Biology of Language: The Epistemology of Reality

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I am not a linguist, I am a biologist. Therefore, I shall speak about language as a biologist, and address myself to two basic biological questions, namely:

1. What processes must take place in an organism for it to establish a linguistic domain with another organism?

2. What processes take place in a linguistic interaction that permit an organism (us) to describe and to predict events that it may experience?

This is my way of honoring the memory of Eric H. Lenneberg, if one honors the memory of another scientist by speaking about one's own work Whatever the case, I wish to honor his memory not only because of his great accomplishments, but also because he was capable of inspiring his students, as the symposium on which this book is based revealed. The only way I can do this is to accept the honor of presenting my views about biology, language, and reality.

I shall, accordingly, speak about language as a biologist. In doing so, I shall use language, notwithstanding that this use of language to speak about language is within the core of the problem I wish to consider.

1 Epistemology

Since I am writing about language as a scientist attempting to address myself to the biological phenomena involved in its generation and use, I shall make the following epistemological assumptions in order to characterize the language I shall use.

Science

We as scientists make scientific statements. These statements are validated by the procedure we use to generate them: the scientific method. This method can be described as involving the following operations: *(a)* observation of a phenomenon that, henceforth, is taken as a problem to be explained; *(b)* proposition of an explanatory hypothesis in the form of a deterministic system that can generate a phenomenon isomorphic with the one observed, *(c)* proposition of a computed state or process in the system specified by the hypothesis as a predicted phenomenon to be observed; and *(d)* observation of the predicted phenomenon.

In the first operation, the observer specifies a procedure of observation that, in turn, specifies the phenomenon that he or she will attempt to explain. In the second, the observer proposes a conceptual or concrete system as a model of the system that he or she assumes generates the observed phenomenon. In the third, the observer uses the proposed model to compute a state or a process that he or she proposes as a predicted phenomenon to be observed in the modeled system. Finally, in the fourth operation he or she attempts to observe the predicted phenomenon as a case in the modeled system. If the observer succeeds in making this second observation, he or she then maintains that *the model* has been validated and that the system under study is in that respect isomorphic to it and operates accordingly. Granted all the necessary constraints for the specification of the model, and all the necessary attempts to deny the second observations as controls, this is all that the scientific method permits.

This we all know. Yet we are seldom aware that an observation is the realization of a series of operations that entail an observer as a system with properties that allow him or her to perform these operations, and, hence, that the properties of the observer, by specifying the operations that he or she can perform determine the observer's domain of possible observations. Nor are we usually aware that, because only those statements that we generate as observers through the use of the scientific method are scientific statements, science is necessarily a domain of socially accepted operational statements validated by a procedure that specifies the observer who generates them as the standard observer who can perform the operations required for their generation. In other words, we are not usually aware that science is a closed cognitive domain in which all statements are, of necessity, subject dependent, valid only in the domain of interactions in which the standard observer exists and operates. As observers we generally take the observer for granted and, by accepting his universality by implication, ascribe many of the invariant features of our descriptions that depend on the standard observer to a reality that is ontologically objective and independent of us. Yet the power of science rests exactly on its subject dependent nature, which allows us to deal with the operative domain in which we exist. It is only when we want to consider the observer as the object of our scientific inquiry, and we want to understand both what he does when he makes scientific statements and how these statements are operationally effective, that we encounter a problem if we do not recognize the subject dependent nature of science. Therefore, since I want to give a scientific description of the observer as a system capable of descriptions (language), I must take the subject dependent nature of science as my starting point.

Explanation

As scientists, we want to provide explanations for the phenomena we observe. That is, we want to propose conceptual or concrete systems that can be deemed to be intentionally isomorphic to (models of) the systems that generate the observed phenomena. In fact, an explanation is always an intended reproduction or reformulation of a system or phenomenon, addressed by one observer to another, who must accept it or reject it by admitting or denying that it is a model of the system or phenomenon to be explained. Accordingly, we say that a system or a phenomenon has been scientifically explained if a standard observer accepts that the relations or processes that define it as a system or phenomenon of a particular class have been intentionally reproduced, conceptually or concretely.

Two basic operations must be performed by an observer in any explanation: *(a)* the specification (and distinction thereof) of the system (composite unity) or phenomenon to be explained; and *(b)* the identification and distinction of the components and the relations between components that permit the conceptual or concrete reproduction of the system or phenomenon to be explained. Since these two operations are not independent, when the observer specifies a system or phenomenon to be explained he or she defines the domain in which it exists and determines the domain of its possible components and their relations; conversely, when the observer specifies the actual components and relations that he or she intends to use in the explanation, he or she determines the domain in which this will be given and in which the reproduced system will exist. Yet the kind of explanation that an observer accepts depends on his or her a priori criteria for the validation of his or her statements. Thus the observer may accept either a *mechanistic* or a *vitalistic* explanation.

