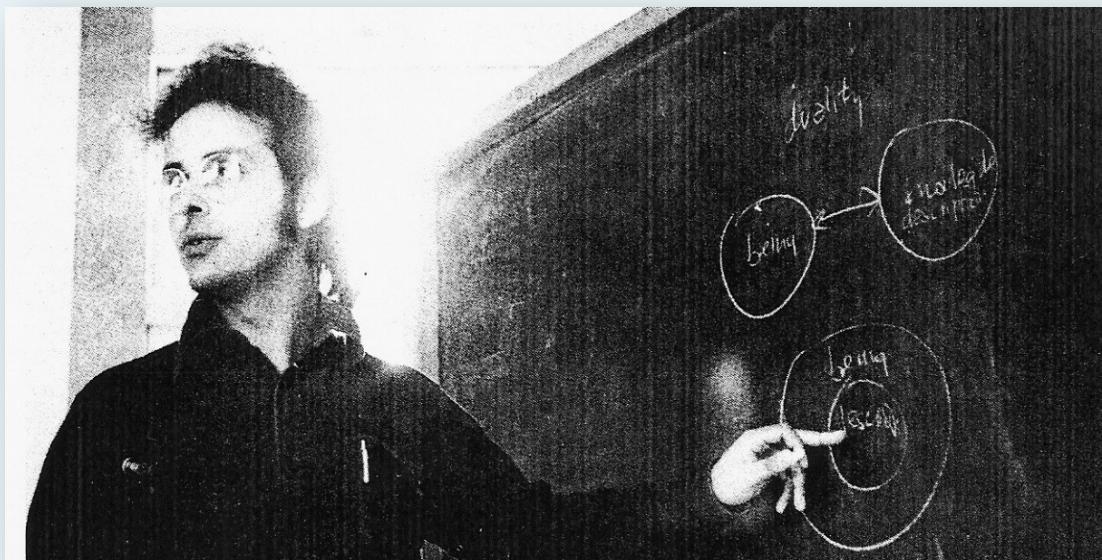
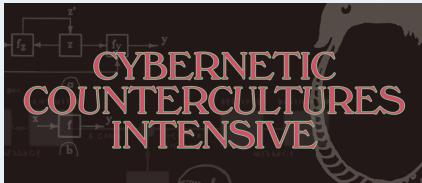


Week 6. Observing Natural Systems: Francisco Varela

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**Form and
System:
“A Calculus
for Self-
Reference”**

In hindsight, Heinz von Foerster's 1973 paper "On Constructing a Reality" can be read as a checklist for items on Francisco Varela's conceptual itinerary going forward:

When we perceive our environment, it is we who invent it.

The emergence of perception through sensorimotor interaction . . . prompts two metaphors: Perceiving is doing, and If I don't see I am blind, I am blind; but if I see I am blind, I see.

The postulate of cognitive homeostasis: The nervous system is organized (or organizes itself) so that it computes a stable reality. This postulate stipulates "autonomy," that is, "self-regulation," for every living organism.

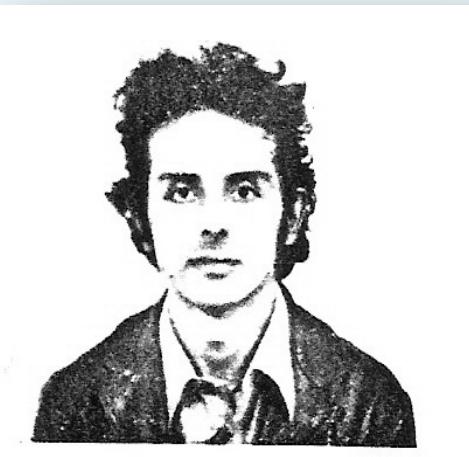
The ethical imperative: Act always so as to increase the number of choices.

The aesthetical imperative: If you desire to see, learn how to act.

However, given the extensive prior interactions among these three cybernetic amigos, by 1973, Heinz may have already taken over a considerable amount of new thinking *from* Maturana and Varela. To some extent, second-order cybernetics is already an extension of their codification of biological and cognitive recursion as presented in the theory of autopoiesis.

Now, in Week 3 we explored key moments in the early history of the concept of autopoiesis: the composition of its seminal statements at the beginning of the 1970s, their early publishing travails, a sample of statements from the theory's initial reception among a handful of systems-theoretical thinkers capable of grasping its potential and, thanks to Heinz von Foerster, its momentary mention in *CoEvolution Quarterly*. In its initial formations the theory of autopoiesis will always be properly attributed to both Humberto Maturana and Francisco Varela, who worked it out in tight collaboration as colleagues at the University of Chile after Varela returned from Harvard in 1970 Ph.D. in hand.

