

Francisco Varela (1946-2001)

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We are sad to report that the field of nonlinear dynamics has lost a great luminary, neuroscientist and researcher, Francisco Varela, at the ripe age of 55. Varela was one of the most original thinkers of his time. He was also a prolific researcher whose contributions made ripples in diverse, multidisciplinary fields. Varela's perspective not only was unique, but also proved revolutionary. With a nonlinear perspective, Varela struck a blend between the physical sciences of biology and neurophysiology and the social ones of psychology, philosophy and spirituality.

Born in Chile in 1946, Varela received his MSc in Biology in 1967 from the University of Chile in Santiago, where he studied with Humberto Maturana. According to an obituary written by longtime friend and collaborator Evan Thompson (2001), Varela liked to tell the story of his bursting into Maturana's office one day as a wide-eyed undergraduate, where he announced his desire "to study the role of mind in the universe." To this, Maturana replied, "My boy, you've come to the right place."

Varela followed in the footsteps of Maturana by pursuing a doctoral degree in Biology at Harvard University. After graduating at 23, he declined a position as researcher there, returning with nationalistic zeal to his native Chile instead. Between 1970 and 1973, Varela and Maturana formulated their stunning theory of autopoiesis. This theory characterizes living systems as being both self-organizing and endogenously controlled (e.g., Varela, Maturana & Utribe, 1979). Autopoiesis is conceptualized as the minimal form of biological autonomy both necessary and sufficient for self-production. Self-production occurs in networks that are operationally closed and membrane-bounded, as well as governed by continual feedback loops. This view, with its emphasis on structural patterns, was consistent with the emerging sciences of cybernetics, but flew in the face of biology's emphasis on DNA as the seat of life.

In *A Calculus of Self-Reference* (1979), Varela elaborated the primitive, logical bases for autopoiesis. This work was an expansion of the seminal "Laws of Form" (1975) by mathematician and logician George Spencer-Brown. Spencer-Brown had innovated a two-valued calculus of indications. He believed his system so primitive as to provide a cradle not only for all of logic, but also for all of creation itself. Varela was particularly impressed by Spencer-Brown's interpretation of paradox when certain higher degree equations reentered themselves. When this occurred, marked states appeared to equate with unmarked ones. Rather than view this as the simultaneous presence of contradictory states, Spencer-Brown understood this as an oscillation between different, opposite states of the form. With this insight, Spencer-Brown believed he'd discovered the primitive foundations of time emanating out of primitive space implied by first distinctions.

By adding reentry as a third term, Varela took Spencer-Brown's work a step further and left behind the tame, two-valued world of Aristotelian logic. Varela made the radical assertion that reentry, along with paradoxical dynamics it entails, is built right into the very structure of the form. Varela upheld reentry as the cornerstone to autonomous functioning in nature. Varela expanded upon these ideas in his magnum opus, *Principles of Biological Autonomy* (1979). While dense and difficult, this work has influenced many a nonlinear dynamicist, including members of our own fold, such as Ben Goertzel. *Principles of Biological Autonomy* provides an important foundation for multidisciplinary work in self-organization. Its essence, as recently interpreted by Marks-Tarlow, Robin Robertson and Allan Combs (under review), is that autopoietic systems become functionally closed, while remaining structurally open via continuous recursive, feedback loops. The notion of emergent, nonlinear dynamics is used to straddle the paradox of a system that is simultaneously both closed and open, and to posit evolution in autonomous systems.

This issue of system openness was a key one that came between Maturana and Varela. The two broke off their collaboration with some bitterness, including a battle on Maturana's part for ownership of the idea of autopoiesis. While Maturana continued to conceptualize autopoiesis in terms of operational closure and equilibrium dynamics, Varela grew beyond these ideas. Varela embraced the contemporary sciences of nonlinear dynamics to break through the solipsism of earlier, collaborative work and to accommodate the

notion of change and evolution in autonomous systems.

Varela returned to Chile in 1970, preceding the election of Salvador Allende by two days. Three years later, the country erupted into great political turmoil. A military coup, staged by General Augusto Pinochet, overthrew the first Marxist government ever freely elected. Because Varela had been a strong Allende supporter, he was forced to flee the country with his family. First he went to Costa Rica, then the United States, he conducted research at the University of Colorado, as Assistant Professor at the Medical School. Later Varela traveled to New York, where he was centered in the Brain Research Laboratories at NYU's Medical School. Between 1980 and 1985 Varela returned to Chile, making his final move to Paris in 1986. Eventually Varela became Director of the Centre Nationale de Recherche Scientifique, a position he held until his death.

Over the course of his professional life, Varela's work and ideas have had widespread influence in many diverse fields, including dynamical systems theory, neuroscience, cybernetics, theoretical immunology, artificial life, theoretical biology, cognitive science and consciousness studies. Many of Varela's most important ideas from the 1970s anticipated critical sea changes in the 1990s.