In a mechanistic explanation, the observer explicitly or implicitly accepts that the properties of the system to be explained are generated by relations of the components of the system and are not to be found among the properties of those components. The same applies to the mechanistic explanation of a phenomenon, in which case the observer explicitly or implicitly accepts that the characteristics of the phenomenon to be explained result from the relations of its constitutive processes, and are not to be found among the characteristics of these processes. Contrariwise, in a vitalistic explanation, the observer explicitly or implicitly assumes that the properties of the system, or the characteristics of the phenomenon to be explained, are to be found among the properties or among the characteristics of at least one of the components or processes that constitute the system or phenomenon. In a mechanistic explanation the relations between components are necessary; in a vitalistic explanation they are superfluous. An example of a mechanistic explanation is: The weight of a body is the sum of the weight of its components. The relation *sum*, applied to the components as defined by their property weight, determines the property weight of the body. Example of a vitalistic explanation: Jacques Monod said in *Le Hasard et la Ncessit* (1970) "L'*ultima ratio* de toutes les structures et performances tlonomiques des tre vivants est donc enferme dans les sequences de radicaux des fibres polipeptidiques, 'embryons' de ces dmons de Maxwell biologiques que vent le protines globulaires. En un sense trs rel c'est ce niveau d'organization chimique que gt s'il y a en a un, le secre de la vie [p. 110]." [The *ultima ratio* of all telenomic structures and functions of living systems is, then, embeded in the amino acidic sequence of the polypeptide chains that truly constitute embryos of Maxwell's biological demons that are the globular proteins. It is at this level of chemical organization that in a very real sense lies, if there is any, the secret of life.] This statement answers the question — What kinds of systems are living systems? — by reference to the properties of one of their components.

In a mechanistic explanation the observer explicitly or implicitly distinguishes between a system and its components, treating the system and the components as operationally different kinds of unities that belong to disjoint sets that generate nonintersecting phenomenic domains. The relation of correspondence between the phenomenal domain generated by a system and the phenomenal domain generated by its components, which an observer may assert after enuciating a mechanistic explanation, is, therefore, established by the observer through his or her independent interactions with the system and with its components and does not indicate a phenomenal reduction of one domain to another. If it appears as if there were a phenomenal reduction, it is because in the description all phenomena are represented in the same domain, and, unless care is taken to preserve it, the relation established through the observer is lost. The reality described through mechanistic explanations, then, implies the possibility of an endless generation of nonintersecting phenomenal domains as a result of the recursive constitution (organization) of new classes of unities through the recursive novel combinations of unities already defined. For epistemological reasons, then, mechanistic explanations are intrinsically nonreductionist.

With vitalistic explanations, the situation is the contrary: They do not distinguish between the phenomenal domain generated by a unity and the phenomenal domain generated by its components. The reality described through vitalistic explanations is, necessarily, a reality of a finite number of phenomenal domains. For epistemological reasons, then, vitalistic explanations are intrinsically reductionist.

Operational Characteristics of a Mechanistic Explanation

Observer

An observer is a human being, a person, a living system who can make distinctions and specify that which he or she distinguishes as a unity, as an entity different from himself or herself that can be used for manipulations or descriptions in interactions with other observers. An observer can make distinctions in actions and thoughts, recursively, and is able to operate as if he or she were external to (distinct from) the circumstances in which the observer finds himself or herself. Everything said is said by an observer to another observer who can be himself or herself.

Unity

A unity is an entity, concrete or conceptual, dynamic or static, specified by operations of distinction that delimit it from a background and characterized by the properties that the operations of distinction assign to it. A unity may be defined by an observer either as being simple or as composite. If defined as simple, the properties assigned to the unity by the operations of distinction that specify it are supposed to be constitutive, and no question about their origin arises. If the unity is defined as composite, it is assumed that it has components that may be specified through additional operations of distinction, and that it is realized as a unity by an organization that determines its properties through determining those relations between its components that specify the domain in which it can be treated as simple.

Organization

This word comes from the Greek term *organon*, which means "instrument"; by making reference to the instrumental participation of the components in the constitution of a composite unity, it refers to the relations between components that define and specify a system as a composite unity of a particular class, and determine its properties as such a unity. Hence, the organization of a composite unity specifies the class of entities to which it belongs. It follows that the concept or generic name that we use to refer to a class of entities points to the organization of the composite unities that are members of the class. From the cognitive point of view, then, it also follows that, in order to define or identify a system as a composite unity of a particular class, it is necessary and sufficient to state (or to point to) its organization; a mechanistic explanation is an explicit or implicit subject dependent statement that entails, or describes, the organization of a system.

Structure

This word comes from the Latin verb *struere*, which means to build; by making reference to the processes of construction, as well as to the components of a composite unity, it refers to the actual components and to the actual relations that these must satisfy in their participation in the constitution of a given composite unity. An observer may recognize a known system by identifying some of its components, but he or she cannot define or characterize an unknown system merely by pointing to its structure — the observer must state its organization.

Organization and structure, therefore, are not synonyms. The organization of a system defines it as a composite unity and determines its properties as such a unity by specifying a domain in which it can interact (and, hence, be observed) as an unanalyzable whole endowed with constitutive properties. The properties of a composite unity as an unanalyzable whole establish a space in which it operates as a simple unity. In contrast, the structure of a system determines the space in which it exists as a composite unity that can be perturbed through the interactions of its components, but the structure does not determine its properties as an unity. An unanalyzable unity can be designated by a name and identified by a concept that refers to the constellation of properties that define it, but it has no organization or structure. A simple unity has only a constellation of properties; it is a fundamental entity that exists in the space that these properties establish. it follows that spatially separated composite unities (systems) may have the same organization but different structures, and that a composite unity remains the same only as long as its organization remains invariant. Whenever the structure of an entity changes so that its organization as a composite unity changes, the identity of the entity changes and it becomes a different composite unity — a unity of a different class to which we apply a different name. Whenever the structure of a composite unity changes and its organization remains invariant, the identity of the entity remains the same and the unity stays unchanged as a member of its original class; we do not change its name. It follows that whenever a system is to be explained, it is necessary and sufficient to reproduce its organization. Yet when a particular system is to be reproduced, both its organization and its structure must be reproduced.