However, that close working relationship was abruptly suspended weeks after the Pinochet coup in September 1973, when Varela went into lengthy exile at the age of 27 while Maturana remained in Chile. These events precipitated Varela's own rapid maturation as a wildly creative scientific thinker. Varela gained employment for a year or so at the National University in Costa Rica, then for another few years at the University of Colorado, until the coast was clear for his temporary return to Santiago at the end of the 1970s, prior to his permanent relocation to the École Polytechnique in Paris in 1984.



FRANCISCO JAVIER VARELA GARCIA was born in Talcahuano, Chile, on September 7, 1946. He received his B.A. from the University of Chile, and his Ph.D. from Harvard University in 1970.

From 1970 to 1973 he was Associate Professor of Biology at the Faculty of Sciences, University of Chile, Santiago. By the end of 1973 he was Visiting Professor at the Universidad Nacional, Heredia, Costa Rica. He is currently associated with the Department of Anatomy at the University of Colorado Medical Center, in Denver.

His scientific activity is centered around the problems of bio-computers, both molecular and cognitive, and has contributed two books and several articles to these problems.

—Headshot and biographical note from Varela's "A Calculus for Self-Reference" (1975)

This week we will concentrate on Francisco Varela in his own right. Throughout his career he had a genius for productive collaboration, while in those later efforts there can be no doubt about his consistently leading role. And it was in the first years of his exile from Chile that, due in great part to the efforts and connections of his American sponsor von Foerster, Varela hung out with the Cybernetic Countercultures in the vicinity of both the Whole Earth network and the Lindisfarne Association, striking up especially fruitful relationships with Gregory Bateson and William Irwin Thompson. In this period during the mid to later 1970s, he established himself on the international stage, both professionally through standard scientific publications, and at wider cultural angle through a set of remarkable notices in *CoEvolution Quarterly*. Tonight we will turn to these very early, already brilliant interventions.

—But let's return for a moment to the years building up the advent of Varela's many contributions to systems theory. As we've seen, thanks to Maturana's friendship with von Foerster, Heinz was a presence in Varela's thinking as far back as his college training.

—from Francisco Varela, “Preface to the second edition of *De Máquinas y Seres Vivos*,” *Systems Research* 28 (1994; 2011).

In the Department of Sciences at University of Chile in the mid 1960's:

“It was at this fertile time that I first encountered Heinz von Foerster as an exponent of the mixing of mathematics with brain studies. Although I didn't meet him in person until 1968, he became quite immediately a figure of great importance for me. In the laboratory, his papers circulated. . . .”

While in graduate school at Harvard between 1968-70:

“I soon came to realize that talking with professors about epistemological problems, as I was accustomed to doing in Santiago, was not looked upon favorably. The reaction was the same when I attempted to find a way to cultivate my interests in theoretical biology. . . . My only point of reference continued to be von Foerster, whom I visited several times at the Biological Computer Laboratory. . . .”

BC] Varela wrote this new preface in 1994 for a Spanish-language reprint of the text we have in *Autopoiesis and Cognition*, which was first completed at the end of 1971.

Portions of this preface were translated and published in 1996 as “The Early Days of Autopoiesis: Heinz and Chile.” This new and full English translation of the preface was published in 2011, evincing a broad continuing interest in the abiding significance of the autopoiesis concept.

Varela first visited von Foerster at the Biological Computer Lab shortly upon arriving in Cambridge, MA, in Fall 1968.

November the 22nd.

Dear Heinz:

It was a real thrill to see and hear you in Cambridge the other day. More than ever I could admire your extraordinary ability to go straight to the core of the argument with elegant simplicity. I hope it is something I will learn how to do some day.

As you can see, I am enclosing two papers that I have produced in the last months, and that are of a general nature. I hope you will find them suggestive, or at least confusing.

My guess is that it was that same fall when Varela sent this letter to von Foerster. It appears that Heinz had recently come to Harvard or MIT to give a talk, which Varela attended: "It was a real thrill to see and hear you in Cambridge the other day. More than ever I could admire your extraordinary ability to go straight to the core of the argument with elegant simplicity. I hope it is something I will learn how to do some day."

At the same time, Varela already had two pieces of graduate work "of a general nature" cued up to run by his BCL mentor.

The continuation of Varela's letter indicates that Heinz had invited him to return to the BCL to give a talk: "Of course, I am very interested in implementing a visit to the BCL for two or three days in the near future."

Should he lecture on his current research training? "I could give a seminar on visual processing in insect retinas." Or, could he stretch out on a philosophical theme? "Also, it would be quite nice, if you think is worth, to submit some of my thoughts on the role of language for the study of mind."

Varela's postscript then elicits mutual interest in a theme that at that moment was still treated primarily as a logical and linguistic topic, but which was in fact pregnant with autopoietic and second-order cybernetic futurity: *self-reference, etc.*

Of course, I am very interested in implementing a visit to the BCL for two or three days in the near future. I think that, to provide some "academic" justification, I could give a seminar on visual processing in insect retinas. Also, it would be quite nice, if you think is worth, to submit some of my thoughts on the role of language for the study of mind (cf. the paper) to the consideration of a discrete audience. Perhaps this could be set as an informal colloquium or something. Please feel free to select any days, according to your convenience, for my visit. Probably January is a good month.

