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Autopoiesis, Structural Coupling and Cognition: A history of these and other notions in the biology of cognition

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Abstract: My intent in this essay is to reflect on the history of some biological notions such as autopoiesis, structural coupling, and cognition, that I have developed since the early 1960's as a result of my work on visual perception and the organization of the living. No doubt I shall repeat things that I have said in other publications (Maturana & Varela, 1980, 1988), and I shall present notions that once they are said appear as obvious truisms. Moreover, I shall refine or expand the meaning of such notions, or even modify them. Yet, in any case, the reader is not invited to attend to the truisms, or to what seems to be obvious, rather he or she is invited to attend to the consequences that those notions entail for the understanding of cognition as a biological process. After all, explanations or demonstrations always become self evident once they are understood and accepted, and the purpose of this essay is the expansion of understanding in all dimensions of human existence.

Keywords: Autopoiesis, structural coupling, cognition, explanations, self-consciousness

Conceptual changes

In 1960 I asked myself "What should happen in the manner of constitution of a system so that I see as a result of its operation a living system?" This was a strange question in a period in which every scientist knew that to know something about something one should go and look what was already there without interfering with it. I was not making a hypothesis about how the system was. I was proposing that the relation between the internal dynamics of the system and the result of that internal dynamics in the domain in which I observed it, would tell me what the system was. I had to create the system to know it.

In 1965 when I was studying color vision in pigeons I realized that I could no longer pretend that one saw the colors as features of an external world, and that I had to abandon the question, "how do I see that color?" and ask instead, "what happens in me when I say that I see such a color?" To make this change meant abandoning the notion that there was an external independent world to be known by the observer. Instead I had to accept that knowing has to do with the congruent interactions between entities each of which is a structure determined system – that

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is a system in which all that happens with it and to it is determined at every instant by the way it is made (its structure) at that instant.

To adopt the epistemological grounding entailed in these changes meant that henceforth I would not ask "what is?", but I would ask myself "what criterion do I use to validate my claim that something is what I say that it is?" Furthermore, to do this entailed a fundamental ontological change, namely the fundamental question was no longer *"what is the essence of that which I observe?"* but rather *"how do I do what I do as an observer in observing?"*

All that follows comes from that basic epistemological and ontological change in my thinking.

1. Autopoiesis

1.1 Origin of the notion of autopoiesis

In November 1960, a first year medical student asked me the question "What began three thousand eight hundred million years ago so that you can say now that living systems began then?" I realized that at that moment I could not properly answer that question, so I replied "I cannot answer this question now, but if you come back next year, I shall propose an answer." Thus, I accepted the question of the student to be answered later and at the same time accepted the question for myself. In so doing I realized that I did not know the answer because I did not know what made living systems living systems, and to answer the question properly I would have to create a living system, either conceptually or practically in the laboratory. This was the case because I had to be able to say what kind of systems living systems are now, to be able to say what had begun when they began some four thousand million years ago.

In the attempt to answer this question it became obvious to me that I had to satisfy two conditions: one was that I had to propose a characterization of the network of processes that constituted living systems as singular entities, a network of processes that I did not know; and two, that I had to propose some feature of living systems that I did know now as a reference to decide whether the network of processes that I proposed was indeed necessary and sufficient to constitute and realize a particular discrete system as a living system.

Some ten years earlier, in 1949, when I was a medical student but was ill with lung tuberculosis in a sanatorium in the Andes, I had realized that what was peculiar to living systems was that they were discrete autonomous entities such that all the processes that they lived, they lived in reference to themselves. Accordingly, I thought then, whether a dog bites me or doesn't bite me, it is doing something that has to do with itself. So, I thought that in order to understand living systems and explain what happens to them and with them in their living, I had to take as a fundamental condition of their being living systems that they existed as autonomous entities in the form of self contained closed molecular dynamics of self production, open to the flow of molecules through them. And I realized that following that understanding one could say that a living system arose

in the history of the earth in the moment in which some network of molecular productions became closed upon itself constituting a discrete entity in which the molecules produced realized the same network of molecular productions that produced them while realizing at the same time its boundaries as an autonomous totality in a molecular medium with which it was in molecular interchange.

Through this understanding my claim became that a living system was a dynamic molecular entity, realized as a unity as a closed network of molecular productions in which the molecules produced through their interactions:

a) recursively constituted the same network of molecular productions that produced them; and,
b) specified the extension of the network and constituted operational boundaries that separate it as a discrete unity in a molecular space.

I said all this in the additional understanding that as a discrete molecular system closed as a netwok of molecular productions, a living system was a molecular system open to the flow of molecules through it as molecules could enter it and become participants of its closed dynamics of molecular productions, and molecules could stop participating in such molecular dynamics leaving it to become part of the molecular medium in which it existed.

My first full understanding of how living systems were discrete self producing molecular networks closed in the dynamics of molecular productions, but open to the flow of molecules through them, took place suddenly at the end of 1963. In a conversation with my friend Dr. Guillermo Contreras I was highlighting a fact that we of course both knew, namely, that nucleic acids participate with proteins in the synthesis of proteins, and that proteins participate as enzymes with nucleic acids in the synthesis of nucleic acids, all together constituting a discrete circular dynamics supported by the continuous flow of the molecules that we usually call metabolites. As I was drawing a diagram of this circularity, I exclaimed "This is it! This is the minimal expression of the circular closed dynamics of molecular productions that makes living systems discrete autonomous molecular systems." My understanding of livivng systems as discrete autonomous closed networks of molecular productions was not conceived in an experiential vacuum because I proposed it as an abstraction of my biological understanding aware of the biological knowledge of the times.

After this event I began to see that the metabolic charts that usually hang on the walls of a biochemistry laboratory showing cases of circular closed molecular dynamics do not show the molecules involved in the closed cyclic metabolic process participating in the realization of a boundary that would make of that circular molecular network a discrete entity in the molecular space. I think that those metabolic charts did not reveal the notion of autopoiesis, nor did they offer the posibility of conceiving autopoiesis because the conceptual understanding of living systems as closed systems of molecular productions did not exist due to the belief that living systems had to be characterized as open systems in terms of the flow of energy through them.

I did not have the word *autopoiesis* then. Accordingly, at the beginning of the year 1964 I began to say that living systems were constituted as unities or discrete entities as circular closed dynamics of molecular productions open to the flow of molecules through them in which everything could change except their closed circular dynamics of molecular productions. So I spoke of living systems as discrete autonomous entities organized as closed networks of molecular productions open to the flow of matter through them, emphasizing their condition of being discrete singular closed entities in their dynamics of states. It was not until 1970 that I chose the word autopoiesis as the name of the organization of living systems as discrete autonomous entities that existed as closed networks of molecular production, claiming that autopoiesis was the necessary and sufficient condition for the constitution of living systems, and that they existed only as long as their autopoietic organization was conserved.

1.2 Molecular systems

We living systems are molecular systems that exist in the molecular domain spontaneously without external processes driving them. As I say this I also claim that autopoiesis occurs only in the molecular domain.

A closed network of molecular productions that recursively produces the same network of molecular productions that produced it and specifies its boundaries, while remaining open to the flow of matter through it, is an autopoietic system, and a molecular autopoietic system is a living system. As such an autopoietic system (a living system) exists only in the molecular medium in which it can operate as a totality in the conservation of its autopoietic dynamics through the continuous change of its molecular architecture through the spontaneous thermal molecular dynamics. Therefore, a living system will arise and be conserved in any part of the cosmos where the molecular conditions that make it possible take place: *a living system as a molecular system occurs as a closed dynamic molecular architecture that in its continuous transformation through thermal agitation continuously gives rise to itself.*

There is more, however. The molecular domain is the only domain of entities that through their interactions give rise to an open ended diversity of entities (with different dynamic architectures) of the same kind in a dynamic that can give rise to an open ended diversity of recursive process that in their turn give rise to the composition of an open ended diversity of singular dynamic entities. Molecules through their interactions give rise to molecules and dynamic systems of molecular productions, in difuse and localized processes that constitute discrete entities. I think that due to this peculiarity of the molecular domain this is the only domain in which autopoietic systems can take place as discrete singular systems that operate through thermal agitation and dynamic architecture.