Property

A property is a characteristic of a unity specified and defined by an operation of distinction. Pointing to a property, therefore, always implies an observer.

Space

Space is the domain of all the possible interactions of a collection of unities (simple, or composite that interact as unities) that the properties of these unities establish by specifying its dimensions. It can be said, of a composite unity on the one hand, that it exists in the space that its components specify as unities because it interacts through the properties of its components, and, on the other hand, that it is realized as a unity in the space that its properties as a simple unity specify. Once a unity is defined, a space is specified.

Interaction

Whenever two or more unities, through the interplay of their properties, modify their relative position in the space that they specify, there is an interaction. Whenever two or more composite unities are treated as simple, they are seen to be realized and to interact in the space that they specify as simple unities; however, if they are treated as composites unities, then they are seen to interact through the properties of their components and to exist in the space that these specify.

Structure-Determined Systems[1]

These systems undergo only changes determined by their organization and structure that are either changes of state (defined as changes of structure without toss of identity) or disintegration (defined as changes of structure with loss of identity). For these systems it is necessarily the case that: *(a)* they may undergo only interactions that either perturb them by triggering in them structural changes that lead to changes of state or disintegrate them by triggering in them structural changes that lead to their loss of identity; *(b)* the changes of state they undergo as a result of perturbing interactions are not specified by the properties of the perturbing entities, which only trigger them; *(c)* the structural changes they undergo as a result of disintegrating interactions are not specified by the properties or the disintegrating entity, which only trigger them; and *(d)* their structure, by specifying which relations must arise between their components as a result of their interactions in order to initiate their triggered changes of state, specifies the configuration of properties that an entity must have in order to interact with them and operate either as a perturbing or as a disintegrating agent.

The organization and structure of a structure-determined system, therefore, continuously determine: *(a)* the domain of states of the system, by specifying the states that it may adopt in the course of its internal dynamics or as a result of its interactions; *(b)* its domain of perturbations, by specifying the matching configurations of properties of the medium that may perturb it; and *(c)* its domain of disintegration, by specifying all the configurations of properties of the medium that may trigger its disintegration.

If the state a system adopts as a result of an interaction were specified by the properties of the entity with which it interacts, then the interaction would be an instructive interaction. Systems that undergo instructive interactions cannot be analyzed by a scientific procedure. In fact, all instructable systems would adopt the same state under the same perturbations and would necessarily be indistinguishable to a standard observer If two systems can be distinguished by a standard observer, it is because they adopt different states under what he or she would otherwise consider identical perturbations and are not instructable systems. The scientific method allows us to deal only with systems whose structural changes can be described as determined by the relations and interactions of their components, and which, therefore, operate as structure-determined systems. Structure-determined systems do not undergo instructive interactions. In these

[1] I (1975) have called these "state-determined systems."

circumstances, any description of an interaction in terms of instructions (or of information transfer) is, at best, metaphorical; it does not reflect the actual operation of the systems involved as objects of scientific description and study. Consequently, every scientific assertion is a statement that necessarily implies a structure determined system proposed by the standard observer as a model of the structure-determined system that he or she assumes to be responsible for his or her observations. For epistemological reasons, then, scientific predictions are computations of state trajectories in structure determined systems, and chance or indeterminism enter in scientific assertions only as computational artifices used in models that assume object systems that cannot be observed in detail, not as a reflection of an ontological necessity.

Structural coupling

For an observer, the organization and structure of a structure determined system determine both its domain of states and its domain of perturbations as collections of realizable possibilities. This is so because an observer can imagine, for any structure-determined system that he or she conceives or describes, different state trajectories arising from correspondingly different sequences of perturbations by imagining the system under different circumstances of interactions. Yet what in fact occurs during the ontogeny (individual history) of any particular structure-determined system is that the structure of the medium in which it interacts and, hence, exists, and which, in this respect, operates as an independent dynamic system even while changing as a result of the interactions, provides the actual historical sequence of perturbations that, in fact, selects which of the imaginable possible state trajectories of the system indeed takes place. If the structure of the medium that matches the domain of perturbations of the structure-determined system is redundant or recurrent, then the structure determined system undergoes recurrent perturbations; if the structure of the medium is in continuous change, then the structure-determined system undergoes continuously changing perturbations; finally, if the matching structure of the medium changes as a result of the operation of the structure determined system, then this system undergoes changingperturbations that are coupled to its own state trajectory. Now, if a structure determined system, as a result of its interactions, undergoes changes of state that involve structural changes in its components (and not only in their relations), then I say that the system has a second-order plastic structure, and that it undergoes plastic interactions. When this is the case, the plastic interactions that such a system undergoes select in it trajectories of second order structural changes that result in the transformation of both its domain of states and its domain of perturbations. The outcome of the continued interactions of a structurally plastic system in a medium with redundant or recurrent structure, therefore, may be the continued selection in the system of a structure that determines in it a domain of states and a domain of perturbations that allow it to operate recurrently in its medium without disintegration. I call this process "structural coupling." If the medium is also a structurally plastic system, then the two plastic systems may become reciprocally structurally coupled through their reciprocal selection of plastic structural changes during their history of interactions. In such a case, the structurally plastic changes of state of one system become perturbations for the other, and vice versa, in a manner that establishes an interlocked, mutually selecting, mutually triggering domain of state trajectories.