I look forward hearing from you on all this matters and the papers. Gracias, y quede usted con mis respetuosos caríños para usted y su señora,

Francisco

P.S.1: The other day I came across a beautiful article by Bronowski (~~Am. Sci.~~ Am. Sci. 54:1, 1966) on self-reference, etc. Probably is old hat to you, but I thought it might have skiped your attention due to the place in which it has published.

Jacob Bronowski, "The Logic of the Mind," *American Scientist* 54:1 (March 1966): 1-14: "Many logical problems grow from this common root, namely that the range of reference of any reasonably rich system necessarily includes reference to itself. This creates an endless regress, an infinite hall of mirrors of self-reflection. And the regress comes sharply to a focus in all the paradoxes of logic, which are cousins of one sort or another to the classical contradiction that the Greeks knew: what they called the Cretan paradox. This is the contradiction implied by the statement of Epimenides the Cretan that all Cretans are liars."

Varela's initial doctoral research was still shaped by Maturana's disciplinary training in cell biology and neurophysiology.

It is these competencies that will undergird the organic foundations of autopoiesis as a theory of cellular organization and cognitive function.

SEMINAR

CELL BIOLOGY LABORATORY

Monday, December 9, 1968

4:00 p.m. Room 258

The Cellular and Optical Basis
of Light Perception in the Honeybee

Francisco Varela

Biological Laboratories
Harvard University

Nonetheless, that at the age of 22 he could shift topics so seamlessly from "insect retinas" to "the role of language for the study of mind" (the topic of Bronowski's article)—from straight-up neurophysiology to philosophical linguistics—indicates a precocious set of multidisciplinary interests that points directly toward his eventual emergence as a pioneer in neurophenomenology.

—However, back in Chile after his graduation from Harvard, Varela's own excitement regarding his collaborative theoretical innovations was not immediately reciprocated.

“... The text we finished toward the end of 1971 wasn't accepted immediately. In fact it was sent to at least five publishers and journals, who without exception considered it unpublishable. I remember in January of 1972, my ex-professor [Keith R.] Porter invited me to visit the new Biology Department at the University of Colorado-Boulder, where I gave an enthusiastic talk entitled: 'Cells as Autopoietic Machines'. The reception was cold and distant, as was that of my colleagues at Berkeley whom I visited around that same time” (“Preface to *De Máquinas y Seres Vivos*”).

Nonetheless, it would appear that, on that brief trip to the University of Colorado, he made some personal connections that would stand him in good stead just a few years later.

Boulder Daily Camera 2/9/72
Chilean Researcher Offers CU Seminar

Dr. Francisco G. Varela of the University of Chile, Santiago, science faculty, a visiting researcher at the University of Colorado, will conduct a free public seminar on his work at 4 p.m. Thursday in 040 CU Biosciences Building.

Varela's talk on “Cells Are Autopoietic Machines: Theory and Experiments About a Characterization of Cell Organization” is sponsored by the CU Department of Molecular, Cellular and Developmental Biology, where for the past two weeks he has been conducting research on the compound eyes of insects, especially bees, and working on a book about the insect retina. He will return to Chile later this month.

—“Preface to the second edition of *De Máquinas y Seres Vivos*,” continued:

“At the same time, the enthusiastic reception from certain individuals I respected was of enormous value. The first one to have a clear understanding of the implications of the idea was naturally our friend Heinz von Foerster in the United States, with whom we had been in constant communication and who visited Chile during those years. Another well-known cyberneticist and system theorist who reacted positively was Stafford Beer . . .”

“In January 1972, with a fresh copy of the manuscript, I was invited to Mexico by Ivan Illich, to his CIDOC center in Cuernavaca. I gave him the manuscript the day I arrived, and I will never forget his reaction the following morning: ‘This is a classic text. You have managed to put autonomy at the center of science.’”

CIDOC

CUERNAVACA, MEXICO

1972

Forty miles south of Mexico City lies Cuernavaca. There, throughout the year, at CIDOC, gather persons who have taken the initiative, each to raise an issue related to radical alternatives to contemporary institutions. For the coming months, the following areas of interest have emerged.

PERU, CHILE, INSTITUTIONAL ALTERNATIVES.
Several closed meetings, primarily between Latin Americans and Africans, in search of appropriate technologies particularly in the fields of medicine, housing, transportation. Participants will report in *El Ciclo*. Among them: Augusto Salazar Bondy, Francisco Varela Luis Ratinoff, José Bulnes, Grimaldo Rengifo. January.