Molecular systems exist only in the satisfaction of the structural conditions of molecular existence, thus the satisfaction of all that is required for molecular processes to occur is implicit in the understanding that living systems are molecular autopoietic systems. The fundamental thing that happens in the

constitution of a living system as a molecular autopoietic system is its continuous realization as an autonomous entity that has a discrete singular existence that is conserved in the continuous flow of molecules through it. Biological phenomena occur in the actual realization and conservation of living systems as singular unities, not in the particular nature of any of the molecular processes that realize them. *Any phenomenon that occurs through the actual realization of the living of at least one living system, is a biological phenomenon.*

Biological phenomena take place in a dynamics that occurs in the present without any operational relation to what we call the past or the future. Past and future are explanatory notions introduced by the observer. The recognition that living systems are molecular autopoietic systems has been minimized by some biologists under the claim that the notion of autopoiesis has already been used by Kant as he thought of organisms as totalities in which each part existed both for and by means of the whole, while the whole existed for and by means of the parts (Kant, 1952; Kauffman, 1995).

Yet, what I say has a precision beyond what Kant said, nor could have said as he did not have the biological grounding for it. I am speaking of how a living system is constituted operationally as discrete singular molecular system that arises as a dynamic architecture which is the spontaneous unintended result of the interactions of molecules that operate in relation to their inmediate locality, without any reference to the totality that they compose. I am not saying, as Kant and others have said, that the parts exist for the whole and the whole exists for the parts. That is a comentary of an observer in relation to what he or she thinks; it does not reveal what happens in the molecular dynamics of a cell or organism. Molecules interact with other molecules in a way in which the result of their interactions does not participate at any moment in the genesis of that result. The notion of autopoiesis, as a characterization of the organization that makes a molecular system a living system, is an abstraction of what an observer sees as a continuous result of the spontaneous operation of the molecular dynamic architecture that constitutes the living system through processes that are structurally congruent yet blind to the consequences to which they give rise. The components of any system exist as local entities only in relations of contiguity with other components, and any relation of the parts to the whole proposed by an observer can only be a metaphor for his or her misunderstanding, and has no operational presence. It is only in the collapsing of domains that we human beings make in our reflections that the result of a process may appear as if it were participating in its genesis. There is nothing in a molecular system that could be properly regarded as an organizing or guiding principle.

Autopoiesis is not something that can be called a property of living systems because it is their actual manner of being as the organization that constitutes them as singular entities in the molecular space. As a molecular autopoietic system a living system exists in the continuous flow of molecules through it in its realization as a closed network of molecular processes that dynamically specify its boundaries as a singular movable entity floating and sliding in a molecular space.

Accordingly, and I repeat, living systems are not the molecules that compose and realize them moment by moment, they are closed networks of molecular productions that exist as singularities in a continuous flow of molecules through them. Indeed, the condition of being closed molecular dynamics is what constitutes them as separable entities that float in the molecular domain in which they exist. It is this manner of constitution of living systems as molecular systems that I denote when I say "it is not the molecules that compose a living system that make it a living system."

Of course living systems are not unique in being dynamic systems that are not the collection of components that realize them at any particular instant. I shall mention two cases in which it is apparent that what constitutes a dynamic system is its manner of dynamic composition, not the elements that compose it. One is a tornado, which is a system that exists as the manner in which the air molecules that realize it as a singular entity flow through it continuously; a tornado is not the particular molecules that compose it at any instant. A tornado through which molecules did not move would not be a tornado. Another is a club, that exists as a discrete network of conversations realized by persons that change in the course of the years, but which remains the same club as long as the network of conversations that defines it is realized and conserved through the interactions of the persons that are its members at any moment. The elements that compose a system are not its components by themselves, they are its components only as they participate in its composition, and only while they do so. So a particular molecule is a component of an autopoietic system only as it participates in the autopoietic molecular dynamics that constitutes it, and stops being a component of it as soon as it stops participating in such dynamics.

1.3 Conservation and historical processes

The notion of conservation is a fundamental notion of which I was aware since I was a medical student in the early fifties, but which I did not begin to use with full understanding until the early sixties. In fact, it was when I began to think on how to answer the question about the origin of living systems that it became obvious to me that that which we usually call relations of conservation are not features of the process in which we see them, but abstractions of the structural coherences under which the historical process takes place. As such, the notion of conservation has heuristic value because it reveals operational coherences in the structural (relational) matrix of the dynamic architecture of the domain in which a process takes place. Thus, in 1978 I began to speak of two relations (or laws) of conservation in the domain of biology that defined the course that different biological processes necessarily had to follow in order to happen at all. These are, the law of conservation of organization (autopoiesis in the case of living systems) and the law of conservation of adaptation, that is operational congruence, with the medium in which a system (a living system in our case) exists. These two laws of conservation are both relational conditions of the realization of living systems that must be satisfied for living to occur at all. That is, the conservation of autopoiesis

and the conservation of adaptation are constitutive conditions for the realization of a living system as such.

Historical processes occur moment after moment following a path constituted at every instant in the conservation of something that connects the successive moments in it, and around which all else is open to change. Thus, to say that living systems are historical systems, is to say precisely that they exist as singular entities in a continuous flow of structural change around the conservation of autopoiesis and adaptation. Accordingly, it is not change that makes biological evolution a historical process, but it is the phylogenic and ontogenic continuous conservation of autopoiesis and adaptation as the relational conditions around which all else is open to change. In these circumstances, what is primarily conserved in the history of living systems is living (autopoiesis and adaptation). And what is secondarily conserved are the different forms of realization of living through the reproductive conservation of different manners of realization of autopoiesis in the conservation of adaptation. An understanding the participation of the processes of conservation makes possible the understanding both of the kind of systems that living systems are, and of the biosphere — as a spontaneous result of the history of conservation of an organism/medium relation in which the organisms and their domains of existence have changed together congruently as a simple result of the reproductive conservation of the realization of living that began millions of years ago. In this sense the biosphere, as I began to describe it in my lectures in 1990, is a historical wave front of co-evolving living systems in the systemic reproductive conservation of both autopoiesis and adaptation (Maturana & Mpodozis, 1992, in press).

1.4 The living

My assertion that living systems are molecular autopoietic systems is neither a definition nor an explanatory proposition, it is an abstraction of the operational coherences apparent in the actual living of living systems as molecular systems. Therefore, my assertion that living systems are molecular autopoietic systems (and that there can be autopoietic systems only in the molecular space) is a claim about what constitutes living systems, a claim about how they arose, and a claim about how they operate in the pragmatics of their living. Moreover, as I have already said, as I claim that living systems are molecular autopoietic systems I do not make a claim about any particular molecular structure in them, rather I make a claim about the kind of molecular network that constitutes them, and in so doing specity the domain in which they exist without any guiding process or center of control of the processes that constitute them. In this view nucleic acids (DNA molecules) are not controlers of what happens in the cells, but elements that participate in the dynamic molecular architecture that constitutes them. In these circumstances, the claim that living systems exist as singular autonomous molecular autopoietic unities through interactions in a medium with which they are in a continuous molecular interchange, is a claim about how they exist in their internal composition as well as about how they exist as totalities.

Systems as composite entities have a dual existence, namely, they exist as singularities that operate as simple unities in the domain in which they arise as totalities, and at the same time they exist as composite entities in the domain of the operation of their components. The relation between these two domains is not causal; these two domains do not intersect, nor do the phenomena which pertain to one occur in the other. The generative relation that an observer may see between these two domains is a historical relation that the observer makes as he or she correlates the dynamics of the domain of composition of the system with what happens with it as a resulting totality in the domain in which it exists as a totality.

