words, to produce a temporary and local reversal of the normal direction of entropy' (Wiener, 1954: 24–5).

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