RESEARCH SEMINAR ON ALTERNATIVES TO A SCHOoled SOCIETY IN LATIN AMERICA. Under the direction of Eduardo Rivera. The personal and national dependencies on rich countries created through the adoption of the school system. Alternatives; adult education; rural education; literacy. Among them: Eduardo Rivera, Santiago Gelinas, Hugo Marquezado, Francisco Julião. January.

DESCHOOLING AND TEACHING COMMUNITIES.
A seminar coordinated by Didier Piveteau. An inquiry into the unique problems faced by members of religious orders now teaching in schools in both rich and poor countries. February.

EDUCATION FOR A GLOBAL COMMUNITY OF MAN.
A seminar initiated by the World Law Fund. Educators focusing on war prevention and survival will explore teaching/learning strategies; policy decisions of economic welfare, social justice, and ecology. Among participants: Betty Reardon, Joan Reimer, Hartmut von Hentig. February 14-25

ALTERNATIVE SOURCES OF HEALTH
John McKnight will join participants in a search for ways to ensure optimum popular access to health tools, skills, and information. February 27 - March 10.

ALTERNATIVES IN EDUCATION. Continuing our inquiry into the disestablishment of schools, and a broadening of the issue. The deschooling of society understood as the move beyond the industrial age in the service sector. Among the participants: Edgar Friedenberg, John Holt, Dennis Sullivan, Layman Allen, Joan K. Ross. February/March/April.

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for a new economics

<https://centerforneweconomics.org/people/ivan-illich/>

Ivan Illich (1926-2002) was born in Vienna, Austria, and grew up in Europe. A Croatian-Austrian philosopher, Roman Catholic priest, and polemical critic of the institutions of Western culture, he could appear as a stern, forbidding character, which he put down to "growing up in five languages, but without a mother tongue".

He studied histology and crystallography at the University of Florence, Italy, as well as theology and philosophy at the Pontifical Gregorian University in Rome, and medieval history in Salzburg. In 1950 he came to New York, where he worked for five years as a parish priest in an Irish-Puerto Rican neighborhood. Illich's enthusiasm for those in his care led him to accept a job as Vice-Rector of the Catholic University of Puerto Rico in 1956. He spent four years travelling widely throughout South America on foot and by bus, studying immigration and alienating many of the local clergy by complaining of their readiness to impose American values on their congregations.

In 1960 Illich moved to Cuernavaca, Mexico, which became his home. There he founded the Centro Intercultural de Documentación, a research center offering language courses to missionaries from North America. He spoke Italian, Spanish, French, and German fluently and later learned numerous other languages. He lectured at Fordham in the department of Political Science and took on many other scholarly posts.

A fellow Austrian expatriate, von Foerster visited CIDOC in the summer of 1971. Varela's invitation to CIDOC the following winter was presumably brokered through the BCL. Illich contributes an entry on "Learning" to *Cybernetics of Cybernetics* (1974).