Let us consider some of the implications and consequences of the fact that living systems are molecular autopoietic systems:

1) Living systems exist as singular entities that operate as totalities in interactions in a medium where each conserves its individual identity under the form of a unicellular or a multicellular organism. That is, living systems exist as organisms in the realization of their living.
2) A living system as a molecular system is a structure determined system, and everything that happens in it or to it, happens in each moment determined by its structure at that moment. That is, nothing external to a living system can specify what happens in it; all that an observer sees as external to a living system can only trigger in it structural changes that are determined in it.
3) Each living system as a molecular autopoietic system is constituted as a closed network of molecular productions in which the molecules produced through their recursive interactions constitute the same closed network of molecular productions that produced them. In so doing the living system dynamically realizes its operational boundaries as a singular entity that operates as a totality of interactions in a molecular domain. That is, the boundaries of a living system are not fixed by the molecules that form the boundary but arise in the molecular dynamics of participation in the autopoiesis of the organism.
4) Living systems as molecular systems are constitutively open to the flow of molecules in the continuous realization of the recursive closed self-producing dynamics that constitutes them as singular entities. That is, as molecular systems living systems necessarily exist in the flow of matter and energy.
5) Everything that happens in the history of living systems occurs through their realization as singular entities that exist as organisms while in interactions with the medium in which they operate as totalities. That is, biological phenomena take place in and through the realization of the living of living systems.
6) Living systems exist in two domains: one; the domain in which they exist as totalities or organisms, that is the domain in which they realize and conserve their identity as multicellular or unicellular singular beings; and two, the domain in which they operate as molecular autopoietic systems which is the domain of their realization as composite molecular entities. This condition entails that the internal dynamics of a living system (its autopoiesis) occurs contingent on the conservation of its living as an organism, and the conservation of the livivng of the organism occurs contingent on the conservation of its autopoiesis.

Frequently the dual existence of living systems in particular, and of systems in general, is obscured by the notion of emergent properties. By treating the features that an observer distinguishes in a system as if they were a property, and hence intrinsic to the system, the notion of "an emergent property" obscures the relational nature of these features. All the characteristics that we as observers distinguish in a system pertain to the relational space in which it arises as we distinguish it, and are dimensions of its existence in that space. So, to speak of emergent properties in the constitution of a system is both a mistake and misleading. As a system is constituted as a totality, a new domain arises, the domain in which the system exists as that totality. Therefore, to say that autopoiesis is an emergent property would be a mistake. To say that the constitution of a organism gives rise to emergent behavior would also be a mistake; the behavior that an observer sees as appearing in the relational space in which he or she distinguishes it is not a feature of the organism, but a relational dynamics that arises with the participation of the medium as the organism interacts in it as a totality: behavior as a relational dynamics involves both the organism and the medium in which it exists as a totality.

1.5 Not an explanatory principle

One of the basic conceptual difficulties in understanding living systems as autonomous autopoietic systems arises from our cultural attitude that leads us to think in terms of "causes" in order to explain the occurrence of any phenomenon. This attitude blinds us to the spontaneous nature of all processes in the molecular domain in which we exist. All molecular processes occur spontaneously following a path that arises moment after moment according to the structural dynamics of the different molecules involved, and their particular relations of neighbourhood at any moment. That is, nothing occurs in the molecular domain through the action of an agent (cause) external to the structural coherences of the circumstance in which it occurs. Thus, in our culture, we are surprised when we see what we call order appearing spontaneously where we did not expect it, and we do not find an external cause for it. When that happens we find ourseves in a conceptual difficulty that we frequently attempt to avoid or deny by resorting to some explanatory principle that we use without full awareness, as if this principle were the external cause of that unexpected order.

This is, I think, what has happened with the use of the notion of autopoiesis as it has been frequently treated as an explanatory principle. But the notion of autopoiesis as I have indicated above, is not an explanatory principle, it is a generative mechanism that when in operation results in what we distinguish as a living system. Autopoiesis happens spontaneously when the molecular dynamic conditions that can give rise to it occur in a process that takes place without external or internal guidance. Moreover, as I have said above I claim that autopoietic systems exist only in the molecular domain, because the molecular domain is the only domain in which the interactions between the elements that compose it produce elements of the same kind as a spontaneous result of their

structural dynamics. Furthermore, since 1971 I have claimed in my lectures that autopoiesis (molecular, of course) is both the necessary and sufficient condition for the constitution and realization of living systems. Later, while answering questions about whether there were other autopoietic systems in other domains, and whether they were living systems or not, I though that it was perhaps possible that autopoietic systems could exist in domains different from the molecular one. However, as I have become more aware of the uniqueness of the molecular domain, I have realized that it is only in the molecular domain that systems like living systems can exist because it is only in this domain where autopoiesis can take place. Let me be explicit.

The molecular space is peculiar in that:

a) It is constituted by dynamic composite entities (the molecules) that as a result of their interactions produce through composition and decomposition elements of the same kind (namely new molecules).
b) The composition and decomposition of the elements of this space (the molecules) occurs while these elements exist as composite entities under thermal agitation that operationally constitutes the energy for their composition and decomposition.
c) The course of the compositions and decomposition to which the elements of this space give rise in their interactions, is determined at every instant by the dynamic architecture (the structure) of the interacting elements (the molecules).

In these circumstances, the molecular space is a space in which all the composite structures or systems that arise through the interactions of the molecules in it arise in a spontaneous dynamic molecular architecture without the guidance of any organizing force, principle, plan or information. There is no other domain like this in which the interactions of the elements that constitute it generate through their composition other elements of the same kind through thermal agitation and without external support. Hence I claim that neither the elements of the sub-molecular nor the elements of the supra-molecular domains can by themselves give rise to autopoietic systems as singular entities constituted as closed networks of productions of components that do not need external support to operate as such.

Accordingly, a living system exists as an autopoietic system in the molecular space. But, at the same time, a living system also exists as an organism in a supra-molecular space where it arises as a totality through its interactions as a whole while being constituted and conserved as a molecular autopoietic system. That is, an organism is an autopoietic system through its molecular composition, not through its supra-molecular existence. *Autopoiesis describes the constitution of living systems as discrete molecular systems.*

1.6 Domains of existence

Autopoiesis describes the internal dynamics that constitues a living system as a living system in the molecular domain, but a living system also exists as a totality in a relational space where it operates as an organism. The constitution of living

systems as autopoietic systems entails their constitution as organisms as a result of the constitution of their operational boundaries which separate the molecules that dynamically participate in their autopoiesis from those that do not. So, living systems exist in two non-intersecting domains, the domain of their components as molecular autopoietic systems, and in the domain in which they operate as organisms (totalities) in a medium that makes them possible. These two domains do not intersect, the processes that take place in one cannot be reduced to the processes that take place in the other. Yet, these two phenomenal domains modulate each other through the structural changes that take place in the autopoetic system in the course of the internal dynamics of the living system as well as through those structural changes triggered in it through its operation as an organism in a medium.

Although a living system operates at each moment in a manner determined by its structure at that moment, because the structure of the living system is continuously changing, the operation of a living system in its two domains of existence is also changing continuously around the simultaneous conservation of its autopoesis and its structural coupling in its changing medium. In this interlaced continuous change of the manner of realization of the molecular autopoiesis of the living system, and the manner of relating of the organism as a totality, it is the conservation of the operational congruence between the organism and the medium in which it exists that guides the path of changes of the living system as a totality.

The understanding of the simultaneous existence of a living system in these two domains is possible only if one understands that molecular autopoietic systems do not have inputs or outputs in the informational sense, and that these two domains interrelate only through the different structural changes triggered in the single bodyhood of living system through their corresponding non-intersecting relational dynamics. This understanding is one of the fundamental outcomes of the understanding of living systems as molecular autopoietic systems. As a result evolution and ontogeny follow the path of the conservation of the different manners of living that arise in the relational space where the living system lives as an organism.

2. Structural coupling

2.1 Structure and organization

A *structure determined system* is a system such that all that takes place in it, or happens to it at any instant, is determined by its structure at that instant. The notion of *structural determinism* is not an explanatory principle, nor an ontological assumption, it is an abstraction that we make as observers of the operational coherences in which we exist as living systems. We living systems, as molecular systems, are structure determined systems. There are two features of the constitution of structure determined systems that I distinguish with the words *organization* and *structure*. These two words correspond to distinctions that we make in daily life as we handle any system or composite entity, even though we

are frequently not consistent in how we use them. I shall consistently use the word *organization* to connote the configuration of relations between components that define the class identity of a composite unity or system as a totality or singular entity. And in what follows I shall consistently use the word *structure* to refer to the components and the relations between them that realize a system or composite entity as a particular case of a particular class.

