Genesis

Life at the end of the information age

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Cyber-netics

John Tresch

The term 'cybernetics' refers to a set of approaches for studying the flow of information and communication. It considers how messages are sent, received and obeyed at various points of any system – whether brain, body, computer, factory or society. Using cybernetic terminology, all such systems can be considered as functionally analogous; since their systematic properties depend purely on relations of 'information', they may be treated as identical. Thus cybernetics treats machines and organisms in exactly the same way. Cybernetics first came into existence in a series of interdisciplinary conferences sponsored by the Josiah Macy Jr. Foundation between 1946 and 1953 under the guidance of the MIT mathematician Norbert Wiener. Originally entitled *Circular Causal and Feedback Mechanisms in Biological and Social Systems* the meetings generated a vocabulary for looking at the processes by which systems regulate themselves, merging perspectives from engineering, biology, mathematics, psychology and the social sciences.

The defining notion of cybernetics is the 'feedback loop', the circular causal mechanism of the Macy conferences' original title. Wiener wrote: "The control of a machine on the basis of its *actual* performance rather than its *expected* performance is known as 'feedback', and involves sensory members which are actuated by motor members and perform the function of 'tell-tales' or 'monitors'."[1] Wiener's own first work in the field, during World War II, involved the design of self-correcting weapons: missiles aimed at a target which changed its course, and thus had to adjust their direction according to input from the external world, i.e. the target's changing trajectory.

To understand cybernetics' approach towards questions of information and control, the word's origin is relevant: the Greek root for cybernetics, *kybernetes*, literally means the helmsman of a ship. Steering a boat is not a matter of simply holding a rudder pointed in a fixed direction. Instead it requires constant adjustments to its position, depending on cues given by several different kinds of sensory input: the feeling of resistance on the rudder's handle, which can require more or less exertion to keep fixed; the tell-tales which indicate the position of the wind; and above all, the visual input of the destination, if one is sailing towards a buoy or landmark. It is not a question of simply setting a course and going: one oversteers, one understeers, and most importantly one 'corrects' the rudder's direction on the basis of the changing signals provided by these indicators. Cybernetics stresses that keeping a steady state or a fixed direction requires constant modifications in response to information gathered from the surrounding milieu.

Another frequently cited example is the thermostat, a device that senses changes in room temperature and uses that information either to increase or decrease the heat supplied to the room. Although the sensor is constantly at work, and the heat source may be modifying its output, the room temperature remains the same. The thermostat is a 'homeostatic mechanism' that uses 'feedback' or self-regulation on the basis of sensory observations of its own state and the state of its environment to maintain a 'dynamic equilibrium'. Cybernetics has applied such notions productively to Watt's steam engine, with its centrifugally spinning 'governor' crafted to

[1] Norbert Wiener, *The Human Use of Human Beings: Cybernetics and Society*. Boston, MA: Houghton-Mifflin, 1954, p. 24.

keep the engine running at a steady pressure. Likewise it has been applied to the adjustments made by the counterbalancing muscles that regulate motor function, and whose disequilibrium results in overcompensation and Parkinsonian tremors. Further, the ensemble of self-monitoring processes directed by an organism's nervous, immune, and reproductive systems – including, especially, DNA – has been analysed as cybernetic loops of information and response. In most of these examples, no 'consciousness' in the sense of an intentional mind is needed. All that is required is 'information' and the sense organs, natural or artificial, to perceive and act upon it.

For cybernetics, information is order – a pattern of differences. It may be as simple as the difference between a 1 and a 0, the presence or absence of an electrical signal or the codes and cues running through the most elaborate calculating engine, brain, body or ecological system. Information resists the universal tendency towards entropy or loss of order, a tendency in both machines and organisms. This identification was visible in the early robots designed by the first generation of cyberneticists. These 'sensitive' machines such as Grey Walter's light-seeking 'tortoises' (which exhibited 'social' and 'narcissistic behaviour) and Claude Shannon's labyrinth-tracking 'mouse' observed and responded to their environment.

Beyond such whimsical identifications between animals and machines, cybernetics has had a major impact on the sciences of life. It has contributed heavily to the metaphor of DNA as 'information'. According to this widespread approach, DNA is treated as a script or program that is faithfully replicated and enacted in an uninterrupted chain. This assumption underwrote what Francis Crick called the 'central dogma of molecular biology: that during the process of replication, DNA and RNA do not interact in any significant way with the cell's nucleic acid. Crick later said that he could just as easily have called this claim a hypothesis; it was simply an unproven assumption that could be used to guide research.[2] Interestingly, however, this 'dogmatic' assumption implies that DNA itself functions as a kind of 'dogma' within the system of a cell: the 'message' is received and replicated with the same faithfulness and determinism as an unquestioning member of a church obeys orthodox proclamations.

