"On Observing Natural Systems"
Francisco Varela in conversation with Donna Johnson, CoEvolution Quarterly (Summer 1976)

26] Donna Johnson: Many people, almost as a matter of principle, of knowing what they're doing, make an effort to think "holistically," in terms of whole systems. But many of us often face a confusion stemming from our knowledge that "you can't consider a rabbit without considering his forest." We don't quite know how to go about considering the rabbit without fading into the forest, the local ecology, the planet, etc., and quickly into Everything. We know too that "the whole is more than the sum of its parts," but please Francisco what is a whole?

Francisco Varela: Well, yes, wholes, or whole systems, are arranged like Chinese boxes. One whole contains another whole and every whole is contained in another whole. There's a recursion principle there. But that does not mean that you cannot stop your unwinding at some point and consider a system.

Francisco Varela is a mathematician and neurologist whose special interest is the logic of self-reference. This sounds abstruse, but I share the opinion of Ludwig Wittgenstein, Gregory Bateson, G. Spencer Brown, Heinz von Foerster and others that failure to understand self-reference is the poison in the brain of most Western misbehavior, public and personal. In his recent landmark paper, "A Calculus [for] Self-Reference" and in this interview, Francisco is helping build what Von Foerster calls "a cybernetics of observing-systems," which is the rest of the story after "the cybernetics of observed-systems""—feedback, goal-seeking, and such.

After several years with Von Foerster's Biological Computer Laboratory at the University of Illinois in Urbana, Varela is now reaching and doing research at the University of Colorado, Denver. Donna Johnson, 28, is an intellectual nomad who goes around making people's ideas clearer.

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And I have come to the conviction that the key to understanding the holism of such systems, the wholeness of systems, is to understand that they are organized, their parts are organized, in a circular form. That is, every part interacts with every other part. That gives us a total self-referential system.

Four laws of ecology: "(1) everything is connected to everything else; (2) everything must go somewhere; (3) nature knows best; and (4) there is no such thing as a free lunch."

Barry Commoner in *The Closing Circle*, A. Knopf, New York, 1971, p. 18.

And of course the analysis of the parts does not account for the emergent properties when these parts are put together.

There has not been a lot of clear, disciplined thinking about wholes. We have a hell of a lot of technology, and ideas, and mathematics, about control of systems, that is, how to design them and how to get them to do whatever you want them to do. That is one step toward talking about systems in general regardless of their specific parts, that is, a proper system theory. But there hasn't been a lot of thinking, as a matter of fact very little thinking, on emerging properties of whole systems, natural systems.

Johnson: So how do you identify the circle that defines your system?

Varela: By the boundaries you put into the system. You say, this is the system I'm going to consider, this dog, or this society. To be sure, there are many ways of splitting up the world into different wholes, but once the criteria for separating one system from the other are given, you have a stable description.

So if you're interested in ecology, a certain kind of ecology, you split up the world in a certain way. If you're interested in economy, you split up the world in a different way. But given a criteria of distinction, you always come up with systems that have some sort of closure of their organization. And if you're a biologist, that's pretty clear, right? In the subject matter of the biologists, every one of the interactions in any organism interacts with every other interaction in a very closed fashion, a closed network of interactions.

27] The fact that wholes have this closed organization implies that in order to describe them we have to deal with self-referential descriptions. You wind up with functions that are functions of themselves, or interactions that interact with themselves, properties that compute themselves, and so on. This has a very weird flavor for most people, because the tradition in the scientific discourse has been that this is not something we can consider. The main trend has been to put it completely aside; anything that is self-referential is a "vicious circle." It was even called a vicious circle by Saint Thomas of Aquinas.

Johnson: We're all vicious circles.

Varela: Yes, but we were forbidden to deal with that in all its formal precision by the Russell-Whitehead Theory of Types, which requires us to completely break up any circularity by establishing a hierarchical form. This is the convention which is predominant, in classical science and therefore in system theory. It's hierarchical; you have input - system - output. You have the beginning and the end, and the beginning is the beginning and the end is the end; there is no confusion between the two. But if you are to really look at wholes, you can't do that. You have to look at the beginning and the end as a circle. So you cannot deal with them hierarchically, you have to look at them as self-referential situations.