The organization of a system is only an aspect of the relations realized in its structure, and does not exist independently of the structure in which it is realized. In these circumstances, a system conserves its class identity, and stays the same while its structure changes, only as long as its organization is conserved through those structural changes. The conservation of the organization of a system is a condition of existence in it; if the organization of a system changes, the system disintegrates and something different appears in its place. This is not the case for the structure of a system. The structure of a system is open to change, and can change in two ways:

1) The structure of a system can undergo changes through which the organization of the changing system (its class identity) is conserved. I shall call these changes *changes of state.*
2) The structure of a system can undergo changes through which the organization of the changing system (its class identity) is lost, is not conserved. I shall call these changes *disintegrative changes.*

In changes of state the particular operational characteristics of the system change while it conserves its class identity. In disintegrative changes the original system disappears and something else arises in its place.

2.2 *Organism and medium*

The structure of a structure determined system changes both as a result of its internal structural dynamics and as a result of its interactions. The structural changes arising as part of the internal dynamics of a structure determined system follow a course that arises determined at any moment by the structure of the system at that moment. The structural changes triggered in the interactions of a structure determined system arise moment after moment also as determined by its structure, but they follow a course that is generated moment after moment by the succession of encounters with the medium in which the system participates. The same applies to the medium as a structure determined system that changes following a course that arises in the interplay of its own structural dynamics and the structural changes triggered in it by the systems that interact with it. As a consequence, in this process the structure of the living system and the structure of the medium change together congruently as a matter of course, and the general result is that the history of interactions between two or more structure determined systems becomes a history of spontaneous recursive structural changes in which all the participant systems change together congruently until they separate or disintegrate. I have called the dynamics of congruent structural changes that take

place spontaneously between systems in recurrent (in fact recursive) interactions, as well as the coherent structural dynamics that result, *structural coupling*.

Living systems, as well as the non-living medium with which they interact recursively, are structure determined systems with plastic structures that change following a course of change that arises modulated by the flow of their interactions. As a result living systems and their non-living medium change together congruently forming a biosphere as a multidimensional network of reciprocal structural coupling that arises spontaneously as a result of the conservation of the autopoiesis of the living systems. In these circumstances, a living system lives only as long as its internally generated structural changes occur with conservation of autopoiesis, and its encounters in the medium do not trigger in it its disintegration. That is, disintegration does not happen to a living system as long as it remains in the uninterrupted dynamic operational congruence with the medium (living and not living) through which its living is conserved. I call the operational coherence between the living system and the medium in which it exists, *adaptation*. In other words, the life history of a living system courses as a spontaneous flow of continuous structural changes that follow a path or course in which the living system conserves autopoiesis and adaptationin its domain of existence. I call this process *ontogenic structural drift*. We biologists do not easily see that the conservation of adaptation is an invariant relation that constitutes a condition of existence for living systems (and in fact for all systems), and this is so because we usually treat it as a variable in the evolutionary discourse.

The most fundamental result of the dynamics of structural coupling is that a living system is never out of place while living. I call the place that a living system occupies in the realization of its living, its *niche*. As a consequence of living in the conservation of adaptation in its niche, a living system will always appear knowing how to live in the circumstances in which it lives until it dies: living systems are never out of place, or "more" or "less" adapted while living. As a living system lives in its niche in spontaneous conservation of adaptation and autopoiesis, the niche is also its cognitive domain in the domain of living. Moreover, it is precisely because a living system exists as a totality, through a molecular architectural dynamics and thus is realized moment after moment according to the operation of the local structural coherences of its molecular components, that there is no general organizational principle or force guiding the operation of the molecules that compose it in the integration of a whole. *The living system as a whole is a result of the local operation of its component molecules, not the realization of a plan.* Furthermore, a particular organism is not a particular kind of whole by itself, rather it results as a particular whole in the relational space in which it is conserved as an autopoietic system through its interactions in its niche. And it is precisely because a living system exists in this way, that that which constitutes the identity of a living system as a particular organism is the manner of living conserved in it through its conservation of autopoiesis and adaptation in structural coupling.

2.3 Conservation of organization

A system arises in the moment in which the organization that defines it, as well as the relation of adaptation in the medium that makes possible the realization and the conservation of that organization, begin to be conserved. Systems arise, exist, and are conserved spontaneously when a particular organization begins to be conserved with the relational circumstances that make such conservation possible. Moreover, the medium in which a system exists also arises spontaneously when the system arises, becoming at that moment a phenomenal domain defined by the system that constitutes it through existing in it. In fact, all systems arise in this way from a background that appears chaotic or unordered from the perspective of the coherences of their existence. That is, a system arises and exists in the constitution of the dynamics of interactions between the system and the medium which realizes and conserves both the system and the system's domain of existence through their recursive interactions.

Nowadays there is much concern with the development of notions such as complexity and chaos, notions that are frequently used as explanatory principles. I think that notions such as complexity and chaos are evocative metaphors for the reflexions of an observer; they do not reveal the processes involved in the constitution of a system. I also think that the formalisms associated with them permit computations in domains that are operationally isomorphic with those formalisms. A mathematical formalism is a conceptual and operational system that reveals the relational coherences of the space that it defines. It is because of this that one can use mathematical formalisms to compute changes of states in systems whose operational coherences appear isomorphic to the relational coherences that they specify. But mathematical formalisms do not provide or create by themselves an understanding of the phenomena that an observer explains to him or herself through them. In this same context one can say that biological phenomena occur on the edge of chaos, because one can use some mathematical formalisms as evocative metaphors. However, to say that does not say what kind of systems are living systems, nor does it show how they exist in the new domains that arise as their operation as totalities begins to be conserved in the flow of their structural coupling with the medium (niche) that arises with them. Living systems, as systems in general, occur in their actual happening as discrete singular entities, not in the formalisms that an observer may use to think about them.

2.4 Constitution of lineages

Living systems arise spontaneously with the spontaneous arising of autopoiesis when the relational conditions in the molecular space take place. However, the *history* of living systems begins with reproduction when relational conditions take place in the autopoietic systems and the molecular space such that the autopoietic system undergoes a spontaneous division which results in the conservation of autopoiesis in the resulting fragments, together with the conservation of the relation with the medium in which their autopoiesis can be conserved. I call this process of reproduction in which the division of an autopoietic system results in

the simultaneous conservation of both autopoiesis and the conditions of the medium that make it possible, *systemic reproduction* (Maturana & Mpodozis, 1992, in press). If systemic reproduction begins to be repeated in a succession of generations, a lineage arises as a reproductive succession of living systems defined by the reproductive conservation of autopoiesis, and the conditions of the medium in which autopoiesis can be realized, while the form of realization of autopoiesis and of the conditions of the medium are open to change. A lineage lasts as long as these conditions are conserved, and many different kinds of living systems arise spontaneously as different lineages defined by the systemic reproduction of different manners of living. The result of this dynamics of constitution of lineages has been the spontaneous diversification of the manners of living in a process in which the living systems and the medium have changed together congruently giving rise to the biosphere as the coherent systems of living and nonliving entities in a continuously changing present.

The diversity of living systems therefore does not arise in a history of competition but in a history of diversification that arises in the conservation of what lives in a domain open to variations around the conservation of autopoiesis and adaptation (structural coupling) (Maturana & Mpodozis, in press).

2.5 *Perception*

The understanding that living systems are molecular autopoietic systems closed in their dynamic of states, and structure determined in their molecular constitution, in 1965 opened in me the possibility of changing the question of perception from, *"how do I see what is there"* to *"what happens that I, as a structure determined system, can say that there is something there?"* This change of question was supported in my reflections by finding in my research on color vision during the years 1963 to 1967 (Maturana, Uribe, & Frenk, 1968) that the nervous system is constituted as a closed neuronal network that operates generating a continuous closed dynamic of changing relations of activity between its neuronal components. Although the nervous system is in structural intersection with the sensory and effector surfaces of the organism, as a structure determined system it cannot operate as a system that generates a representation of the medium in order to compute adequate behavior for the organism. What we as observers see as the adequate behavior of an organism in a changing medium is the operation of the organism in its domain of structural coupling. Accordingly, what we observers do, then, is to call *perception* what we see as adequate behavior of an organism in a particular circumstance while comparing the behavior of the organism with our own behavior as both the organism and we ourselves operate in our respective domains of structural coupling.