Of special interest to psychology, Varela extended his ideas about autopoiesis to the biological bases of cognition as well. He helped transform the popular model of cognition from an input-output information processing system to a functionally closed, autonomous system that is composed of invariant patterns of activity in neuronal ensembles. Varela began to refer to his perspective as 'embodied' or 'enactive cognition' (see Varela, Thompson & Rosch, 1991). As most recently formulated (see Thompson & Varela, in press) and rephrased (Marks-Tarlow et al, under review), enactive cognition includes the following three elements:

1. Embodiment: The human mind is not confined within the head, but extends throughout and even beyond the living body to encompass the world outside of the organism's physiological boundaries;
2. Emergence: human cognition emerges through self-organized processes that span and interconnect the brain, body and environment in reciprocal loops of causation. In addition to the 'upwards' causation of personal consciousness by neural and somatic activity, there is the 'downwards' causation of neural and somatic activity by the person as an active, conscious agent;
3. Self-Other Co-Determination: because open boundaries exist at all levels, which include the social, the individual human mind does not emerge in isolation, but instead is embedded within an interpersonal context. Through ongoing, dynamic interaction, self and other create one another at the most fundamental levels.

This view of cognitive autonomous functioning places the body, physical environs and even the interpersonal environment all within the purview of subjectivity. Both of the current authors have been greatly influenced by this perspective. Martinez places the notion of embodiment under the even broader umbrella of culture. He studies how structural coupling to the environment occurs within a cultural context, that includes one's systems of beliefs about illness and its cure and how these beliefs affect biology. Martinez corresponded several times with Varela via email, between June 2000 and February 2001, until a couple of months before Varela's death. They discussed Varela's book in progress that he was coauthoring with his colleague and friend Evan Thompson. The intriguing title *Lived Body: Why the Mind Is Not in the Head* addresses more comprehensively the non-locality concept of cognition that Varela had begun to articulate in his previous book, *The Embodied Mind* (with E. Thomson and E. Rosch, 1992).

Martinez (2001) notes that his own model of *coemergent causality* evolved from Varela's embodied cognition and his inclusion of both upward and downward causality in neurophenomenology research. While the model of coemergent causality embraces the linearly upward and downward causalities, Martinez argues that there is also a non-linear and non-local communication within a field of bioinformation that seeks maximum contextual relevance where cause is both sequential as well as simultaneous (See Institute of Biocognitive Psychology at www.Biocognitive.com)

Martinez credits Varela's Buddhist conceptualizations for expanding his theory of biocognition from emergence to coemergence causality. At the personal level, Varela had been an avid student of Tibetan

Buddhist meditation and philosophy since the 1970s. Along with his personal practice, Varela also became active organizationally, for example with the Mind and Life Institute, where he helped to organize private meetings between the Dalai Lama and Western scientists (see Varela, 1997). Varela was able brilliantly to combine his personal experience with Buddhist thought and his vast knowledge of cognitive science to introduce an operational language of Buddhist psychology that could be discoursed in the field of neurophenomenology. Although Buddhist psychology has heuristic value in the study of consciousness, before Varela's contribution, it lacked the non-linear terminology that could appeal to complexity theorists.

Philosophically, Varela believed that scientific research needs to be rounded out by first person, phenomenological accounts of human experience. Professionally Varela strove to integrate epistemological and spiritual strands into his work. This is evident in his active support and involvement of a number of interdisciplinary groups devoted to the study of consciousness. Varela was on the faculty of the Naropa Institute and was a Fellow of the Association for the Scientific Study of Consciousness. He was on the Editorial Advisory Board of the *Journal of Consciousness Studies* and helped to found a new journal, *Phenomenology and the Cognitive Sciences*, where he would have served as Consulting Editor.

Varela was an insatiably curious fellow. He was an amazingly prolific researcher and writer who welcomed collaboration throughout his career. His publications (details can be viewed at www.ccr.jussieu.fr/varela/varela/index.html) include over 45 pages of articles and books to his credit. The following is a smattering of topics related to psychology, neuroscience and nonlinear dynamics:

optics in the compound of the honeybee,
the arithmetic of closure,
perceptual framing and cortical alpha rhythms,
non-hebbian synaptic learning rules,
experimental epistemology,
nonlinear neural networks,
cognitive networks,
structural coupling of simple cellular automata,
auto-immunity and networks of immunity,
chaos as self-renewal,
cognitive maps,
neuronal synchrony,
depression as dynamical disease,
neurophenomenology of time consciousness,
neurodynamics of retention,
entropy maps,
steps to a science of interbeing,
structural dynamics of awareness

In the early 1990s Varela contracted Hepatitis C and had been battling with liver failure ever since. He received a liver transplant in 1998 and contended gracefully and productively with declining health until he died. During their communications, Martinez eagerly asked Varela about the progress of his book and not once did Varela use his illness as an excuse for the delays. Instead, he courageously expressed optimism about completing the book as soon as he was able, very poignantly reflecting his Buddhist serenity in the face of death.

In Varela's early work, *A Calculus of Self-Reference*, he chose the icon of the Uroboros to symbolize his third term, reentry. The Uroboros appears in myth worldwide to represent eternal and time bound cycles of self-fertilization, regeneration and renewal. Varela himself completed a full circle that demonstrated reentry when he self-referentially applied his own ideas to the final examination of his life. There is both a poignant and tragic feel to this piece as Varela senses immanent death and studies the paradoxical phenomenology of his own illness and fragmenting consciousness (Varela, 2001).

Varela's longtime collaborator and friend, Evan Thompson, visited Varela just before he died. Like Martinez, he also reports (Thompson, 2001) feeling deeply touched by "the serenity, kindness, and intelligence he continued to radiate," describing Varela as calm and at peace when he died with his family

at his side. Varela is survived by his wife, Amy, their son Gabriel, a former wife, Leonor, their daughters Alejandra and Leonor, and a son Javier. Many will sorely miss him but, just like the Uroboros that he so ominously chose for his icon, his contributions will breathe life to a new generation of non-linear thought.

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