Heinz von Foerster and the second-order cybernetics

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Introduction

This issue of *E:CO* is reprinting a classic paper by Heinz von Foerster, one of the key players in the formation and development of cybernetics. Von Foerster was an Austrian/American engineer, scientist, science expositor, philosopher, and cultural commentator (rather than listing each reference which would render this document unwieldy, history of cybernetics were taken from Heims[1], Kline[2], Dupuy[3], Cybernetics at Wikipedia[4], Bio-von Foerster[5]. After WWII, Von Foerster worked with other World War II technocrats from both the Allied and the Axis Powers who aimed at continuing and expanding the unprecedented scientific, mathematical, and engineering advances that had been brought on by the unprecedented war effort. Cybernetics grew-up in this atmosphere out of the working and personal relationships, professional associations, research and theoretical collaborations that had been established during the war.

Central to the issues which cybernetics took-up were *control/guidance* systems such as found in ballistic missiles with built-in goal or purposive-seeking dynamics considered "teleological" designs despite the fact that strict Darwinian evolution had banned this notion from science altogether. The purpose of guided weaponry, of course, was hitting a target, largely accomplished through the quite clever understanding of and use of the new concept of feedback, sometimes called "back afferentiation" in the modeling of regulatory and self-regulatory processes. Control or guidance was achieved via a comparison of the pre-set with actual conditions and the consequent activation of "negative feedback" processes to close the difference between pre-set and actual. Thus, present measurements of velocity, distance, and other related variables are fedback (in a kind of causal loop of information) into a guidance system in order to correct by a readjustment of the guiding mechanisms.

The attainment of effective purposes on the part of such machines required a great deal of focus, resources, technical skills, and sheer imposing intellectual power which was made available via military and industrial research as well as university/academic participation. The awesome force of the two atomic bombs detonated on Japan to end the war demonstrated just how total this war was. Tragically, this horrifying force was not to depart at the end of the war but at least there were a plethora of peaceful ramifications of the same research which cybernetics was about to exploit for positive directions.

The actual cybernetics movement began in the US among a core group of scientists, mathematicians, engineers, and social scientists who formed and attended a series of Macy Conferences. The founders and participants were certainly the cream of the crop of Western intellect who had come together to fashion the most powerful warrior determination in world history, among whom cluded luminaries of the intellect no less than John von Neumann, Norbert Wiener, Claude Shannon; Benoit Mandelbrot, Humberto Maturana; Warren McCulloch, Walter Pitts, W. Grey Walther, W. Ross Ashby, Staffor Beer, Gregory Bateson, Arturo Rosenblueth, von Foerster, Enst von Glasersfeld (whose life and work was uncannily strangely similar to that of von Foerster (in my opinion at least), Gordon Pask, even Alan Turing showed at times. von Foerster's own contribution covered many of the major themes of cybernetics in general, from its formation in the aftermath of World War II until his death in 2002, although as we'll see below, he was mainly involved with what has been called "second-order" cybernetics Specific areas of interest within cybernetics on the part of von Foerster were:

1. advances in control theory coming out of WWII ballistics and guided missile research (the "self-guided" missiles giving rise to the term cybernetics for "self-steering); explanations in terms of negative and positive feedback loops;

2. the advent of and advances in modern electronic computers (covering such breakthroughs as computer storage and programming languages, machine languages and learning, artificial intelligence, and so forth);

3. mass communication, network technologies, and information theory;

4. the possibility of self-organizing systems characterized by the building-up of order/structure in the face of what was supposed to be only the Second Law's increase of entropy or the degradation of order.

Just a brief glance at this list reveals the presence of themes that have also been taken-up in complexity theory. Although*E:CO* is well-known as a journal devoted to complexity science as such, this issue's classic paper by von Foerster was authored not by a complexity researcher/theorist but rather a well-known and well-respected cybernetician. There is nothing untoward about

this since cybernetics and complexity science have had a close long-term relationship with a great deal of overlapping, crossing-over, interacting among complexity researchers and cybernetics researchers even to the point where it can be quite difficult to discern differences between the fields. This closeness, of course, is also demonstrated by the overlapping of the personnel involved (it is common for one and the same person to credibly claim fealty to both traditions).