2.6 *Explanations*

The development of the insight that led to my abstraction of the notion of autopoiesis from the biological molecular dynamics known to me during the years

1960 to 1966, forced me to generate a conceptual frame that would allow me to say what I wanted to say.

The notion of structural determinism is an abstraction that the observer makes from the coherences of his or her experiences. The notion of structural determinism, therefore, does not arise as an ontological assumption about a domain of transcendental realities, it arises as an abstraction that grasps the operational coherences of our living as human beings as we use the coherences of our experiences to explain our experiences. As such, *the notion of structural determinism is at the same time the conceptual and the operational fundament of all explanations*. Accordingly, we live in as many different domains of structural determinism as we live different domains of operational coherences as human beings. Further, we live as many different domains of explanations as we live different domains of experiential coherences that we use to explain our experiences. Indeed, *we explain our experiences (that which we distinguish as happening to us) with the coherences of our experiences.*

An explanation entails two conditions that must be satisfied together:

1) The proposition of a process or mechanism that if it were to operate in the structural domain in which it is proposed, the result would be that the observer would live the experience that he or she wants to explain. I call this condition, the proposition of a *generative mechanism.*
2) The acceptance by an observer of such a proposition as doing what it claims to do because it satisfies some other conditions that he or she puts through his or her listening. I call this condition the listening for the satisfaction of a *criterion of validation.*

I call the first of these two conditions the *formal condition*, and I call the second one, the *informal condition.* The formal condition has a fixed form, namely, the form of the proposition of a generative mechanism, which is what formally defines an explanation as such. The informal condition can be any, whatever the observer chooses to use in his or her listening, in an explicit or implicit manner, aware or not aware of his or her doing so, as a condition that has to be satisfied by the generative mechanism proposed for him or her to accept as an explanation. The informal condition is arbitrary, yet it is the satisfaction of this condition in the listening of the observer that makes him or her accept some particular generative mechanism as an explanation. The informal condition is what gives an explanation its character as a particular kind of explanation. We always put some arbitrary informal condition in our listening to accept or to reject what somebody else says. Hence it is not what is said that determines the validity of what we accept, but rather what we accept as valid from the perspective of our listening. This is why I call the criterion of validation the informal condition that the listener puts in for accepting or not accepting an explanation.

In any case, the formal condition in an explanation has an entirely different character. Indeed, since the formal condition in an explanation entails the

proposition of a generative mechanism, there are two necessary consequences, namely:

a) the phenomenon explained and the mechanism that gives origin to it take place in different operational (phenomenal) domains that do not intersect.
b) as a direct consequence of the above, explanations do not constitute, and cannot constitute, phenomenal reductions.

In addition, since the informal condition in an explanation is arbitrary in the sense that it is accepted out of preference, it also has two main consequences, namely:

a) there are as many different kinds of explanations as there are different informal conditions that an observer can put in his or her listening.
b) if the informal condition that an observer puts in his or her listening is not made explicit, one does not know what the observer accepts when he or she accepts a particular generative mechanism as an explanation.

Furthermore, all that I have just said is valid for scientific explanations. Yet, what is peculiar of science as an explanatory domain is that there is a particular informal condition that scientists put in their listening as a condition that must be satisfied for a particular generative mechanism to be accepted as a scientific explanation. I shall hence forth call this informal condition, which is in fact what defines science as the the explanatory domain that it is, *the criterion of validation of scientific explanations*. This criterion of validation can be made fully explicit as a set of four operations that an observer must realize in his or her living in order to claim that he or she is proposing a scientific explanation. What is remarkable is that these four operations are made with no assumption about the existence of an independent reality. And this is so because what is explained is always an experience of the observer explained with elements of his or her experiential coherences. The four operations of a scientific explanation are:

1) The description of what an observer must do to experience the experience to be explained.
2) The proposition of a generative mechanism such that if it is allowed to operate the result would be that the observer experiences the experience that he or she wants to explain presented in point 1.
3) The deduction from all the operational coherences implicit in point 2 of other possible experiences for the observer, as well as of what he or she should do to live them.
4) The realization of what has been deduced in point 3, and if it happens as deduced, point 2 becomes a scientific explanation.

The criterion of validation of scientific explanations presented above is not an idiosyncratic reformulating of what scientist and philosophers usually call the experimental scientific method as some philosophers and scientists have suggested. The epistemological fundaments implicit in the *criterion of validation of scientific explanations* and in what is called the *experimental scientific method*,

are quite different, even though they appear to lead to what seems to be the same result: namely, something that is accepted as an explanation. Thus, in the application of the criterion of validation of scientific explanations the observer is fully aware that a scientific explanation is the proposition of a generative mechanism, while in the use of the scientific method the observer speaks as if he or she were making a model or an hypothesis of reality as something independent of his or her doings. These differences can be presented as follows: the criterion of validation of scientific explanations does not entail the implicit or explicit assumption of the existence of a reality as something independent of what the observer does as it only involves the experiential coherences of the observer in his or her living. As a result, for him or her a scientific explanation reveals and gives rise to an expansion of those experiential coherences. Contrary to this, in the use of the experimental scientific method the observer operates under the implicit or explicit assumption that there is a reality independent of what he or she does, and expects that his or her explanations will reveal that reality, even if only indirectly. I claim that we scientists say that we apply the experimental scientific method, but what we do in fact is to apply the criterion of validation of scientific explanations without knowing that we are doing so.

I claim that scientific explanations do not explain the phenomena of a domain of reality independent of what the observer (a scientist in our case) does. An observer becomes a scientist when he or she uses the criterion of validation of scientific explanation to explain his or her experiences with the coherences of his or her experiences. I also claim that the observer itself does not exist as a trascendental entity but arises in the the distinction of another observer, and is explained as a biological process by an observer who uses his or her distinctions of biological processes in the course of his or her living to propose biological processes that would give rise to observing (Maturana, 1980).

2.7 Grounds for the claim

The main difficulty that one encounters in the attempt to answer any question is to know when one has indeed answered it. The power of scientific explanations rests on the fact that it constitutes at the same time both the procedure that generates the explanation, and the criterion that tells when the explanation has been fulfilled. Some authors have criticized the notion that living systems are molecular autopoietic systems as unscientific on the ground that I claim that the condition of autopoiesis cannot be observed directly as a feature of the living system because it occurs in the flow of its changing present as a historical process. They say that a scientific theory must have empirical support. Yes, indeed! But, what constitutes the empirical support or validation of a scientific explanation is the actual observation that the criterion of validation of scientific explanations has been fulfilled in the domain in which it is claimed. In the claim that autopoiesis in the molecular space is the organization of living systems, two things are claimed:

1) that as a molecular autopoietic system arises in the molecular space, a living system arises in it, and;
2) that as a molecular autopoietic system arises, all biological phenomena arise or become possible as a direct or indirect historical consequence of their operation as molecular autopoietic systems.

Accordingly, the scientific demonstration of the claim that living systems are in fact molecular autopoietic systems would be to show one of two things. One is to show that all the molecular processes in living systems course in a way that they constitute a closed network of molecular productions that realizes the autopoietic organization. The other is to show that all biological phenomena would necessarily occur as a direct or as an indirect consequence of the operation of a molecular autopoietic system, but would not occur if the molecular autopoiesis were interrupted. Francisco Varela and I show that the latter is the case in a book that we called "De Máquinas y Seres Vivos" first published in 1972 in Spanish, and then in English as part of a book published in 1980 with the title, "Autopoiesis and Cognition".

Therefore, I claim that living systems are molecular autopoietic systems, and that such a claim is a scientific claim as I claim that autopoiesis is the scientific explanation of what constitutes living.