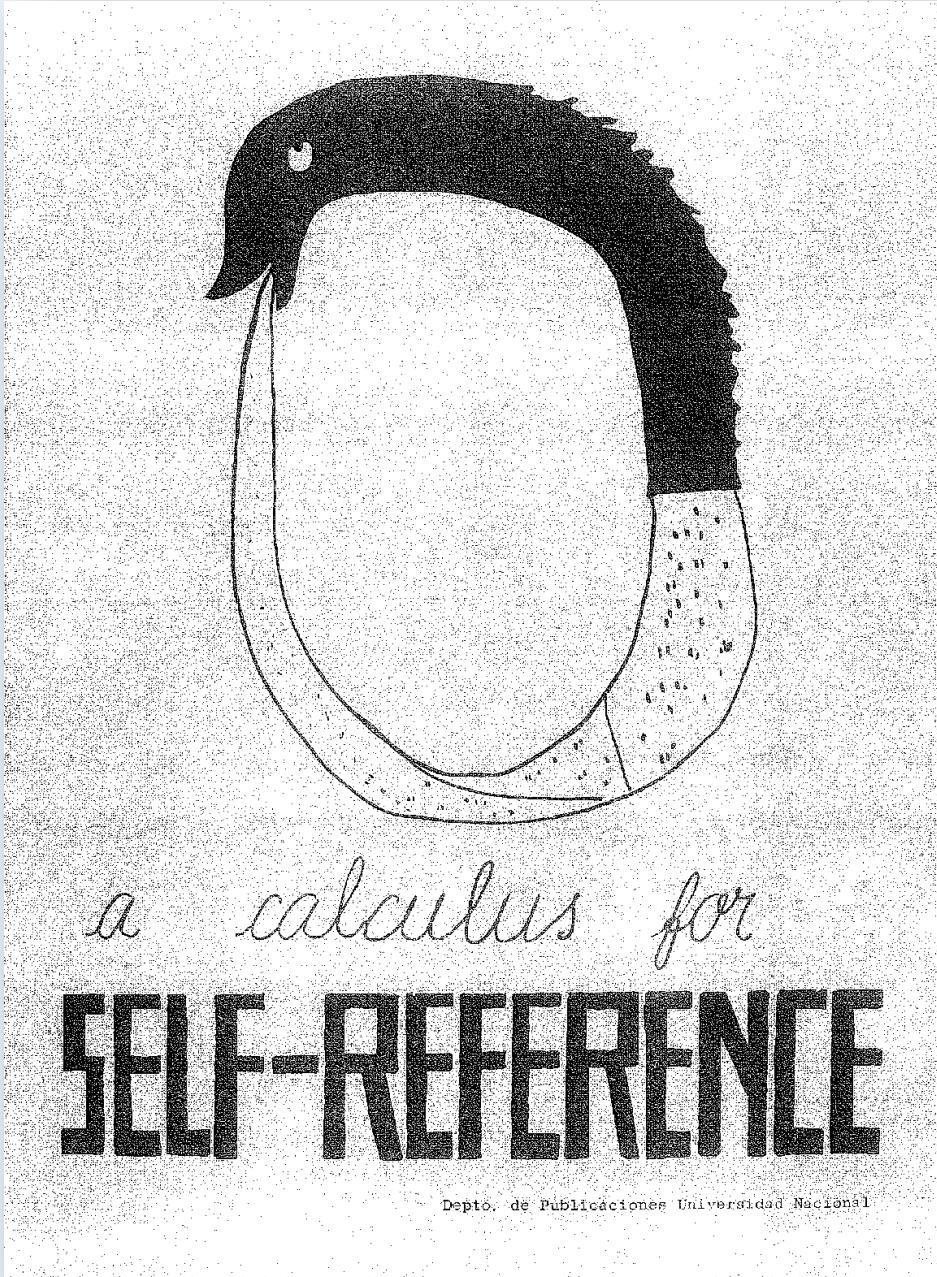


Ivan Illich

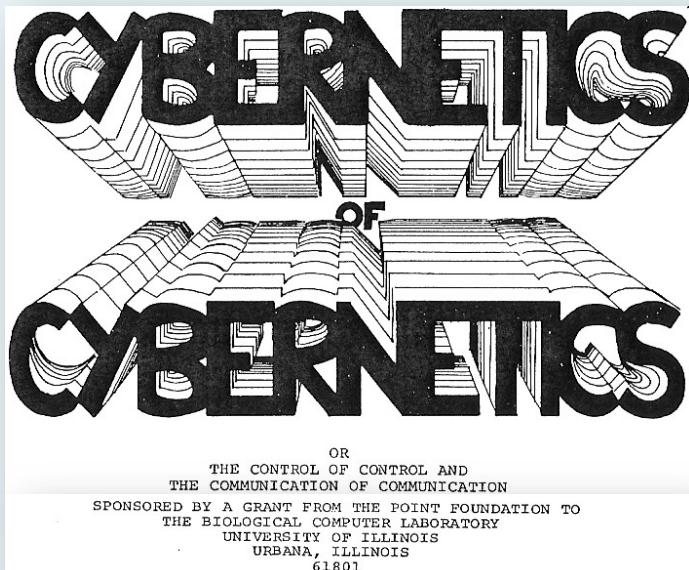
Then the calamity in Chile on September 11, 1973, forces Varela into exile:

Heinz's visit in July of 1973 took place in the midst of the approaching storm which plunged us all into an atmosphere of permanent crisis, with desperate attempts to stabilize a country that was breaking in two. As an active and militant supporter of President Allende's government, after the coup of 11 September I found myself under personal threat. Military intelligence came to the Department with lists of ex-party members, and on two occasions night patrols came looking for me at my house, where I no longer dared to sleep. I was dismissed from my post at the university on orders "from superiors." Together with my family I decided to sell everything and leave. The majority of my colleagues in the Department of Sciences also dispersed throughout the world. With the diaspora of the Department's scientists ended a period of science in Chile, an important stage of my personal life, and with it the context which gave birth to the idea of autopoiesis. But naturally the idea would find new proponents, especially outside of Chile. ("Preface to *De Máquinas y Seres Vivos*")