I think that it is too early in the game to accurately evaluate accurately exactly how cybernetics and complexity science are related . From my perspective, complexity science can be considered as having emerged from conceptual ground prepared by cybernetics even though, to an important extent, the two disciplines have remained separate endeavors. This can be seen, for example, in how certain themes from one side or the other have remained ensconced on one side or the other. A case in point is the epistemological perspective of *radical constructivism* (see below) which has served as a chief defining characteristic of the epistemological stance of so-called "second-order" cybernetics (see below) but does not have anywhere near that same status in complexity theory. Furthermore, complexity sciences tend to be more associated with academically-inclined mathematical/scientific/philosophical/cultural research pursuits whereas cybernetics began and continues to be more pragmatic in its wide-scope social and cultural issues. For instance, take the idea of self-organization, the topic of von Foerster's classic paper. This is a phenomenon that has occupied pretty much the same interest on the part of both cybernetics and complexity theory so that any difference in attention between the two endeavors amounts mostly to a difference that does not make a difference, to adapt a phrase from the cybernetician Gregory Bateson.

Von Foerster: Biographical remarks

Heinz von Foerster was born in Vienna on Nov 13, 1911 into a family of engineers, architects, and artists, a family well-respected and comfortable in means. One can appreciate from the kinds of careers taken on by family members, i.e., a focus on *design* principles, that von Foerster would follow suit on being interested in design which indeed he does appear to have pursued. Moreover, his family and home environments were steeped in artistic, aesthetic, and creative endeavors in general and more specifically in the Viennese *avant-garde*, crucial factors in encouraging von Foerster's general outlook. Noteworthy in this context is that much family time was spent in the artistic circles surrounding the great expressionist painter Oskar Kokoschka, and von Foerster even played with Ludwig Wittgenstein as a child and attended the famous Vienna Circle where Wittgenstein could be found at times.

In the early nineteen thirties, von Foerster enrolled at the Viennese Technische Hochschule to study "technical physics" while also attending lectures at the Vienna Circle. Von Foerster recalled that one of his favorite topics of discussion at the Vienna Circle was Wittgenstein's *Tractatus*. Around the same time, von Foerster deepened his lifelong interest in the foundations of mathematics, a subject that was "hot" in Vienna and whose logical basis became a template for computational logic and thus figured in cybernetics. With all this familiarity with Wittgenstein, I find it rather strange that von Foerster did not have occasion to apply Wittgensteinian insight to some of the more extreme sounding, implausible epistemological claims associated with the "radical constructivism" (more on this below).

Getting back to the war, for a moment, there have been murmurings concerning von Foerster's wartime record in Berlin. For instance, the claim has been made that one of von Foerster's grandfathers was not of pure Aryan stock but rather a "Mischling", i.e., mixed blood meaning part Jewish and that, as a result, von Foerster was in a sense hiding from the Nazis when he worked in Berlin. This is certainly a case of hiding in plain sight since I can hardly imaging a Jew (however fractionated his DNA as a Jew he really was) wanting to spend any time at all in Berlin. Moreover, if there was even the slightest hint that von Foerster was thereby a "Mischling" himself, how could he have possibly landed a technical, even war related job in Berlin (e.g., with Siemens or GEMA both of which did military work). There are also questions about his war record itself which appears to have disappeared, or been mislaid, or is still classified. All of this is troubling not because anyone seriously thinks of von Foerster was a brown shirt but rat her because of the aura of "hush hush" around the whole thing. I direct the reader's attention to a review I wrote for *E:CO* several years back of a book about the general systems founder Ludwig Bertalannfy. Dear old Ludwig von, it turns out, was in fact a card-carrying member of the National Socialist Party although, of course, he made it a point to importunately deny he was not a true believer, only an opportunist Nazi. Why would anyone would think that was any better, genocide via opportunism or genocide via true belief? Becoming a representative of evil because it helps your career? Traveling in Germany in the late sixties, I was very surprised to hear how many of the Germans told me they were actually in Switzerland during the war or they were Swiss citizens (yet they lacked Swiss German accents!) I guess they meant they were climbing the hierarchy in the Swiss Regions of Bergen-Belsen or Dachau.