2 Living and Nervous Systems

Living System: Autopoiesis[2]

Living systems are autonomous entities, even though they depend on a medium for their concrete existence and material interchange; all the phenomena related to them depend on the way their autonomy is realized. A perusal of present-day biochemical knowledge reveals that this autonomy is the result of their organization as systems in continuous self-production. This organization in terms of self-production can be characterized as follows.

There is a class of dynamic systems that are realized, as unities, as networks of productions (and disintegrations] of components that: *(a)* recursively participate through their interactions in the realization of the network of productions (and disintegrations) of components that produce them; and *(b)* by realizing its boundaries, constitute this network of productions (and disintegrations) of components as a unity in the space they specify and in which they exist. Francisco Varela and I called such systems *autopoietic systems*, and *autopoietic organization* their organization (Maturana & Varela, 1973). An autopoietic system that exists in physical space is a living system (or, more correctly, the physical space is the space that the components of living systems specify and in which they exist) (Maturana, 1975).

In this characterization of the organization of living systems, nothing is stipulated about their structure, which can be any form that satisfies it. Also, nothing is said about the medium in which an autopoietic sys-

[2] Autopoiesis is a word composed of the Greek words for 'self' and 'to produce.'

tem may exist, or about its interactions or material interchanges with the medium, which can be any that satisfy the constraints imposed by the actual structure through which the autopoiesis is realized. In fact, to the extent that an autopoietic system is defined as a unity by its autopoiesis, the only constitutive constraint that it must satisfy is that all its state trajectories lead to autopoiesis; otherwise it disintegrates. Therefore, an autopoietic system, while autopoietic, is a closed dynamic system in which all phenomena are subordinated to its autopoiesis and all its states are states in autopoiesis. This conclusion has several fundamental consequences.

Autonomy

Autopoietic closure is the condition for autonomy in autopoietic systems in general. In living systems in particular, autopoietic closure is realized through a continuous structural change under conditions of continuous material interchange with the medium. Accordingly, since thermodynamics describes the constraints that the entities that specify the physical space impose on any system they may compose, autopoietic closure in living systems does not imply the violation of these constraints, but constitutes a particular mode of realization of autopoiesis in a space in which thermodynamic constraints are valid. As a result, a structurally plastic living system either operates as a structurally determined homeostatic system that maintains invariant its organization under conditions of continuous structural change, or it disintegrates.

Phenomenal Distinctions

As I stated when discussing the notion of explanation, a scientist must distinguish two phenomenal domains when observing a composite unity *(a)* the phenomenal domain proper to the components of the unity, which is the domain in which all the interactions of the components take place; and *(b)* the phenomenal domain proper to the unity, which is the domain specified by the interactions of the composite unity as a simple unity. If the composite unity is a living system, the first phenomenal domain, in which the interactions of the components are described with respect to the living system that they constitute, is the domain of physiological phenomena; the second phenomenal domain, in which a living system is seen as if it were a simple unity that interacts with the components of the environment in which its autopoiesis is realized, is the domain of behavioral phenomena. Accordingly, from the point of view of the description of behavior, a living system interacts as a simple unity in the space it specifies through its interactions as a unity and changes its relations with the components of its environment as a result of these interactions; from the point of view of physiology, the components of the living system interact with each other and or with elements of the medium in their space, and as a result, their structure and or reciprocal relations change. For the observer who beholds simultaneously both phenomenal domains, however, the changes in the relations of the components appear as changes in state in the living system that modify its properties and, hence, its interactions in its environment — all of which he or she describes by saying that the physiology of the organism generates its behavior. Yet, since these two phenomenal domains do not intersect, the relations that an observer may establish between the phenomena of one and the phenomena of the other do not constitute a phenomenal reduction, and the generative operational dependency of behavior on physiology that the observer asserts in this manner does not imply a necessary correspondence between them. Accordingly, in no particular case can the phenomena of one domain be deduced from the phenomena of the other prior to the observation of their actual generative dependency. The implicative relation that an observer can use a posteriori to describe an observed generative dependency existing between a particular behavior and a particular physiological phenomenon is necessarily contingent on the particular structure of the living system which, at the moment of observation, determines the changes of state that the observer sees as behavior. Therefore, the implicative relation used by the observer in his description is not a logical implication as would be the case if behavioral and physiological phenomena belonged to the same phenomenal domain. The result is that, in order to explain a given behavior of a living system, the observer must explain the generation and establishment of the particular structures of the organism and of the environment that make such behavior possible at the moment it occurs.

Adaptation

The history of structural change without loss of identity in an autopoietic unity is its ontogeny. The coupling of the changing structure of a structurally plastic autopoietic unity to the changing structure of the medium is called ontogenic adaptation. The history of successively produced, historically connected unities generated through sequential reproductive steps is evolution. The coupling of the changing structures of the sequentially generated unities to a changing medium is called evolutionary adaptation.