Johnson: So studying the organization of a whole system is studying the nature of its self-reference?

Varela: That's it. That is, the kind of self-referential organization that has provided the stable properties that it shows. And this is what gives the system its nature. When you have a closed interaction of chemical productions, you can have a cell, and not before that. When you have a closed interaction of descriptions, you can have self-consciousness, and not before. When you have a closed interaction of species, you have an ecological system, and not before. That is, the closure, the self-referential-ness, seem to be the hinges upon which the emergent properties of a system turn.

Johnson: Are we dealing here with natural systems exclusively, or also with designed things?

Varela: Designed systems can be looked at as closed systems, but most designed systems can be understood in a hierarchical analysis, because they are to have a purpose. But how can you do that with, say, a dog? The dog has an

> *Taciturn systems are those for which the observer asserts or discovers the goal (purpose in), which is thereafter equated with the purpose for the system in question. In contrast, language-oriented systems can be asked or instructed to adopt goals by anyone who knows the object language and they may state and describe their own goals, using the same medium; in a very real sense these are "general purpose" systems.*
>
> Gordon Pask in "The Meaning of Cybernetics in the Behavioral Sciences,"

organization which manifests itself in a certain behavior which arises from its organization - but it's not designed to have a purpose <u>for</u> it.

We should remark that when we talk about natural systems, in no way do we imply that a man-made or designed system is "unnatural." That is, the word "natural" here is functioning in an ambiguous sense. Every man-made system is of course also natural, in the sense that whatever we humans do belongs to the same natural order as what birds do. The connotation of "natural" here, then, as in "natural system," is only one of non-design, in contradistinction to manmade or designed.

Johnson: So any system can be looked at in terms of its closure. . . .

Varela: As a matter of fact a system is stable <u>because</u> of its closure of organization, that's the source of its stability. Now this was already identified by Wiener, by his central concept of feedback. The notion of feedback is a self-referential one, but it was seized by the engineers who made it appear hierarchical. They apply a reference signal, identify input and output, and the output affects the input with a little delay. So the self-reference becomes hidden underneath, because of the trick of dealing with it in time.

But time, that trick of dealing with it in time, can work only at a very concrete or numerical level of description. As soon as you abstract properties a little bit more, for instance in a

situation where you don't have access to a time delay, you are stuck with a self-reference language. And the structure itself is of course timeless, the computation of the structure is timeless, so it's a self-referential organization.

Johnson: Do you think it's an obvious point that all whole systems are self-referential?

Varela: I think it's obvious once we see it. It's not obvious in general because the history of modern Western thinking has pressed upon us the convention of putting self-reference in a cognitive blind spot.

But everybody intuitively understands mutual interactions in a whole system. If I try to understand how my brain interacts with my liver, I know right away that it is not that my brain acts on my liver in hierarchical form but that my liver also acts on my brain, in a simultaneous fashion.

Unless you confront the mutualness, the closure, of a system, you just lose the system. It is the simultaneity of interactions that gives whole systems the flavor of being what they are.
28] So I agree with you that it's not obvious, but it's not something that can be demonstrated. It's like, when People say, "Hey! We've discovered that we have an environment." Of course, everybody has an environment, yet it was a discovery fifteen years ago.

And some of the most interesting examples are those which have not been obvious at all. For instance the understanding of our nervous system, not as an input-output information processing device as is the current understanding in neurophysiology, but rather as a closed unit of perception and action to maintain internally generated reference levels.