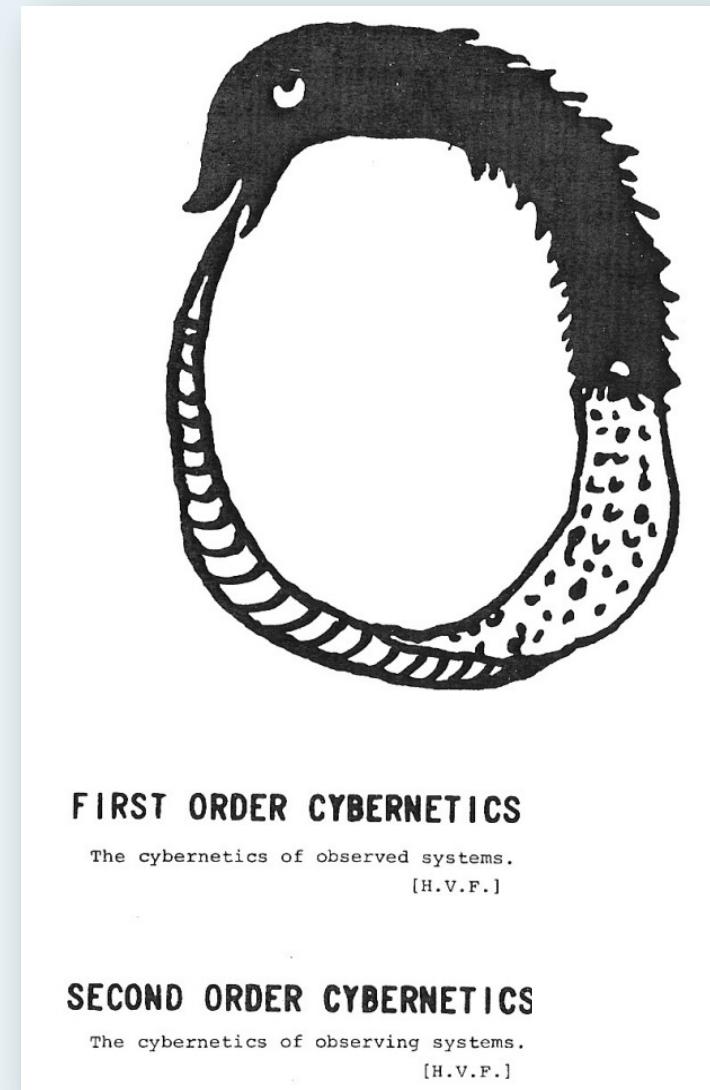
A year later, having temporarily secured an academic position in Costa Rica, Varela sent von Forester the draft of a new paper. It suggested that the addition of a "self-referential operator" to the calculus of indications presented in *Laws of Form* could open it directly to issues of biological autonomy.



For the cover page of his as-yet unpublished manuscript on self-reference, Varela redrew the rendering of the Ouroboros—the neocybernetic emblem par excellence of circular or self-referring processes—that von Foerster had appended to the recently released BCL volume, *Cybernetics of Cybernetics*.



Sidenote. Production costs for this 500-page behemoth were subvened by a grant from Stewart Brand's Point Foundation, established to distribute the profits made from the mass marketing of the *Last WEC*.



A CALCULUS FOR SELF-REFERENCE

FRANCISCO J. VARELA G.

Department of Anatomy, University of Colorado Medical Center, Denver, Colorado, U.S.A.

(Received August 15, 1974; in final form October 3, 1974)

An extension of the calculus of indications (of G. Spencer Brown) is presented to encompass all occurrences of self-referential situations. This is done through the introduction of a third state in the form of indication, a state seen to arise autonomously by self-indication. The new extended calculus is fully developed, and some of its consequences for systems, logic and epistemology are discussed.

BC] Varela's extension of Spencer-Brown's calculus of indications implicitly links the operation of autopoiesis, through the concept of self-reference, to the form of autonomy. This is a literal example of the "biological computation" sponsored at von Foerster's BCL.

ONE: THE DOMAIN

1. Presence

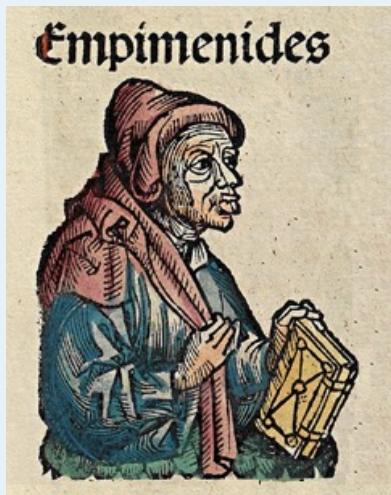
Self-reference is awkward: one may find the axioms in the explanation, the brain writing its own theory, a cell computing its own computer, the observer in the observed, the snake eating its own tail in a ceaseless generative process.

Stubbornly, these occurrences appear as outstanding in our experience. Particularly obvious is the case of living systems, where the self-producing nature of their entire dynamic is easy to observe, and it is this very fact that can be taken as a characterization for the organization of living systems. Similarly, the physiological and cognitive organization of a self-conscious system may be understood as arising from a circular and recursive neuronal network, containing its own description as a source of further descriptions. . . .

The difficulties in dealing with self-referential systems are rooted in language. Antinomies are to be expected when the self-referential capacity of language is used upon itself, as known for long in the capsular form of the epimenidean paradox . . .