Ontogenic and evolutionary adaptations in living systems arise through the selection of the structures that permit the autopoiesis of the living system in the medium in which it exists. In both cases, selection takes place as a differential structural realization that results from the operational confrontation of systems endowed with independently determined domains of structural diversity and plasticity. In the case of the evolution all the structural diversity of living systems, available for selection is produced in them in parallel, through each reproductive step, as a result of their genetic properties, and the selection takes place as differential survival or differential reproductive success. In the case of ontogenic changes, the structural diversity of living systems available for selection is present, at any instant, in the domain of perturbations of each living system, and selection takes place during the history of each individual according to the sequence of perturbations provided by the medium. No example of evolutionary selection is needed. As examples of ontogenic selection the following two are presently adequate:

1. In vertebrates, specific immunity responses result from the differential multiplication of cells capable of producing antibodies when the organism is confronted with antigens that select, through differential triggering, which cells multiply (Edelman, 1975).

2. The consolidation of bone lamelli following the lines of stress is a result of the preferential reabsorption of lamelli that are not under stress from a domain of lamelli otherwise in continuous turnover and initially deposited with no preferential relation to stress (J.Y. Lettvin, personal communication, 1976).

Adaptation, then, is always a trivial expression of the structural coupling of a structurally plastic system to a medium. Adaptation always results from sequences of interactions of a plastic system in its medium that trigger in the plastic system structural changes or changes of state that, at any instant, select in it a structure that either matches (is homomorphic to) the structure of the medium in which it operates (interacts or behaves) as such a system, or disintegrate it. It follows that, in the operation of living systems as autopoietic unities in a medium, the coincidence between a given structure of the medium (place in the medium) and a given structure in the living system is always the result of the history of their mutual interactions, while both operate as independent, structurally determined systems. Furthermore, as a result of the structural coupling that takes place during such a history, history becomes embodied both in the structure of the living system and in the structure of the medium, even though both systems necessarily, as structure-determined systems, always operate in the present through locally determined processes. Therefore, although from the cognitive point of view adequate behavior as a case of adaptation cannot be understood without reference to history and context, from the operational point of view adequate behavior is only an expression of a structural matching in the present between organism and medium, in which history does not participate as an operative component. History is necessary to explain how a given system or phenomenon came to be, but it does not participate in the explanation of the operation of the system or phenomenon in the present.

Selection

Although the result of selection, whether through evolution or ontogeny, is structural coupling (because what is selected is always a structure), selection takes place through the operational confrontations of a composite system in the medium in which it interacts as a simple unity through the properties of its components. Thus, it is the differential effectiveness of the actual operation of different structures of different organisms of the same kind in parallel existence, or of the same organism in different instances of its individual history, that constitutes the process of selection in living systems. Accordingly, selection always takes place in a domain orthogonal to (different from) the domain of existence of that which is selected. It is this feature of the process of selection that enables an observer to claim that selection takes place through the functional value of the structures selected, giving with this judgment, a posteriori, the misleading impression that what takes place in selection is a semantic coupling that allows for an infinity of structural realizations. In other words, although the metaphorical description in functional (semantic) terms is useful for referring to the orthogonal relation between the domains in which the selective interactions take place and in which the selected structures exist, the result is structural coupling, because the operational effectiveness of the selected system depends exclusively on the unique correspondence thus obtained between its structure and the structure of its medium. Furthermore, it is also this feature of the process of selection that allows for the diversity of sequential or simultaneous structural couplings that may take place during evolutionary or ontogenic adaptation. if the organization of a system is homeostatically maintained invariant, as occurs in autopoietic systems, adaptation is the homeostatic clamping through behavior (the actual operation of the autopoietic system in its medium) of the structural coupling of a system (ontogeny) or of a succession of systems (evolution) to their static or changing medium.

Nervous System: Neuronal Network

The nervous system is a network of interacting neurons that generates a phenomenology of neuronal interactions subservient to the autopoiesis of the organism in which it is embedded and of which it is a component. Therefore, in order to explain the nervous system as a system, it is necessary and sufficient to point to the organization that defines a neuronal network that generates its phenomenology of neuronal interactions as a constitutive component of an autopoietic system, such as a metazoan.

Such organization can be described as follows. The nervous system is defined as a system (a unity) by relations that constitute it as a closed network of interacting neurons such that any change in the state of relative activity of a collection of its component neurons always leads to a change in the state of relative activity of other (or the same collection of) neurons: All changes in relative neuronal activity in the nervous system always lead to other changes in relative neuronal activity in it. With respect to its dynamics of states, the nervous system is a closed system.A closed neuronal network does not have input or output surfaces as features of its organization, and, although it can be perturbed through the interactions of its components, for it, in its operation as a system, there are only states or changes of states of relative neuronal activity, regardless of what the observer may say about their origin. Given a closed system, inside and outside exist only for the observer who beholds it, not for the system. The sensory and effector surfaces that an observer can describe in an actual organism do not make the nervous system an open neuronal network, because the environment where the observer stands acts only as an intervening element through which the effector and sensory neurons interact, completing the closure of the network. This organization of the nervous system has several fundamental consequences.

Closure

If an observer of a nervous system, either experimentally or conceptually, were to stand in a synaptic cleft, and if while observing the pre- and post-synaptic surfaces he were to describe the transfer properties of the system thus obtained in terms of input and output relations, he would describe an open network not a nervous system. This is what, in fact, happens when an observer describes the organism as a system that has independent sensory and effector surfaces for its interactions with the environment. By doing this, the observer opens the nervous system and destroys its organization, leaving another system organized as an open network that one can describe in terms of hierarchical transfer functions that are relevant only for the system of references that the observer introduces when he or she describes the changes of state of the nervous system by mapping them on the changes of state of the environment (observable medium). As a closed neuronal network, however, the nervous system operates only by generating relations of relative neuronal activity determined by its structure, not by the environmental circumstances that may trigger changes of state in it.