2.8 Implications of the claim: molecular autopoiesis constitutes the living

What we scientists distinguish as "phenomena of the natural world" occur spontaneously. As such the natural world is in its spontaneous presence the proof of its own existence. That is, natural phenomena occur when they occur, and we human beings as observers distinguish them, as we distinguish what we do, as we distinguish what happens in us or with us. An observer attempts to explain only those of his or her experiences (phenomena) which do not seem obvious to him or her. In order to do so he or she resorts, as I have said above, to the coherences of his or her experiences and uses them to propose a generative mechanism under the operation of which the phenomenon that he or she wants to explain will appear or result spontaneously. Accordingly, the theory of autopoiesis says that whenever the adequate dynamic structural conditions occur in the molecular domain for molecular autopoietic entities to arise they, will arise spontaneously, and a living system will appear as if out of nowhere. If in addition the conditions for the systemic reproduction (division of a system with the conservation of its organization in the resulting fragments together with the conditions of the medium that make such conservation possible) of the molecular autopoietic system occur, the result will be the spontaneous beginning of a lineage of molecular autopoietic systems. In these circumstances, what is the proof that living systems are molecular autopoietic systems? I claim that the proof is the actual closed dynamics of the network of molecular productions and transformations that becomes apparent when one observes the cellular metabolic processes as constituting a closed dynamic of molecular production that constitutes its own boundaries while it is open to the flow of molecules through it.

Many scientists and philosophers are not aware that explanations are propositions of generative mechanisms or processes that give rise in the living of the observer to the experience (phenomenon) to be explained, and thus think that explanations have to be reductionist propositions in which what is explained is presented in more fundamental terms. But explanations as propositions of generative processes are constitutively not reductionist propositions because the generative mechanism and its result take place in non-intersecting phenomenal domains (see Maturana, 1990).

But there are still other difficulties for the full understanding of all the implications of the claims that living systems are molecular autopoietic systems, and that they can be seen to be so when one observes the cellular metabolism as a systemic whole. These other difficulties have to do, I think, with two other claims that I have made, namely: that a living system does not have inputs or outputs, and that the observer cannot see the organization of a system directly because the organization of a system is the configuration of relations that makes and defines a system as a singular totality through its conservation in the historical flow of its structural dynamics.

Let us consider first the claim about the absence of inputs and outputs. As living systems are structure determined systems, all that occurs in them or to them, happens determined in their structure. The same happens to the medium that contains them to the extent that the medium is also a structure determined system. Accordingly, an external agent acting upon a living system does not and cannot specify what happens in it as a result of its action. Such an external agent can only trigger in the living system a structural change determined in it. An external agent, therefore, does not and cannot be claimed to constitute an input for the living system because it "tells" nothing to the living system about itself or about the medium from which it comes. The same happens as the living system impinges upon the medium: the living system can only trigger in the medium a structural change determined in the structural dynamics of the medium, and cannot be properly claimed to be an output of the organism because it "tells" nothing about itself to the medium. It is in this sense that I claim that a living system does not have inputs or outputs, and that its relation with the medium cannot be described in informational terms.

The relation between a living system and the medium in which it exists is a structural one in which living system and medium change together congruently as long as they remain in recurrent interactions. I have called this relation *structural coupling*, and I have shown that a living system flows in its living in the path of conservation of structural coupling with a the medium that makes this possible, until the living system dies. Living occurs in the path of structural changes that continuously result in the conservation of autopoiesis and adaptation or structural coupling (Maturana, 1998).

Unless we see how it is that living systems do not have inputs and outputs, it is not possible to understand cognition as a natural phenomenon, nor can we see that that which we call cognition in a living system is that which we see or consider as

its adequate behavior or operation in the domain in which we observe it. Furthermore, unless we see that a living system does not have inputs or outputs, we cannot see that the effective operation of a living system in its living which leads us to claim that "the living system knows what to do in its domain of existence", results from its operating in a domain of structural coupling that has arisen with it in the course of its epigenesis. Moreover, if we do not understand that living systems do not have inputs or outputs, we cannot understand how the domain of structural coupling of a living system as the domain in which it realizes its living (autopoiesis), is indeed its domain of cognition (Maturana, 1980; Maturana & Varela, 1988).

The second claim, namely, that an observer cannot see the organization of a system directly, is related to the fact that the the organization of a system is the configuration of relations that defines its class identity as that which is conserved and remains invariant through the structural changes of the system along its individual history. In the case of living systems molecular autopoiesis is the organization that realizes their living in a historical process that cannot be stopped, and that is apparent only in the result of its operation, and not in the componets that realize it. So the organization of living systems as the organization of any system cannot be directly observed, it can only be infered: all that we can be directly observed in a system is components and relations between components.

That the observer cannot directly see the organization of a system, then, does not invalidate the notion of organization or the fact that the organization must be inferred from the history of interactions of the system and from its structural dynamics. Accordingly, only the results of the operation of an autopoietic system as such can tell an observer that it is an autopoietic system. Moreover, only the participation of an element in the relations of composition that constitute a system tells the observer whether the element is or is not a component of that system. This is why not all that an observer sees as a "part" of what he or she thinks is an autopoietic system, is a component of that system as an autopoietic system. As I said above, something is a component of a system only if it participates in its composition.

The whole situation is circular in the sense that although a system defines itself through its presence and operation, an observer can only know it through its operation as it defines itself.

3. Cognition

3.1 What is "to know"?

The understanding of structural determinism brought with it for me the question of cognition as I asked myself: "If structural determinism is the case, what then, is "*to know*"? If living systems are structure determined systems, and if all that occurs to them and in them arises in them at every instant determined by their structure at that instant, and if all that the external agents that impinge on them

can do is to trigger in them structural changes determined in them by their structure at the moment of their interactions, what is "to know"?

That which we human beings call cognition is the capacity that a living system exhibits of operating in dynamic structural congruence with the medium in which it exists. It does not matter if the living system observed is an insect or a human being. We may ask ourselves whether the knowledge that the living system exhibits is learned or instinctive, but our assessment is the same: namely, if we see a living system behaving according to what we consider is adequate behavior in the circumstances in which we observe it, we claim that it knows. What we see in such circumstances underlying the adequate behavior of the living system is:

a) that the living system under our attention shows or exhibits a structural dynamics that flows in congruence with the structural dynamics of the medium in which we see it; and,
b) that it is through that dynamic structural congruence that the living system conserves its living.

We may ask how the living system arrived at having the dynamic structure that allows it to operate in dynamic structural congruence in the medium or the circumstances in which it happens to live. If we come to the conclusion that the living system attained that dynamic structural congruence with the medium or circumstances in which we see it living as a result of its evolutionary development as the kind of living system that it is, and independently of its individual life history, we claim that the knowledge that we see in it is instinctive. On the contrary, if we come to the conclusion that the dynamic structure with which we see the living system operating in dynamic structural congruence with the medium has arisen in the course of its individual history as a result of its interactions in the medium, we claim that the knowledge that we see in such operational congruence has been learned. Instinctive and learned knowledge thus differ only in what claim about their historical origin. The origin of instinctive knowledge is phylogenic, a feature of the evolutionary history to which the living system belongs, and the origin of learned knowledge is ontogenic, a feature of the individual epigenesis of the living system, otherwise instinctive and learned knowledge are indistinguishable.

Since whatever occurs to or in a living system at any moment, occurs determined by its structure at that moment, nothing external to a living system can determine what happens in it or with it. Therefore, due to the structural determinism of living systems neither the notion of reception of information, nor the notion of computation through processing information obtained by the senses can be used to explain cognition as the adequate behavior of living systems. In these circumstances I claim that the process which gives rise to the operational congruence between an organism and its niche, that is the process that we distinguish in daily life either as either learned or instinctive knowing, is *structural coupling*. In other words, I claim that any attempt to explain the adequate behavior of human beings, or any other living system, (which in daily

life we call cognition) as if it were the result of some computation made by the nervous system using data or information obtained by sensors about an external objective world, is doomed to fail. Knowledge is something that an observer asigns to a human being or to a living system when he or she sees such an organism behaving adequately (in operational coherence) with a changing medium. We are usually not aware that we ascribe knowledge to any living being, human or not, *when we see it operating in a manner that we consider adequate* for the domain in which we behold it, even though we do this regularly in daily life as we operate as teachers when we grade examinations.

Indeed, that is what you are doing now as you read what I have written, and you will either accept or reject what I have said as revealing knowledge according to whether what I say agrees or does not agree with what you consider adequate behavior in the domain in which you are attending to what you are reading of what I have written. The teacher gives or does not give knowledge to the student according to whether the student does or does not do what he or she considers adequate behavior in the domain specified by his or her listening. Similarly you give or deny me knowledge according to whether what I have written satisfies or does not satisfy what you consider adequate in the domain in which you attend to what I write.