> *A cognitive system is a system whose organization defines a domain of interactions in which it can act with relevance to the maintenance of the system itself, and the process of cognition is the actual (inductive) acting (or behaving) in this domain. Living systems are cognitive systems, and living, as a process, is a process of cognition. This statement is valid for all organisms, with and without a nervous system.*
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> Humberto Maturana in "Neurophysiology of Cognition," *Cognition: a*

In other words, the idea is that the organism's stability produces certain levels to be maintained, and all the nervous system does is to maintain those internally generated levels in the face of perturbations. So behavior becomes the compensation for those perturbations. This was first proposed by H. Maturana,[1] and followed by W. Powers[2] in his book Behavior: The Control of Perception. "Perception" in this context means the organism's view of whatever impinges on it. And his view is precisely dependent upon the reference levels he is set up to maintain, rather than on an externally defined "stimulus" that is to be "processed," as defined by an external agent. Of course "perturbations" can be external or arise internally from the organism itself.

> *The fundamental anatomical and functional organization of the nervous system is basically uniform: the same functions and operations (excitation, inhibition, lateral interaction, recursive inhibition, etc.) are performed in its various parts, although in different contexts and integrated in a different manner. A partial destruction of the nervous system does not alter this basic uniformity and, although the parts left untouched cannot do the same things that the whole does, they appear in their mode of operation identical to the untouched whole. To the observer, once the boundary of the sensors is passed, the nervous system, as a mode of organization, seems to begin at any arbitrary point that he may choose to consider: the answer to the question "What is an input to the nervous system?" depends entirely on the chosen point of observation.*
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> Humberto Maturana in "Neurophysiology of Cognition," *Cognition: a*

Now, "compensation" and "perturbation" are very different things from "input" and "output," although they might work in a similar way. "Input" and "output" carry the connotation of being something arising in the design of a system. When I put my coin into the Coke machine, I know that it is designed to receive that input, and no other input. But if I call my dog "Fido" and he comes to me, it's not because he was designed for me to call him "Fido" or anything else. He wasn't designed; he just does his thing. The basic difference between input-output and perturbation-compensation is that one puts emphasis on the design of a thing, and the other puts emphasis on the stability arising from the closure of its organization.

The other example of the expansion of our understanding of whole systems is that of a dialogue, or even more concretely the situation where there is a teacher and a taught. Both have to learn simultaneously, one to teach, the other to learn. This has been described in great detail in Gordon Pask's theory of the p-individual.[3] We could go on with interesting examples; interpersonal relations (Laing),[4] world models,[5] management (Beer),[6] communication (Bateson),[7] economics (Boulding)[8] and so on.

> *In this discussion, questions of energy play almost no part—the energy is simply taken for granted . . . Cybernetics might, in fact, even be described as the study of systems that are open to energy but closed to information and control—systems that are "information tight."*
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> H. Ross Ashby in *Introduction to Cybernetics,* Chapman and Hall, London,

Now, a word of caution here. We are <u>not</u> saying that such systems are closed for <u>interactions</u>. This a point where there is much semantic confusion; when you say that a natural system has organizational closure, people think that you mean closed for interactions. Nothing of the sort, though this is the common meaning. This connects to your original question; no system is

closed for interactions, that is, it is not closed for matter and energy. But it can be organizationally closed, as was said by Ashby many years ago.

Johnson: Closed for computation.

Varela: Yes, closed for computation or information. And if you take this seriously, that it's closed for information, then you see that its structure has to be made up of self-referential interactions. Circular interactions, where there is no linearity, where like in the feedback loop, there is no meaning is establishing cause and effect. Because the cause and effect are mixed together.

Johnson: I'm trying to understand what the observer has to do with the closure. I ask myself the false question, is it a property of me or a property of the system?

Varela: Well, it's both. It's a property of their coupling. What you do with the closure of a system is actually what we do all the time, i.e., we interact with a system by poking at it, throwing things at it, and shouting at it and doing things like that, in various degrees of sophistication. That is a perturbation on the stability of the system, which it will compensate or will not compensate (and hence disintegrate). If it does compensate then we sense in it a stability for that interaction. So if each time I say "Fido" my dog comes around, that "Fido" is a perturbation in its organization that produces a compensation, i.e., the locomotion of coming to me. That is how it is with all systems. Now it is system-dependent in that its behavior will depend upon its organization. It is observer-dependent upon the kind of perturbation that I throw at it, which depends on me. Therefore my ability to see what its properties are is limited by what kinds of interactions I can have with it. So it's both.