After the war, von Foerster returned to Austria where he worked for the large telephone and electrical engineering company there, and also became known as an effective science journalist and writer for the broadcasting company of the US occupation forces. At the same time, he worked in research involving quantum physics and memory capacity, notices of which did reach as far as the academies in the US where it would eventually help his career.

Von Foerster and his family then managed to emigrate to the US as part of the great exodus of German technocrats being gobbled up by the US and the Soviets. Through a combination of luck, skill at both administration and scientific method/theory, and his often remarked-upon feature of being personable, von Foerster built up a social network of quite high level researchers and thought leaders. At this time von Foerster was encouraged to pursue his research, refine his systemic approach, and try his

hand at promulgating "popular" understandings of new scientific developments as he had done so in Austria and Germany. For instance, the preeminent researcher and cybernetician Warren McCulloch asked von Foerster to deliver a paper at one of the early Macy Conferences on the quantum physics of memory. As a result of his successes at such forums, von Foerster was asked to become the general secretary of the Macy conferences, an ideal position for a smart, ambitious and young (after all he was only 35 years old in 1946) engineer/scientist. It was also a time of relative prosperity as the technology spawned during the war led not only to important scientific findings but an incredible profusion of technology-driven culture changes, particularly in regards to computerization.

During the nineteen fifties von Foerster continued his work in electrical engineering and physics, but also began to switch his direction towards investigating and promoting the themes of homeostasis, self-organizing systems, system-environment-relationships, bionics, biologic machine communication and others. He became head of the Biological Computer Lab at the University of Illinois in Urbana founded in 1957. The juxtaposition of these three terms—"Biological", "Computer" "Lab" says a lot about the "spirit of the times".

During his tenure at the Biological Computer Lab, von Foerster focused on interdisciplinary endeavors and educational innovations, all within a systems-conceived learning environment. He became a professor emeritus in 1976, then moved to Pescadero, California where he became a key figure in the emerging synthesis of cybernetics, the counter-culture, the human potential movement, and new systemic frameworks for psychotherapy. It was also during this time that the so-called "radical constructivist" approach to epistemology in second-order cybernetics became solidified. Von Foerster died in 2002.

Von Foerster and second-order cybernetics

Heinz von Foerster was one of the principal architects of what became known as "second order" cybernetics whose ideational kernel had been gestating since the beginnings of cybernetics until it emerged during the nineteen seventies. Key to this phase was the conceptualization of observer/observed systems as involving a kind of circular causality linking agents and observers as integral and responsible components of the system which, in an important sense, stipulate her/his purpose. In fact, circular causality was not new in cybernetics, the title of their first meeting in 1946 affords insight into this direction: "Feedback Mechanisms and Circular Causal Systems in Biological and Social Systems," a theme which remained in effect for the duration of the conferences until the last one in 1953[3]. As pointed out by the polymath Gregory Bateson[6], who, as a contributor to many of these Macy Conferences helped introduce systems ideas into the social sciences, a cybernetic system was one in which causal influence was traceable around a feedback circuit all the way back to any arbitrarily chosen starting point. Furthermore, this kind of circularity implied that any event in any position in the causal circuit of feedback would affect all other events at different positions, thus implying a *self-referential* structure since the causal influence was bent back on itself (we will come back to this crucially important theme later on).

Franciso Varela, who had with his mentor and colleague Humberto Maturana come up with the notion of autopoeitic systems (see below) around the same time, stated that von Foerster had formulated, with his new systemic category of "second-oder", "a framework for the understanding of cognition. This framework is not so much a fully completed edifice, but rather a clearly shaped space, where the major building lines are established and its access clearly indicated"[2]. Von Foerster went even further by underscoring the *self-referential* structure of circular causality, an idea that eventually broke forth as the basis of radical constructivism.

