

- [HOME](#)
- [site guide](#)



CYBERNETICS: A Definition

[In 1990 Heinz von Foerster was approached by Macmillan to compose an entry for their 1991 Macmillan Encyclopedia of Computers. Von Foerster recommended them to me and I composed the following text and incorporated a figure that I had created for [an earlier purpose](#). My original text follows, which was published in a slightly re-edited form. Final text is Copyright (c) Macmillan Publishing.]

Artificial Intelligence and cybernetics: Aren't they the same thing? Or, isn't one about computers and the other about robots? The answer to these questions is emphatically, No.

Artificial Intelligence (AI) uses computer technology to strive toward the goal of machine intelligence and considers implementation as the most important result; cybernetics uses epistemology (the limits to how we know what we know) to understand the constraints of any medium (technological, biological, or social) and considers powerful descriptions as the most important result.

The field of AI came into being when the concept of universal computation [Minsky 1967], the cultural view of the brain as a computer, and the availability of digital computing machines were combined. The field of cybernetics came into being when concepts of information, feedback, and control [Wiener 1948] were generalized from specific applications (e.g. in engineering) to systems in general, including systems of living organisms, abstract intelligent processes and language.

Origins of "cybernetics"

The term itself originated in 1947 when Norbert Wiener used it to name a discipline apart from, but touching upon, such established disciplines as electrical engineering, mathematics, biology, neurophysiology, anthropology, and psychology. Wiener, Arturo Rosenblueth and Julian Bigelow needed a new word to refer to their new concept, and they adapted a Greek word meaning "steersman" to invoke the rich interaction of goals, predictions, actions, feedback and response in systems of all kinds (the term "governor" derives from the same root) [Wiener 1948]. Early applications in the control of physical systems (aiming artillery, designing electrical circuits and maneuvering simple robots) clarified the fundamental roles of these concepts in engineering; but the relevance to social systems and the softer sciences was also clear from the start. Many researchers from the 1940s through 1960 worked solidly within the tradition of cybernetics without necessarily using the term, some likely (R. Buckminster Fuller) but many less obviously (Gregory Bateson, Margaret Mead).

Limits to knowing

In working to abstract concepts common to all systems, early cybernetic researchers quickly realized that "the science of observed systems" cannot be divorced from "the science of observing systems" [von Foerster 1974] --- because it is we who observe. The cybernetic approach is centrally concerned with this unavoidable limit of what

we can know: our own subjectivity. In this way cybernetics is aptly called "applied epistemology". At minimum, its utility is the production of useful descriptions, and, specifically, descriptions that include the observer in the description. Cybernetic descriptions of psychology, language, arts, performance, or intelligence (to name a few) may be quite different from more conventional, hard "scientific" views --- although cybernetics can be rigorous too. Implementation may then follow in software and/or hardware, or in the design of social, managerial and other classes of interpersonal systems.

Origins of AI in cybernetics

Ironically but logically, AI and cybernetics have each gone in and out of fashion and influence in the search for machine intelligence. Cybernetics started in advance of AI, but AI has dominated for the last 25 years. Now recent difficulties in AI have led to renewed search for solutions that mirror the past approaches of cybernetics. Warren McCulloch and Walter Pitts were the first to propose a synthesis of neurophysiology and logic that tied the capabilities of brains to the limits of Turing computability [McCulloch & Pitts 1965]. The euphoria that followed spawned the field of AI [Lettvin 1989] along with early work on computation in neural nets, or, as then called, perceptrons. However the fashion of symbolic computing rose to squelch perceptron research. Only when discontent slowly grew over repeated failures to achieve machine intelligence by symbolic means within AI did interest in neural networks rise again in the late 1980s. However this is not to say that current fashion in neural nets is a return to where cybernetics has been. Much of the modern work in neural nets rests in the philosophical tradition of AI and not that of cybernetics.