Johnson: Then you should know just what you did to it, as much as you can.

29] Varela: Yes, as much as you can. And the larger the domain of interactions you can have with a system, the more you get to know the system. The ultimate of that is of course a very close person, or a very well-known society, where you know what kinds of compensations will arise from certain interactions.

More formally, once you know the laws of a closure, rather than attempting to make a stimulus-response analysis, you can predict the compensation for any perturbation.

Johnson: So we're back at the beginning, at a self-referential system preserving itself.

Varela: Yes, and I think that here we can summarize the three key points we've been discussing by stopping for a moment and thinking about, just what is the meaning of "wholeness?" This relates to two key processes. One is the process of recognizing the stable properties of wholes, by interacting with them. The other is the recognition that the stability we see arises from the self-referential, mutual, reciprocal interactions that constitute the system. Thus, the three notions I mentioned are distinction, stability and closure, and are really one and the same.

We recognize wholes because they have certain stable properties, and the stable properties arise from the closure of the organization, and the closure of the organization is the key to the

appearance of new properties, which is the characteristic of a whole that has the new emergent properties. In summary, I would say something like "the whole is more than the sum of its parts, it is the organizational closure of its parts."

Johnson: Okay, what does all this have to do with G. Spencer Brown and his Laws of Form,[9] and your work on the logic of self-reference?

Varela: Well, the fact is that, in Western thought, self-reference has been completely put aside. So in the kinds of descriptive apparatuses we are accustomed to for precise descriptions, that is the logic and mathematics that have been available to us for describing the world, self-reference has been completely out except in a very crude form involving time delays, or recursive expressions. These are adequate for things like computers and control systems, but they don't give us the full flavor of the closed organizational structure, which stays hidden underneath as it were.

> *By tracing the way we represent a severance, we can begin to reconstruct, with an accuracy and coverage that appear almost uncanny, the basic forms underlying linguistic, mathematical, physical, and biological science, and can begin to see how the familiar laws of our own experience follow inexorably from the original act of severance. The act is itself already remembered, even if unconsciously, as our first attempt to distinguish different things in a world where, in the first place, the boundaries can be drawn anywhere we please. At this stage the universe cannot be distinguished from how we act upon it, and the world may seem like shifting sand beneath our feet.*
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> *Although all forms, and thus all universes, are possible, and any particular form is mutable, it becomes evident that the laws relating such forms are the same in any universe. It is this sameness, the idea that we can find a reality which is independent of how the universe actually appears, that lends such fascination to the study of mathematics. That mathematics, in common with other art forms, can lead us beyond ordinary existence, and can show us something of the structure in which all creation hangs together, is no new idea. But mathematical texts generally begin the story somewhere in the middle, leaving the reader to pick up the thread as best he can. Here the story is traced from the beginning.*

Now, an entirely new, fresh beginning for that was provided by G. Spencer Brown in his Laws of Form [CATALOG, p.12]. Brown is an important key to what we're discussing, because he shows that the action of indication, of distinguishing something, is really what is happening at the basis of any description of any universe. Distinguishing or not distinguishing, as he proves, is much more general, more fundamental, than true or false. True-False is just one particular case of the general act of distinguishing.

Thus the notion of indication is the domain which he explores, the indication of forms, the most bare outline of anything we can describe. Brown strips systems down to their bare bones, which is just the pure indicational forms. Reading his book cannot be replaced by any summary we can do here.

Johnson: Enter the observer, with trumpets.

Varela: Yes, this does bring out the full importance of introducing the observer into the observation. That is, 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.

In its purest form, that means that whatever description we do of the world will be based on the act of splitting it apart in different ways. And the way we see the world, therefore, reveals what is our choice of cleavage, as it were, and that there are many of them precisely because there are many observers.