Behavior

The observer sees as behavior, or conduct, the changing relations and interactions of an organism with its environment, which appear to him or her to be determined by sequences of changes of state generated in the organism by sequences of changes of state in its nervous system. Furthermore, the observer can, with no difficulty, describe any given behavior or conduct in purposeful (functional or semantic) terms that reflect the value or role that the observer ascribes to it in reference to the realization of the autopoiesis of the organism. Yet it is also apparent to the observer that, since the nervous system is a structure-determined system, the sequence of changing relations of relative neuronal activity that appears to him or her as determining a given behavior is not determined by any functional or semantic value that he or she may ascribe to such a behavior, but that, on the contrary, it is necessarily determined by the structure of the nervous system at the moment at which the behavior is enacted.

An example may clarify this situation. Let us consider what happens in instrumental flight. The pilot is isolated from the outside world; all he can do is manipulate the instruments of the plane according to a certain path of change in their readings. When the pilot comes out of the plane, however, his wife and friends embrace him with Joy and tell him: "What a wonderful landing you made; we were afraid, because of the heavy fog." But the pilot answers in surprise: "Flight? Landing? What do you mean? I did not fly or land; I only manipulated certain internal relations of the plane in order to obtain a particular sequence of readings in a set of instruments." All that took place in the plane was determined by the structure of the plane and the pilot, and was independent of the nature of the medium that produced the perturbations compensated for by the dynamics of states of the plane: flight and landing are irrelevant for the internal dynamics of the plane. However, from the point of view of the observer, the internal dynamics of the plane results in a flight only if in that respect the structure of the plane matches the structure of the medium; otherwise it does not, even if in the nonmatching medium the internal dynamics of states of the plane is indistinguishable from the internal dynamics of states the plane under observed flight. It follows that since the dynamics of states of an organism, or of a nervous system, or of any dynamic system, is always determined by the structure of the system, adequate behavior is necessarily only the result of a structural matching between organism (dynamic system) and medium.

Coupling

The presence of a nervous system in a living system does not entail a change in the nature of the operation of the living system as a structure determined autopoietic unity; it implies only an enlargement of the domain of possible states of the living system through the inclusion of structure determined relations of relative neuronal activity in the autopoietic network. The observable effectiveness that the relations of relative neuronal activity have for the realization of the autopoiesis of a given organism in its medium is the result of the structural coupling existing between the nervous system and the organism, and between these and the medium.

The argument for structural coupling of autopoietic systems can be summarized as follows. Given that the interactions of a composite unity in the space of its components are interactions through its components (that is, are structural interactions), if, as a result of a structural interaction, the components of a unity or their relations change, the structure of the unity changes and, if this structural change occurs without a change in the organization of the composite unity, the identity of the unity remains invariant. A composite unity whose structure can change while its organization remains invariant is a plastic unity, and the structural interactions under which this invariance can be sustained are perturbations. Since it is a constitutive feature of an autopoietic system to maintain homeostatically invariant its organization under conditions of structural charge, the realization of the autopoiesis of a plastic living system under conditions of perturbations generated by a changing medium must result in the selection of a structure in the living system that incorporates, in its autopoietic network, specific processes (changes of state) that can be triggered by specific changes of state of the medium; otherwise, the system disintegrates. The result of establishing this dynamic structural correspondence, or structural coupling, is the effective spatiotemporal correspondence of the changes of state of the organism to the recurrent changes of state of the medium, while the organism remains autopoietic.

The same general argument can be applied to the nervous system in particular. The organization of the nervous system as a closed network of interacting neurons must remain invariant, but its structure may change if it is coupled to the structural change of other systems in which it is embedded, such as the organism, and through this, the medium in which the organism exists as an autopoietic unity, or, recursively, itself. If the structure of the nervous system changes, the domain of possible states of relative neuronal activity of the nervous system changes, and, hence, the domain of possible behavioral states of the organism itself changes, too. Therefore, if as a result of the structural changes of the nervous system the organism can go on in autopoiesis, the nervous system's changed structure may constitute the basis for a new structural change, which may again permit it to go on in autopoiesis. In principle, this process may be recursively repeated endlessly throughout the life of an organism.

That the ontogenic structural coupling of the nervous system to the organism, to the medium, and to itself should occur through recursive selective interactions is an epistemological necessity. Which interactions select which structural change in a particular nervous system depends on the particular case under consideration. There are well-documented examples that I will not describe, but I will add that to the extent that the nervous system operates as a closed neuronal network its actual operation in the domain of relations of relative neuronal activities could not lead in it to second-order structural changes. However, since, in addition to their participation in the closed neuronal network that the nervous system is, neurons exhibit properties common to all other cells, neurons can be perturbed chemically or physically by the products of other cells of the organism, whether or not they are members of the nervous system, or of the medium. These perturbations, which are operationally orthogonal to the domain of relations of neuronal activities in which the nervous system operates, may trigger structural changes in the neurons that result in second order structural changes in the nervous system that result in changes in its domain of states that result (for the observer) in changes in behavior. Since these orthogonal perturbations constitute selective interactions, structural selection must take place through them in the domain of potential structural diversity constituted by the domain of perturbations of the organism, and it must take place through the spatial and temporal concomitances of chemical and physical neuronal perturbations determined by the structure of the media in which the nervous system is embedded. At this point it should be apparent that the only structure of the nervous system that allows for this sort of structural change is that in which the nervous system operates as an homeostatic closed neuronal network that generate, and maintains invariant relations of relative neuronal activity that are selected, through interactions orthogonal to this domain of operation, by the actual realization of the autopoiesis of the organism that it integrates.