3.2 Language

As I found myself facing the matter of cognition I became aware that I had to consider language as a biological phenomenon that took place in the living and through the living of the organism, and that any attempt to understand language through philosophical reflections would be inadequate because such reflections had no way of taking into consideration the way living systems operate as structure determined systems.

We human beings exist as observers in language as we operate in the domain of structural coupling to which we belong. That is, we human beings exist in structural coupling with other living and not living entities that compose the biosphere in the dimensions in which we are components of the biosphere, and we operate in language as our manner of being as we live in the present, in the flow of our interactions, in our domains of structural coupling. Living in language, doing all the things that we do in language, however abstract they may seem, does not violate our structural determinism in general, nor our condition as structure determined systems. As I observed our languaging behavior and the behavior of other animals, I realized that the central aspect of languaging was the flow in living together in recursive coordinations of behaviors or doings, and that notions of communication and symbolization are secondary to actually existing in language. I say this in a synthetic manner: *language is a manner of living together in a flow of coordinations of coordinations of consensual behaviors or doings that arises in a history of living in the collaboration of doing things together* (Maturana, 1988).

We human beings exist and operate as human beings as we operate in language: languaging is our manner of living as human beings. Language occurs in the actual flow of coordinations of coordinations of behaviors, not in any particular gesture, sound or attitude taken outside of that flow. It is like the movement seen in a film that exists as such only as long as the film runs. We human beings language while operating in the domain of structural coupling in which we coexist as languaging beings with other languaging beings. As we language, objects arise as aspects of our languaging with others, they do not exist by themselves. That is, objects arise in language as operations of coordinations of coordinations of doings that stand as coordinations of doings about which we recursively coordinate our doings as languaging beings. I shall call the domain of objects that arises in our coordination of coordinations of behaviour a domain of *shared objects or entities*. In other words *objects and any entity that arises in languaging pertains to a domain of inter-objectivity that we live with the other languaging beings with whom we generate (we language) the objects and other entities that constitute that domain*. It follows that we humans can generate and, therefore, exist as languaging beings in as many different domains of objects (or domains of different kinds of entities) as domains of coordinations of coordinations of behavior we can generate in our living in structural coupling in the biosphere, and through this, in the cosmos. Accordingly, we human beings can in fact live with each other in as many domains of shared entities, or domains of inter-objectivity, as there are dimensions of structural coupling in which we can live in coordinations of coordinations of doings with other beings. Living in languaging is living a domain of shared objects in inter-objectivity.

3.2 Conversations

In the course of the expansion of our understanding of our operation as structure determined autopoietic systems it also becomes apparent that as we human beings exist in language, we exist in emotions as well. When we distinguish emotions we distinguish different domains of relational behaviors that at every moment constitute the relational fundament on which we human beings do all that we do as languaging beings. In fact we human beings exist in the continuous interlacing of our coordinations of coordinations of doings and emotions in what I call conversations, and all that we do we do it in networks of conversations. Different networks of conversations constitute different domains of existence or domains of reality in which different kinds of entities exist brought forth by the recursive coordinations of coordinations of doings that constitute them. So, the understanding of language brings forth the understanding of existence. Existence is a word that connotes that about which an observer can talk, so that about which an observer cannot talk does not exist. Given this, the observer can only talk about that which arises within the network of conversations in which he or she distinguishes it in his operation in language.

3.3 Self-consciousness

The other central problem that changed its character through the notions that I was developping as I followed implications of becoming aware that we living systems are molecular autopoietic systems, was that of self-consciousness. The difficulty in understanding self-consciousness rests in finding the process through which we distinguish ourselves as if we were independent entities of our operation so that we can see ourselves as such, and of finding the domain in which we exist as selves. I found the answer through understanding language and the arising of objects and our living in inter-objectivity.

As I have shown above objects arise in languaging in the flow of recursive coordinations of doings in the flow of living together. The arising objects are lived as if they were independent entities that can be distinguished as such and handled in the coordinations of doings. Thus, when an observer sees two persons in a flow of coordinations of coordinations of doings through the coordinations of doings on their bodies, he or she can claim that those persons are operating in a domain of awareness of aspects of their doings that are seen as parts of their own bodies. Furthermore, the observer can see that those persons treat their bodies and the arising parts of their bodies as if they were independent entities at the same time that through their sensations they are those parts and doings. The body, and its parts and the self as the distinction of their distinguishing them, arise in language in the same manner as any other entity arises in the flow of languaging as a manner of doing things together. The observer sees that the operation of self-consciousness is the reflexive distinction of a self in language that takes place as an operation that constitutes our body and our being as an object in inter-objectivity, yet the person in the flow of his or her living in languaging lives the self distinction in the paradox of distinguishing an independent entity that feels as being the doing of the distinction.

Verden-Zöller has shown that self-consciousness arises in human babies in their play relations with their mothers (Maturana & Verden-Zöller, 1993). I myself have show in a study with Ibanez of the arising of languaging in babies (Maturana & Ibanez, 2002) that self-body awareness begins with the mother in play with the baby, for example when she says "nose" as she touches the baby's nose or "foot" as she touches the babies foot in the same manner that she uses when she says "ball" while handling a ball to her baby. Accordingly, self-consciousness arises as an operation of coordinations of doings in languaging, and as such occurs as an interpersonal process in the relational space. Indeed, one can observe how self-consciousness begins to arise in the growing child in the mother/child play of touching the nose which constitutes self-awareness as the nose arises as an object in inter-objectivity in the recursive coordinations of behavior of the baby with the mother in a play that calls the sensorial attention of the child to his or her nose.

It is not easy to see the nature of self-consciousness as an operation in living in language when one thinks that language takes place as a symbolic operation that refers to entities that can be distinguished because of their independent existence. If to be conscious means to be aware of something as it exists independently of the

being that is aware of it, how could a human being become aware of him or herself, if he or she is not an entity that exists independently of him or herself? It is because of this difficulty that we speak as we refer to ourselves as if we had a dual existence (e.g., when we say, "*I* am speaking about *myself*", or "*I*, in my true *self*".) The conceptual problem generated in this apparent existential duality dissolves as we understand that language consists in living together in a flow of coordinations of coordinations of consensual behaviors that arise in the pleasure of the flow of doing things together in recursive interactions.

No doubt we feel in an act of self-distinction the same that we feel when we distinguish something that for an external observer has the quality of being an entity independent from us as distinguishers. We feel as we feel with any object in the domain of shared objects that we live with others. And this is so precisely because the self arises as any other entity in inter-objectivity. Feelings take place as an aspect of our self-distinction in language as in the recursive coordinations of doings the distinction of relations among the body distinctions expands the domain of inter-objectivity into a meta-domain of self-distinctions: feelings, like all entities in inter-ojectivity, are secondary to language.

In the origin of humanness the self must have arisen in the same manner that it arises in modern human babies, namely in the flow of the coordinations of coordinations of behaviors that bring about the body and its parts as shared objects in inter-objectivity through the mother/child play that calls attention to the proprioceptive sensations that arise through doing things together in coordinations of coordinations of doings. It is because of this that I say that self-consciousness is a recursive operation in languaging that constitutes an open-ended possibility for the continuous arising of new worlds that we may live as we recursively live as self-conscious languaging beings. Indeed, we can generate many new worlds but we do not have to do so: wherever we may be, conceptualy or manipulatively, there is always another realm that we may bring forth through our languaging.

We are living in a culture that acts as if we should do everything that we imagine as possible. We do not see that in doing so we are not just letting things be, we are making a choice – and we do not see that we should be responsible for it. Indeed, since languaging occurs as a manner of flowing in living together in coordinations of coordinations of consensual behaviors, we can generate any new world that we may language into existence[2]. But we do not have to do so. No matter in what operational domain we may be, there is always another domain of existence that we may bring forth in the recursions of our languaging by conserving the configuration of dynamic relations that define the new domain. We can realize all that we imagine if we respect the structural coherences of the domain in which we imagine it. But we do not have to do everything that we can do, or that we can conceive to be possible. We do not have to engage in all the reflections, or develop all the concepts, or build all the technologies that we can

[2] This does not imply that any world we may be described can be realized – rather any manner in which we can flow together in coordinations of coordinations of consensual behaviors generates a new world and as we are aware of this we become responsible for the choice of such a world. [Ed.]

imagine. It is precisely because of this that we have to choose. It is in our living as reflective self-conscious human beings that we can be aware of the possible consequences of what we do, of the nature of the domains of existence that we bring about, and of the implications to our living of what we do in the different worlds that we may live forth. And it is because we are aware of what we can do as self-conscious languaging beings that we not only can chose but also have to chose what to do.