Spencer Brown shows that, in the most precise mathematical sense, every description can be based, including logic of course, on the act of distinction. The calculus of these distinctions is what is contained in his book. He develops a calculus related to these forms of indication. So our ideas about systems and their stability have a very natural foundation in Brown's profound insights, and in his formalism.

It is from his grounds that a different view about self-reference can be developed. For, in its purest indicational form, self-reference appears as forms that in-form themselves. This may sound just poetic but it isn't. It also
30] can be represented as very well-defined mathematical expression. And lo and behold! Once you start fiddling around with these re-entering, self-informing expressions, you find that an entirely new extension of Brown's initial ground is necessary.

It is something like this in an analogy to the numerical domain: suppose you start with an initial ground composed just of the integers (i.e., 1, 2, 3, . . .). Then you fiddle around with them, making more and more complex expressions. At a point, new kinds of numbers will emerge, real numbers (something like pi or $\sqrt{2}$). Thus it becomes necessary to extend the initial ground on which we started.

In the domain of indications, of course, numbers do not exist yet. This domain precedes their appearance. But a similar situation arises: as soon as self-reference is introduced, the ground has to be expanded considerably. And this says, to me, that in its most basic forms, self-reference is a very unique domain, that cannot be trapped into non-self-referential grounds. Which we knew all along, but didn't want to acknowledge. So this is what my own work[10] has been concerned with, exploring this brownian foundation for a general theory of systems where closure and self-reference takes the place it deserves. It is a very beautiful subject, and there is lots to do.

> *Thus we cannot escape the fact that the world we know is constructed in order (and thus in such a way as to be able) to see itself.*
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> *This is indeed amazing.*
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> *Not so much in view of what it sees, although this may appear fantastic enough, but in respect of the fact that it* can *see* at all.
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> *But* in order *to do so, evidently it must first cut itself up into at least one state which sees, and at least one other state which is seen. In this severed and mutilated condition, whatever it sees is* only partially *itself. We may take it that the world undoubtedly is itself (i. e., is indistinct from itself), but, in an y attempt to see itself as an object, it must, equally undoubtedly, act so as to make itself distinct from, and therefore false to, itself. In this condition it will always partially elude itself . . .*
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> *We see now that the first distinction, the mark, and the observer are not only interchangeable, but, in the form, identical.*

Now, for me, one of the most attractive features of this approach, this brownian view, is that it combines in one conceptual stroke the act of seeing systems (i.e., some universe) and he who does the seeing, so that the formal ground fits hand in glove with our previous point about the observer, the interlocking between what is seen and who sees it.

Johnson: It's interesting how this also fits into the many spiritual traditions that say that the only way to know what you're doing is to know yourself, as much as you can, to know what is knowing. That entails a frightening responsibility, if you have those sensibilities. I wonder about the question of people "becoming more objective" as many say, by ridding themselves of, or at least recognizing, their ego trips, their preconceptions, false beliefs, etc. Is there a way to talk about these things in Spencer Brown's language, perhaps more clearly than in the previous languages?

Varela: I have two related points to make here, which I feel very strongly about. One, I would reformulate what you just said about this "objective" business. When you realize that whatever you see reflects your properties, instead of putting so much intent, so much energy, investing so much, in a particular content, you turn back and focus on your capacity to do such a thing as a distinction. So the capacity to compute a reality becomes much more interesting than the content of the reality. Not so much intent, thus, on the something, but on the process of doing what we do to arrive at the something.

It seems to me that what is properly human, our responsibility (and John Lilly would say the next stage of evolution), is to have a hold on these laws of cognition and reality, rather than on any specific, particular realities.

The West has always been sold on a certain, particular way of doing things. What an understanding of what we have talked about today would bring about, is a recognition that the more we know about these things, the more we know about how to compute any universe whatsoever. So the more "objective" we would be in the sense that we would know what the contents of any universe would really mean.