Yet the process of information transfer implied by the central dogma may be critiqued in terms that also derive from cybernetics. The field's basic concern is to establish the conditions under which a message can be sent and received with integrity. This means that the deterministic, encapsulated transmission implied by the central dogma can only be assured by constantly monitoring its passage and sites of possible modification. Cybernetics must embrace the endless opportunities for alterations of the message: disturbance, randomness or *noise*. This means careful attention all along the course of the message to the mechanics of sending and receiving, securing channels, passing through various states, and maximising redundancy. What is true of sound transmission is true for genetic information: "the efficient use of amplitude modulation or any other form of modulation must be supplemented by the use of decoding devices adequate to transforming the received information into a form suitable for reception by human receptors or use by mechanical receptors. Similarly, the original message must be coded for the greatest compression in transmission".[3] There are many steps in the coding and decoding of a message, many filters and templates that shape and reshape it on its way to its destination. The moral for the

[2] Francis Crick, 'Central Dogma of Molecular Biology' in Nature no. 227, 1970, pp. 561-563.

[3] Norbert Wiener, *Cybernetics: Control and Communication in the Animal and the Machine*. New York: J. Wiley and Sons, 1948, p.67.

geneticist is clear: cybernetics-inspired approaches of 'systems biology' draw attention to the loops of priming, verification and adjustment established between DNA, RNA and their surrounding nucleic milieu. The shortest distance between two points requires many detours through regions that had been set as off-limits by the central dogma.

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Broader lessons can also be taken from cybernetics for the study of life. While DNA is surely involved in processes of growth, at a higher logical level the organism itself is constantly involved with and shaped by its environment. The overlapping loops of information that regulate DNA replication are part of much bigger systems of cells, tissues, organs, all the way up to social groups, ecosystems and the planet as a whole. In other words, the 'reductive' programme encouraged by the metaphor of DNA as information is constantly undermined by cybernetics' focus on system and context; there is always a wider pattern to consider. For example, the growing field of epigenomics considers variations in regulatory sequences and inheritance due to factors beyond genes, looking, for instance, at variable processes of DNA methylation. For epigenomics, the limited system addressed by the central dogma fails to explain the "multiplex modifications" actually involved in inheritance.[4] Further, the 'second-order cybernetics' developed by Heinz von Foerster concentrates on the impact of the observer upon the system being observed. In cognitive science, these cybernetic themes have directed attention away from the assumption that thought can be reduced to a linear, determinate programme or algorithm. On one hand, cognition is treated as an emergent property of various parallel processes; on the other, consciousness is considered from the point of view of the organism's enmeshment with its environment and its physical embodiment. Cognition and perception become 'relational' phenomena emerging at the interface between an observer and the system of which he or she is a part.

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In these cases 'information' is treated as much more than a direct, deterministic transmission between sender and receiver. Instead, multiple layers of mediation, multiple levels of causality, and the temporality of an ongoing 'process' are implied. Wiener spoke of the opposition between the reversible time of Newtonian causality and the irreversible time of growth and development. Since the self-regulating machines he described are endowed with circular causality – their future state may be unpredictably modified according to changes in their environment – machines now also partake of irreversible time. He drew a philosophical conclusion: "Vitalism has won to the extent that even mechanisms correspond to the time structure of vitalism."[5]

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Yet for Wiener this was no cause for celebration by those who believe in a distinct substance of life or thought. Rather, "this victory is a complete defeat, for from every point of view which has the slightest relation to morality or religion, the new mechanics is fully as mechanistic as the old."[6] However, Despite Wiener's warning, cybernetics has, almost since its inception, fostered thinking with close affinities to religion. To name just a few: Gregory Bateson's inquiries into the informational criteria of 'grace' and 'the sacred'[7]; Marshall McLuhan's cross-fertilisation between cybernetics' interest in automation and media with Teilhard de Chardin's 'divine milieu'; Joanna Macy's work on the common ground between systems theory and Buddhist notions of dependent origination and Francisco Varela's influential theorisation of 'autopoeisis' or the principles of self-organisation in cells, organisms, and

[4] Pauline A Callinan and Andrew P. Feinberg, 'The Emerging Science of Epigenomics' in *Human Molecular Genetics* 15, (Review Issue 1) 2006, p. R95.

[5] Norbert Wiener, op. cit., 1948, p. 44.

[6] ibid.

[7] Gregory Bateson, *Steps to an Ecology of Mind: Collected Essays in Anthropology*, Psychiatry, Evolution, and Epistemology. Chicago: University of Chicago Press, 1999 (1972)

minds.[8] Perhaps cybernetics' alignment with religious thought has something do with its quasi-monistic ontology, its interest in big questions such as the origins of life and consciousness, or the extremely general, even cosmological sweep of its arguments. Whatever the specific causes, this proof of cybernetics' adaptability shows that despite its role in reductive approaches in biology, its treatments of feedback, learning and development have encouraged open-ended and frequently unorthodox investigations into the nature of thought and life.

[8] Francisco Varela, Evan Thompson and Eleanor Rosch, *The Embodied Mind: Cognitive Science and Human Experience.* Cambridge, MA: MIT Press, 1991.