—“A Calculus for Self-Reference” indicates that the point of Varela’s engagement with *Laws of Form* is to adapt its abstract notation to the description of living systems and neuronal networks, which are variously “self-producing,” or autopoietic, or “circular and recursive.”

The paradox of Epimenides of Knossos.



Epimenides the Cretan says: "All Cretans are *liars*." Now then, if he is telling the truth, then he's lying, but if he's lying, then he's telling the truth. That's the paradox: it renders the conclusion indeterminate, or, true and false at the same time.

The paradox is set up by the self-reference embedded in the major proposition: Epimenides' general statement also refers to his particular person, as he, too, is contained in its major class—all people from Crete.

However, this would not necessarily matter, if the content of his proposition did not also involve a matter regarding the truth of statements. For instance, he could have reasoned, "All Cretans are wise, I am Cretan, therefore I am wise." This major proposition may be untrue, or a lie, but the conclusion of *that* syllogism does not generate a paradox—at most, a misstatement, or a deception.

Varela remarks: "The difficulties in dealing with self-referential systems are rooted in language." That is to say, these difficulties are *not* rooted in *systems* as such, but rather, they are rooted in the propositional structures of linguistic statements *about* systems (or about anything else). The point is that *living systems* are clearly *not* "rooted in language," and so matters of self-reference in relation to them must be resituated to an appropriate domain.

Laws of Form as applied to autopoietic systems theory, once more:

The Form

the distinction: a mark

the indication = the marked state

"the inside of the distinction"

the unmarked state

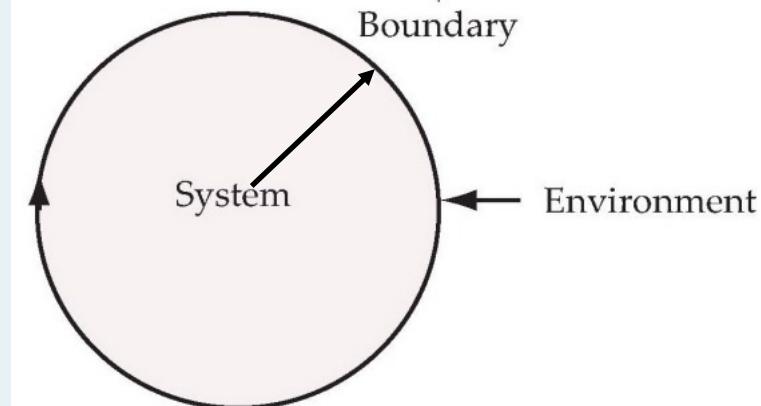
"the outside of the distinction"

Autopoietic system

Boundary

System

Environment



3. Notation.

Let the autonomous state be marked with the mark \square , and let this mark be taken for the operation of an autonomous state, and be itself called self-cross to indicate its operation.

Initial 2: Order

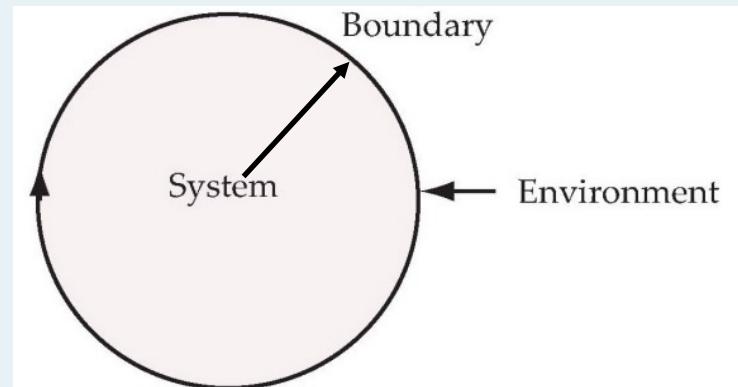
$$\overline{\square} =$$

Initial 3: Constancy

$$\square \mid = \square$$

Varela extends the formal operation Spencer-Brown calls *re-entry* by adding a new notation that links the “autonomous state” to the dynamics of self-reference. Paradoxically, to exit the autonomous state is to circle back into it. In Varela’s extension of the calculus the expression for this self-referential operation is *self-cross*. This extension of the calculus is meant to bring *biological* autonomy under its remit. For instance:

Autopoietic systems must continuously protect the integrity of their formal organization. At the same time, they are not atemporal structures but finite “self-crossing” autonomous productions that operate *in time*.



In face of an environment in constant change from moment to moment, given its incessant self-repair and replacement of its own molecular components, **any living system at t_2 both is and is not the same system it was at t_1** . The same organization persists amidst an incrementally differing structure of components. This situation may have the *form* of paradox, but only if one treats it as a timeless propositional statement instead of a temporal description of system operation.