While autopoiesis lasts, *(a)* continued ontogenic structural coupling of the nervous system selects the neuronal network structure that generates the relations of relative neuronal activity that participate in the continued autopoiesis of the organism in the medium to which it is coupled; and *(b)* the structural coupling of the nervous system to the organism, to its medium, or to itself that adequate behavior (interactions without disintegration) reveals may appear to an observer as a semantic coupling, because he or she can ascribe functional significance or meaning to any behavior, and can describe the underlying physiology as if caused by these semantic relations.

Learning and Instinct

If the structural coupling of an organism to its medium takes place during evolution, the structure that the organism exhibits at a particular moment as a result of such evolution would have arisen in it through a developmental process and not as a result of the history of its interactions as an individual. Any behavior that an observer may detect in an organism determined by a dynamics of states dependent on structures acquired by the species during evolution will be called instinctive behavior by the observer. If the structural coupling of the organism to its medium takes place during its ontogeny, and if this structural coupling involves the nervous system, an observer may claim that learning has taken place because he or she observes adequate behavior generated through the dynamics of states of a nervous system whose structure has been specified (selected) through experience. If, in these circumstances, the observer wants to discriminate between learned and instinctive behavior, he or she will discover that in their actual realization, both modes of behavior are equally determined in the present by the structures of the nervous system and organism, and that, in this respect, they are indeed indistinguishable. The distinction between learned and instinctive behaviors lies exclusively in the history of the establishment of the structures responsible for them.

Any description of learning in terms of the acquisition of a representation of the environment is, therefore, merely metaphorical and carries no explanatory value. Furthermore, such a description is necessarily misleading, because it implies a system in which instructive interactions would take place, and such a system is, epistemologically, out of the question. In fact, if no notion of instruction is used, the problem becomes simplified because learning, then, appears as the continuous ontogenic structural coupling of an organism to its medium through a process which follows a direction determined by the selection exerted on its changes of structure by the implementation of the behavior that it generates through the structure already selected in it by its previous plastic interactions. Accordingly, the significance that an observer may see a posteriori in a given behavior acquired through learning plays no part in the specification of the structure through which it becomes implemented. Also, although it is possible for us as human beings to stipulate from a metadomain of descriptions an aim in learning, this aim only determines a bias, a direction, in a domain of selection, not a structure to be acquired. This latter can only become specified during the actual history of learning (ontogenic structural coupling), because it is contingent on this history. A learning system has no trivial experiences (interactions) because all interactions result in a structural change, even when the selected structure leads to the stabilization of a given behavior.

Finally, to the extent that the nervous system operates as a closed neuronal network, the performance of learned or instinctive behavior as an expression of a structural coupling is always the action of a spatiotemporal network of relations of relative neuronal activities that appear to an observer as a network of sensori-motor correlations. If the observed behavior is instinctive and is realized in an inadequate environment, the observer claims that it is instinctive behavior in a vacuum. If the observed behavior is learned and is realized in an inadequate environment, the observer calls it a mistake. In both cases, however, the situation is the same: circumstantial structural uncoupling due to operational independence between the dynamics of states of the organism and the dynamics of states of the medium, under circumstances in which their time courses for structural change do not allow structural coupling.

Perception

When an observer sees an organism interacting in its medium, he observes that its conduct appears to be adequate to compensate for the perturbations that the environment exerts on it in each interaction. The observer describes this adequacy of conduct as if it were the result of the acquisition by the organism of some feature of the environment, such as information, on which it computes the adequate changes of state that permit it to remain in autopoiesis, and calls such a process perception. Since instructive interactions do not take place, this description is both operationally inappropriate and metaphorically misleading. Similarly, if the observer beholds a conduct that he or she usually sees under conditions of what he or she calls perception to be enacted in the absence of the adequate environmental perturbations, the observer claims that the observed conduct is the result of an illusion or hallucination. Yet, for the operation of the nervous system (and organism), there cannot be a distinction between illusions, hallucinations, or perceptions, because a closed neuronal network cannot discriminate between internally and externally triggered changes in relative neuronal activity. This distinction pertains exclusively to the domain of descriptions in which the observer defines an inside and an outside for the nervous system and the organism. In fact, for any given animal, the structure of its nervous system and its structure as a whole organism, not the structure of the medium, determine what structural configuration of the medium may constitute its sensory perturbations and what path of internal changes of states it undergoes as a result of a particular interaction. Furthermore, since these structures are the result of the structural coupling of the organism to its medium, closure in the organization of the nervous system and the organism make perception an expression of the structural coupling of an organism to its medium that is distinguishable from illusion or hallucination only in the social domain.