This is what von Foerster has called the "cybernetics of second order,"[11] i.e. not the cybernetics of observed systems, but the cybernetics of observing systems. I think this is quite central. It's really the same theme that from the cognitive point of view Bateson[7] and Lilly[12] and von Foerster[13] and Spencer Brown[9] and Joseph Chilton Pearce[14] and John Brockman[15] and Ornstein[16] are addressing, which fits hand-in-hand with the traditional spiritual techniques, but seems to me the more Western way of embodying it, rather than the more disembodied kinds of spirituality.

The second point in relation to your question is that once you realize the full cognitive impact of these ideas, which I don't think we really have, you begin to understand that your participation in this reality has a limit, i.e., that you're a part of it, and you cannot possibly hope to comprise the whole of it. The establishing of the limits of our actions as a result of our epistemological understanding, seems to be very fruitful in the light of world models, urban growth,
31] population, and all of these current human problems that find their solution in a limit.

But it cannot be a limit imposed from the outside, as Ivan Illich[17] has said so clearly about, say, medicine, law and transportation. None of these limits can be arrived at by arbitrary decision, nor by myth, as it used to be, but must arise from an understanding that these limitations can be seen with the utmost precision. We can understand that we have a limited capacity to comprehend what is happening at any given moment, and we can therefore limit our actions with respect to the reality we are confronting. This is opposed to the current idea of precision, that an action, when it is faulty or wrong, can be corrected by more complex technological or scientific improvement along the same lines on which the fault was discovered.

So the two things go side by side, the intrinsic limitation, which is a self-referential kind of limitation, and the understanding of the importance of focusing on the nature of our capacity to invent realities, rather than on their specific content.

Johnson: We are then faced with the self-consciousness of seeing ourselves seeing the world, and the other-consciousness which sees its limits in the knowledge that each of us is constructing a reality for himself.

Varela: Yes, and this takes us far, because it leads us to a meta-understanding of humanity. If everybody would agree that their current reality is a reality, and that what we essentially share is our capacity for constructing a reality, then perhaps we could agree on a meta-agreement for

computing a reality that would mean survival and dignity for everybody on the planet, rather than each group being sold on a particular way of doing things.

Thus self-reference is, for me, the nerve of this logic of paradise, that is, the possibility of common survival with dignity of humankind.

That paradise is something very concrete, founded on the logic of self-reference, on seeing that what we do is a reflection of what we are. This is the other aspect of my interest in having a full grasp of what self-referential descriptions are, how we can make them approachable, handleable, meaningful.

Johnson: Even the simplest levels of that haven't been done, say in places like medicine, where it seems generally not to occur to people to ask "What else happens when you push this button," when you administer this antibiotic? What happens besides killing off certain bacteria? How does the organism compensate? Even this is not done, let alone the kind of paradigm switch that is going to be necessary if your paradise is to come about.

Varela: Well, either it comes about or we're done for. The transition of paradigm here, is from a classic one - the observer shall not enter into the description - to, how shall I call it, a communal one - the description shall reveal the properties of the observer.[13] The essential flavor of descriptions of the world in the classic paradigm is hierarchical; and this reminds us a lot of our hierarchically organized corporate society. In the hopefully coming paradigm a central feature of any description is the acknowledgement that everything affects everything else, and reflects everything else; it is much more like a communal structure.

Well, we're being awfully loose and general, but all these things do relate. It is amazing, that systems theory in the sense used here; mathematics in the brownian sense; proper understanding of the nervous system and cognition; and human issues such as exploring the nature of consciousness and of institutional overgrowth - all these things do come together into a common understanding. That's a lot of ground, but there it is.

Johnson: And the moral of the story . . .

Varela: The moral of the story is, we have to have this understanding. But whether this survival with dignity comes about or not, is not only a matter of ideas. It also implies a hell of a lot of other things. It's not just a matter of knowing it, we also have to live up to it. We have to have the being adequate to the understanding, and this is not arrived at by intellectual means. Self-reference applies here as well: to understand the whole of us and the world, we have to participate with the whole of us. Specially, the bringing together of verbal and non-verbal forms of knowledge, rational and intuitive, is necessary.

Without understanding, it would not be possible, but we have to guard against settling for intellection only. •

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