—“A Calculus for Self-Reference,” continued:

7. *The Imaginary State and the Intercrossing of Domains.*

In this calculus antinomic forms are allowed to appear without restrictions and thus we have found a way to *construct* from an antinomic situation, which, formerly, we might have avoided rather than face. By not doing so [that is, by *not* avoiding paradox], we have found a *new, wider domain* where all the preceding forms can be lodged. . . . By allowing an antinomic form (from the point of view of logic) we have constructed a new larger domain akin to the complex plane [formed by the coupling of real and imaginary numbers], where new forms can be lodged, including those of the preceding primary domain found to be in conflict by the introduction of re-entering expressions. Again, rather than avoid the antinomy, by confronting it, a new domain emerges.

This intercrossing of domains at the point of *self-referring, hence, antinomic*, situations in a given domain, repeats itself. The most impressive instance being the appearance of living systems when a set of chemical productions closes onto itself to become a self-productive and self-constructive unity. . . .

BC] *Antinomic* is basically synonymous with *paradoxical*.

—Recall that *imaginary* numbers supplement the domain of *real* numbers by allowing for the inclusion of a paradoxical value, *i*, the square root of -1. The inclusion of imaginary numbers allows for a major expansion of the range of real-world calculations.

—As we sketched out in the previous slide, Varela’s *self-cross* is designed to overcome the *logical* paradox of autopoietic recursion.

8. Conclusion.

The starting point of this calculus, following the key line of the calculus of indications, is the act of indication. In this primordial act we separate forms which appear to us as the world itself. From this starting point, we thus assert the primacy of the role of the observer who draws distinctions wherever he pleases. Thus the distinctions made which engender our world reveal precisely that: the distinctions we make—and these distinctions pertain more to a revelation of where the observer stands than to an intrinsic constitution of the world which appears, by this very mechanism of separation between observer and observed, always elusive. In finding the world as we do, we forget all we did to find it as such, and when we are reminded of it in retracing our steps back to indication, we find little more than a mirror-to-mirror image of ourselves and the world. In contrast with what is commonly assumed, a description, when carefully inspected, reveals the properties of the observer. We, observers, distinguish ourselves precisely by distinguishing what we apparently are not, the world.

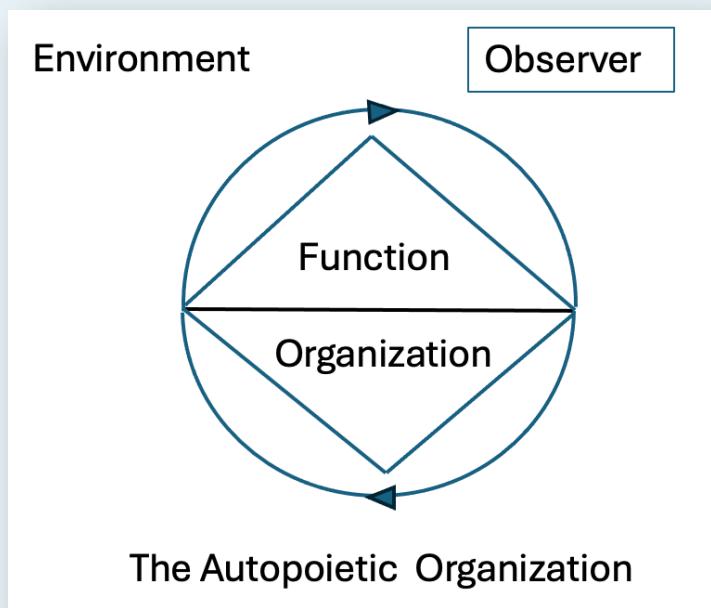
—In “On Observing Natural Systems,” Varela puts the same point this way: “whatever we purposely distinguish will reveal not only the properties we are looking at but the fact that we are doing these interactions out of our own properties, that is, the properties we discover in systems will depend on our own properties” (p.29). The previous year, von Foerster had admonished the readership of *CQ* to recall the same epistemological point: systemic concepts “are not names for properties of things, but those for properties of descriptions, or—if you wish—are names reflecting properties of the observer (describer).”

—Such “forgetting” is typically unconscious: it derives from the nervous system’s tendency to put its own operations into our “cognitive blind spot.”

—In the idiom of *Laws of Form*, one would say that the drawer of any distinction (the observer) thereby indicates *both* the entity distinguished as a separate datum (the indication proper) and the agent doing the distinguishing (the observer once again). This is why all cognition is self-referential in the first instance, as a condition of the possibility of indicating the world at all.

The conclusion of “A Calculus for Self-Reference” drives home and amplifies von Foerster’s own constructivist program and its implicit reinforcement in *Laws of Form*:

We then see that we stand in relation to the world by mutual negation, and that the union *of us two* has therefore an autonomous structure whereby the negation engenders a distinction which leads to its own negation in a ceaseless circular process which is, in fact, the symbol which tradition has chosen to represent the creation of everything since time immemorial. . . .



≈