The importance given to circular causality and its self-referential core was attributed to very influential research on the frog's brain written-up in 1959 on the part of the cyberneticians Lettvin, Maturana, McCulloch, and Pitts[7] notice that this is the same Maturana who had co-authored with Varela the idea of autopoeisis. The conclusion of this paper had it that the frog's eye, instead of transmitting to the brain some more or less precise information stemming from the distribution of light on the receptor, "speaks" to the brain in a manner already organized and interpreted. An analogy was offered (versions of which are often found in radical constructivist circles): someone is observing cloud formations and reports his sightings to a weather station. This person's reports won't be couched in terms of light stimuli distributions but rather in categories coming from everyday impressions of the weather which are already understandable by those at the weather station. That is, the receivers of this report must already possess sufficient extant knowledge and it must be organized in such a way that the reporter's descriptions should make enough sense that they can be acted upon. Similarly, because the purpose of a frog's vision is to get food and avoid predators, the information coming from the light receptors has to be arranged, organized, prepared for correct interpretation and resulting action.

The crucial point is that the latter preparations must already be present to *construct* (hence "constructivism") the meaning of the incoming data. In a sense we can conceive the constructional preparatory apparatus like Kant's transcendental categories of the understanding (e.g., temporality, spatiality, causality), that is, "cognitive schemas" already present making sense of experience. Second-order cyberneticians contend that without these constructional "devices" we can't experience anything at all and that in experience all we experience is the innate subjective schemas of experience with which we construct the world. But notice that although the conclusion of this research resembles Kant's transcendental idealism, Kant never went to the extreme that radical constructivists go.

This early research on the frog's brain was just the start of the radicalizing of von Foerster's second-order epistemology. He was also strongly influenced along the way by several logical/mathematical interpretations of strong self-reference put forward by the respective conceptualizations of the German and Swedish logicians/philosophers Gotthard Günther[8] and Lars Löfgren[9] but most powerfully for von Foerster the notion of autopoiesis put forward by Maturana and Varela (1980).

Günther, for example championed his quasi-self-referential idea of "contexturality" as emblematic of living system. What exactly "contexturality" refers to is not at all clear to me, an obscurity not helped by Gunther's overly idiosyncratic language: "It is an object; but it is also something utterly and inconceivably different from an object. There is no way to describe it as a contextural unit of thingness." Perhaps one way to describe might be to not include in an explanation of something that something itself. *Petition principii* galore! Beware the lexicons of novel neologisms.

Löfgren[9] approached his explication of self-reference more from assumptions in mathematical logic. Indeed, he had demonstrated that his axiom of complete self-reference is independent from set theory and logic in a way related to Gödel's theorems and Paul Cohen's proof of independence regarding the Contiuum Hypothesis. For his exposition of the logic of self-reference, Löfgren appealed to his analyses of the role of self-reference in Gödel's code (i.e., Gödel numbering) that was used in his completeness theorem.

The most influential rendition of self-reference inspiring von Foerster as he was conceptualizing second-order cybernetics was Maturana's and Varela's theory of autopoeisis (1980). Varela[10,11,12], in particular, had turned to the work of the English mathematician Spencer-Brown whose novel approach to Boolean algebra incorporated self-referentiality as a fundamental element[13]. Emphasizing Spencer-Browne's self-referential notion of reentry, Varela's "calculus of self-reference" (his term) placed self-referentiality on the same logically primordial level as true and false. This move effactually pushed self-reference down into the core of nature, thereby making Varela's approach into a kind of *pan-self-referentialexperiencism*.