Presently we live a culture that pressures us to do whatever we imagine under the argument of creativity. But, do we have to do so? The fact that as a consequence of our being self-conscious beings we can always become aware of the possible implications of whatever we do, makes every human act an explicit or implicit choice of a domain of existence. In this manner we may conserve or destroy our own existence as the kind of living beings we are. We may live in the conservation or destruction of ourselves as *Homo sapiens amans*, or in the conservation or destruction of *Homo sapiens arrogans* (see also Bunnell & Sonntag, 2000). We modern human beings are the present of a history of neotenic expansion into adulthood of our loving childhood. Self-consciousness arose as a result of the neotenic expansion of the mother/child relation of mutual care in play. Self-consciousness, as the possibility of seeing ourselves in our reflections and doings, is a gift of the biology of love that allows us to escape from any trap in which we may happen to fall: self-consciousness is the opening for reflective autonomy and freedom.

If we indeed understand our existence as self-conscious languaging beings that continuously bring forth the world and worlds that we live, because that is the nature of languaging as living in coordinations of coordinations of consensual doings, and if we indeed want to generate well-being in the human and animal world in which we live, we must continuously create such a world with the network of languaging and emotioning that we as adults live so that our children grow generating the same network of languaging and emotioning in which they grew in well-being.

Language cannot be understood as a biological phenomenon if we do not take seriously our operation as structure determined systems. If we do not do so we remain trapped in the belief that language is a system of communication and thinking with representations (symbolizations) of an independent reality that contains us as its primary constitutive feature. And if we do not understand language as a biological phenomenon we shall remain in the mystery of self-consciousness through believing that this somehow reveals an intrinsic cosmic duality, and we shall not be able to understand ourselves as the self-conscious transitory beings that we are.

4. Epistemology and conclusions

In 1965 when, as a result of my research on perception, I began to ask myself about how do we do what we do as observers, I made a fundamental

epistmological shift that constituted an ontological change. Namely, I turned from the question that asks about "the being" to the question that asks about "our doing". Through this shift I moved away from a question that has no answer in the domin of being to a question that can be answered in the domain of doing. In other words, I did a fundamental conceptual change in the philosophical domain, I moved away from a basic question that denies us the possibility of understanding perception as a biological process to a question that leads us to understand and explain perception as an operation of the organism in a medium with which it is in structural coupling as a result of a history of structural changes in which the organism and the medium (niche) have changed together congruently as a matter of course. As a result of this fundamental conceptual change, my central theme as a biologist (and philosopher) became the explanation of the experience of cognition rather than reality, because reality is an explanatory notion invented to explain the experience of cognition (see Maturana, 1980).

In the process of explaining cognition I made a fundamental epistemological change in the domain of understanding explanations and scientific explantions. I realized that as we operate as observers we explain our experiences with the coherences of experiences, and that this could not be otherwise since we, as languaging beings, exist in a domain of coordinations of coordinations of doings – which is in fact to operate inmersed in the coherences of our experiences. That is, to say that any particular entity has existence only as it arises as the observer brings it about in his or her distinction in language by specifying its condition of constitution, is to say that such an entity occurs in the same domain of existence in which the observer operates as a living system.

To claim that, is to claim that the entities that an observer distinguishes in his or her operation in language have the concreteness of the operations with which the observer distinguishes them through his or her operation in coordinations of coordinations of doings as he or she operates as a living human being. It is in this sense that living systems are living systems, and molecules are molecules, as real or objective entities in their respective domains of existence as the observer brings them about through his or her participation in the network of coordinations of doings in which he or she distinguishes them. It is in this sense that we as observers can claim that molecules arise as the conditions of their constitution apply, and it is in this sense that I say that molecules exist in a domain of existence that the observer brings about with his or her operations of distinctions in the domain of conversations that constitutes their domain of reality.

Part of the difficulty in understanding the relation between language and existence rests on the view of language as a domain of representations and abstractions of entities that pertain to a diffeent concrete domain. Yet language is not so, languaging occurs in the concreteness of the doings of the observer in his or her actual living in the praxis of living itself. The realization of autopoiesis, the living of the organism, as well as the observers themselves, all arise in the conversations of observers, so that all that there is, is languaging as coordinations of coordinations of consensual doings of observers that operate in language. No

doubt for epistemological motives we seem to need a substratum in which everything that happens occurs, but as soon as we bring forth such a substratum it is not what we wanted to refer to, but more of the same, something in inter-objectivity that cannot operate as a substratum in itself. Nothing exists outside the networks of conversations through which we bring forth all that exists, from ourselves to the cosmos that makes us possible, not in an arbitrary creative operation, but as a result of our coordinations of coordinations of doings in our living, including our living. And this statement is not arbitrary or vacuous, because it says that whenever the conditions that constitute a system, an entity or a process apply, the result will be the system, entity or process, in the operational domain specified by the conditions that made them possible.

Following the conceptual, operational and epistemological implications of the notion of autopoiesis does not lead us to the knowledge of everything, because we find ourselves in a continuously changing living arising from nowhere and supported by nothingness. However it does lead us to see that as languaging beings we operate in the most basic domain of understanding possible: namely the domain in which we understand our living.

What follows is said under this understanding of all that I have said so far.

It seems to me that the main difficulty that biologists have in accepting that the notion of autopoiesis describes the organization of the living, is our cultural refusal to accept that things, systems, relations, and entities in general, arise into existence in the instant in which the conditions of their constitution take place. We as observers can claim that a living system arises in the moment in which autopoiesis begins to take place, and it lasts as long as its autopoiesis is conserved. This claim, as a cognitive claim, has operational validity in the operational domain (the molecular domain) in which what it claims, happens. In our culture we like to explain with causes and principles that are external to that which is explained. This is why saying that "a living system exists by itself", or claiming that an explanation of living systems consists in proposing the generative mechanism that gives rise to a living system as a consequence of its operation in a different domain than the domain of its components, appears epistemologically unacceptable. However, such a statement is valid and sound epistemologically in the domain in which one is aware that explanations constitute the proposition of generative mechanisms. In these circumstances the claim that living systems are molecular autopoietic systems can only be dismissed by showing that there are biological phenomena that do not directly or indirectly entail molecular autopoiesis. The claim that living systems are molecular autopoietic systems cannot be dismissed on epistemological grounds.

Biologists have frequently claimed that they ignored the notion of autopoiesis and the theory of cognition that it supports (Maturana, 1970, 1980), because it does not seem to be pragmatic enough. Some philosophers have objected to it because it relates abstractions and pragmatics (Scheper & Scheper, 1996). I think that sometimes scientists and philosophers do not see that explanations do not replace that which they explain. They forget or ignore that what explanations

indeed do is to propose generative mechanisms such that if they were allowed to operate, they would generate, as a consequence of their operation, that which they intend to explain, and do not see that in doing so they relate abstractions and pragmatics. Finally I think that what is commonly presented as an epistemological difficulty is the frequent mistake of using autopoiesis as an explanatory principle. To conclude, I wish to insist in that the epistemological shift that I have made with the notion of autopoiesis and the biology of cognition that I have developed together with it, lies in abandoning the question of reality for the question of cognition while turning to explain the experience of the observer with the experience of the observer. This is a fundamental move away from a domain of transcendental ontologies to a domain of constitutive ontologies.

If we can replace the question about reality that leads us into an epistemological and conceptual blind alley with the question about how we do what we do as living systems when we claim cognition, all that I have said will become apparent with no effort.

The notion of autopoiesis denies the need for having any trascendental notion to explain or to understand any biological phenomenon in any kind of living system. What it does not deny is any human experience whatever it may be, nor does it tell what we should or should not do with our experiences. Our human living is biological living, but how we do live as human beings is a human endeavour in the biological domain.

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