Philosophy of cybernetics

AI is predicated on the presumption that knowledge is a commodity that can be stored inside of a machine, and that the application of such stored knowledge to the real world constitutes intelligence [Minsky 1968]. Only within such a "realist" view of the world can, for example, semantic networks and rule-based expert systems appear to be a route to intelligent machines. Cybernetics in contrast has evolved from a "constructivist" view of the world [von Glasersfeld 1987] where objectivity derives from shared agreement about meaning, and where information (or intelligence for that matter) is an attribute of an interaction rather than a commodity stored in a computer [Winograd & Flores 1986]. These differences are not merely semantic in character, but rather determine fundamentally the source and direction of research performed from a cybernetic, versus an AI, stance.

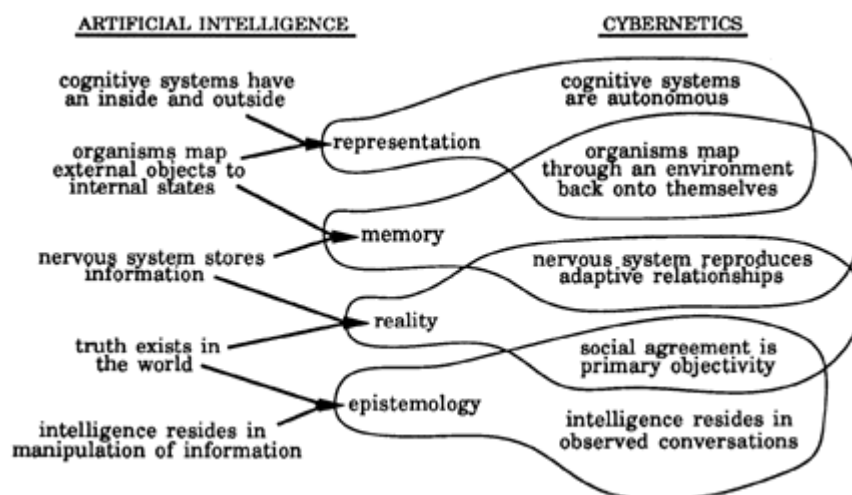


Figure 1. Underlying philosophical differences between AI and cybernetics are displayed by showing how they each understand the terms in the central column. For example, the concept of "representation" is cast quite differently in the two fields. Relations on the left are causal arrows and reflect the reductionist reasoning inherent in AI's "realist" perspective of the world-as-it-is. Relations on the right are non-hierarchical and circular and reflect a "constructivist" perspective, where the world is invented by an intelligence acting in a social tradition, rather than discovered.

Influences

Winograd and Flores credit the influence of Humberto Maturana, a biologist who recasts the concepts of "language" and "living system" with a cybernetic eye [Maturana & Varela 1988], in shifting their opinions away from the AI perspective. They quote Maturana: "Learning is not a process of accumulation of representations of the environment; it is a continuous process of transformation of behavior through continuous change in the capacity of the nervous system to synthesize it. Recall does not depend on the indefinite retention of a structural invariant that represents an entity (an idea, image or symbol), but on the functional ability of the system to create, when certain recurrent demands are given, a behavior that satisfies the recurrent demands or that the observer would class as a reenacting of a previous one." [Maturana 1980] Cybernetics has directly affected software development in intelligent training, knowledge representation, cognitive modeling, computer supported cooperative work, and neural modeling. Useful results have been demonstrated in all these areas. Like AI, however, cybernetics has not produced recognizable solutions to the machine intelligence problem, or at least has not for domains considered complex in the metrics of symbolic processing. Many beguiling artifacts have been produced with an appeal more familiar in an entertainment medium or to organic life than a piece of software [Pask 1971]. Meantime, in a repetition of history in the 1950s, the influence of cybernetics is being felt throughout the hard and soft sciences, as well as in AI. This time however it is its epistemological stance, rather than its abstraction of the concepts of information, feedback, and purpose, that is its contribution to these fields.

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