Varied critiques of Varela's strict notion of self-reference have been offered over the years[14]. Indeed, a troublesome side effect of the manner by which Varela's formalism has its primary elements fold back on themselves (as in fixed point theorems) so stringently is a curtailment of the possibility for change, motion, evolution, morphogenesis, and so forth in such systems. On a purely formal level, Kaehr (cited in Reichel[15] Kaehr was a student of Günther; also he has pointed to what he takes in Varela's formalism as a plague of infinities that renders Varela's self-referential systems as not operationalizable). Moreover, Schatten[16] has argued that this kind of self-reference can only be applicable to single or micro-celled organisms and thereby not pertinent to more complex systems.

The claims of radical constructivism, the governing epistemological stance found in von Foerster's work and second-order cybernetics in general, are said to emanate from the self-referential nature of observing/observer systems. It is not difficult to see radical constructivism as a radicalization of the self-enclosedness of self-referential systems. However, a careful philosophical reading of radical constructivism reveals a host of philosophy 101 mistakes, perhaps the most egregious being:

- We know the world through our experience. Therefore the only thing we can know is experience

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It seems to me at least, that this proposition is as invalid as:

- We see the world through our eyes. Therefore the only thing we see are our eyes

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As I remarked above, it is ironic that despite his close acquaintance with Wittgenstein, von Foerster (or for that matter von Glasersfeld) does not seem to have incorporated an iota of Wittgenstein's philosophical method. Any good Wittgensteinian on the block could debunk radical constructivism in a short time for its numerous unsound inferences. I guess I can sort of sympathize why Austrians might want to glom onto a philosophical creed like radical constructivism; for it means that whatever horrors were experienced (or worse, helped perpetrate) are just in our head.

The respected contemporary cybernetician Stuart Umpleby[2] has called attention to the fact that that von Foerster was such an adamant holder of second-order cybernetics principles that he and his close colleagues excluded from their associations anyone "who wasn't a second-order cybernetician." Umpleby has strongly attacked such a "brutal, intolerant" outlook, calling both von Foerster and the closely related track of Maturana as "closed and ungenerative".

Von Foerster's take on self-organization

The classic paper reprinted in this issue of *E:CO* comes from a talk on self-organization given by von Foerster in 1959. Self-organization has been a major interest in cybernetics since its early days. Foerster's approach is not easy, containing as it does multifaceted explanatory "folds". But right from the start he confronts one of the more problematic issues accompanying the

reception of the idea of self-organization: the building-up of order or organization characterizing self-organization would seem to violate the increase of entropy and associated degradation of order according to the Second Law of Thermodynamics, at least in the Boltzmannian understanding of the law. In fact, this issue is one that all proponents of the idea of self-organization have needed to face since the Second Law is nearly unanimously accepted.

One tack by von Foerster was s to play around with how to conceive self-organization in relation to the "nearness/distance" of a system to the environments it is embedded in. The inspiration here is explicitly that of Schrödinger from his *What is Life?*, a work prescient in many ways, e.g., "predicting" the need for something like DNA. As von Foerster put it when discussing the need for the self-organizing system to take-in the energy needed for its internal activity of building order: the system "eats" energy and order from its environment. That is, the environment has a certain amount of given structure. The "closer" the system is to its environment in the sense of interacting with "local" access to the environment, the more plausible it seems the order/structure can be introjected by the system, this flow of energized order is what runs the processes of self-organization. Again, this point is an echo from Schrödinger and von Foerster winds-up limiting what should truly be thought as a self-organizing process to those held within close environmental conditions. If the distance is too great, entropic tendencies will swamp local ordering. Thus there is plenty in this classic paper for both proponents as well as critics can munch over.

Von Foerster also appealed to Shannon's famous definition of information along the lines of redundancy (and surprise), that self-organizing systems need to show an increase of order over time. The "negentropy" (Schrödinger's term for the order/structure the systems takes in from the environment) needs to be amplified and this leads to an embrace of the "order through noise" thesis of Prigogine and his school of self-organizing physical systems.

We see therefore von Foerster going through the various ways that order and self-organization in the face of entropic decay. He offers varied thought experiments along the way to illustrate the outlines of various "mechanisms' that might responsible for this building up of order, some of which are hard to follow or are unconvincing or ad hoc hand waving.

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