3 Language and Consensual Domains

Consensual Domains

When two or more organisms interact recursively as structurally plastic systems, each becoming a medium for the realization of the autopoiesis of the other, the result is mutual ontogenic structural coupling. From the point of view of the observer, it is apparent that the operational effectiveness that the various modes of conduct of the structurally coupled organisms have for the realization of their autopoiesis under their reciprocal interactions is established during the history of their interactions and through their interactions. Furthermore, for an observer, the domain of interactions specified through such ontogenic structural coupling appears as a network of sequences of mutually triggering interlocked conducts that is indistinguishable from what he or she would call a consensual domain. In fact, the various conducts or behaviors involved are both arbitrary and contextual. The behaviors are arbitrary because they can have any form as long as they operate as triggering perturbations in the interactions; they are contextual because their participation in the interlocked interactions of the domain is defined only with respect to the interactions that constitute the domain. Accordingly, I shall call the domain of interlocked conducts that results from ontogenic reciprocal structural coupling between structurally plastic organisms a *consensual domain* (Maturana, 1975).

Once a consensual domain is established, in the same manner as occurs generally whenever there is structural coupling between several systems, any member of the coupling can be replaced by a novel system that, with respect to the structural features involved in the coupling, has the same structure. Thus, a consensual domain is closed with respect to the interlocking conducts that constitute it, but is open with respect to the organisms or systems that realize it.

Descriptions

What is significant for an observer in a consensual domain is that the observed organisms can be described as simultaneously existing as composite and simple unities, and, thus, as defining two nonintersecting phenomenic domains. In the first domain, the observer can describe the organisms as interacting through the properties of their components; in the second domain, he or she can describe them as interacting through their properties as unities. In both cases, the interaction of the organisms can be described in strictly operational terms, without recourse to such semantic notions as function or meaning. Yet, when an observer communicates with another observer, he or she defines a metadomain from the perspective of which a consensual domain appears as an interlocked domain of distinctions, indications, or descriptions, according to how the observer refers to the observed behavior.

If the observer considers every distinguishable behavior as a representation of the environmental circumstances that trigger it, he or she considers the behavior as a description, and the consensual domain in which this behavior takes place as a domain of interlocked descriptions of actual environmental states that are defined through the behaviors that represent them. In this manner a description always implies an interaction. What we do as observers when we make descriptions is exactly that: We behave in an interlocked manner with other observers in a consensual domain ontogenically generated through our direct (mother-child relation) or indirect (membership in the same society) structural coupling. But if the observer forgets that the interlocked adequacy of the mutual triggering changes of state of the mutually perturbing systems in the consensual domain is the result of their ontogenic structural coupling, he or she may describe the consensual domain as if it constituted an intrinsic descriptive system in which the descriptive interactions give information to the organisms to compute the ad hoc states needed to handle the described environment. To do this is both to assume instructive interactions that for epistemological reasons are out of the question and to lose the domain of descriptions as a metadomain that exists only in a consensual domain in reference to another domain. The following considerations should make this clear.

1. If the organisms that operate in a consensual domain can be recursively perturbed by the internal states generated in them through their consensual interactions and can include the conducts generated through these recursive interactions as behavioral components in their consensual domain, a second-order consensuality is established from the perspective of which the first-order consensual behavior is operationally a description of the circumstances that trigger it. Yet, for the establishment of this second-order consensuality and, hence, for the occurrence of the recursive operation of consensus on consensus that leads to the recursive application of descriptions to descriptions, it is necessary that all perturbing processes, including the descriptions, should take place in the same domain.

2. The presence of a structurally plastic nervous system in animals makes possible this recursive mapping of all the interactions of the organism and its nervous system, as well as of most (if not all) of its internal processes, in a single phenomenic domain. In fact, since the nervous system operates as a closed neuronal network in which all states of activity are relations of relative neuronal activity, all the interactions and all the changes of state of the organism (including its nervous system) that perturb the nervous system, regardless of how they arise, necessarily map in the same domain of relations of relative neuronal activities. As has been said, the result of this is the ontogenic recursive structural coupling of the structurally plastic nervous system to its own changing structure through a process in which the sequence of structural changes is determined by the sequence of structural perturbations generated either by these same structural changes, or by the interactions of the organism in its medium.

3. The magnitude of this recursive ontogenic structural coupling in any particular organism depends both on the degree of structural plasticity of its nervous system and on the degree to which the actual structure of its nervous system at any instant permits the occurrence of distinct relations of relative neuronal activity that operate as internal structural perturbations. When this takes place, even in the slightest manner, within the confines of a consensual domain, so that the relations of neuronal activity generated under consensual behavior become perturbations and components for further consensual behavior, an observer is operationally generated. In other words, if as a result of the mapping of all the states of the organism onto the states of activity of its nervous system, an organism can be perturbed by the relations of neuronal activity generated in its nervous system by relations between relations of neuronal activity triggered in it through different interactions, consensually distinguishing them as components of a second-order consensual domain, the behavior of the organism becomes indistinguishable from the behavior of an observer; the second-order consensual domain that it establishes with other organisms becomes indistinguishable from a semantic domain. In still other words, if an organism is observed in its operation within a second-order consensual domain, it appears to the observer as if its nervous system interacted with internal representations of the circumstances of its interactions, and as if the changes of state of the organism were determined by the semantic value of these representations. Yet all that takes place in the operation of the nervous system is the structure-determined dynamics of changing relations of relative neuronal activity proper to a closed neuronal network.

4. Representation, meaning, and description are notions that apply only and exclusively to the operation of living systems in a consensual domain, and are defined by an observer to refer to second-order consensual behavior. For this reason, these notions have no explanatory value for the characterization of the actual operation of living systems as autopoietic systems, even though they arise through structural coupling. Because a description always implies an interaction by a member of a domain of consensus, the domain of descriptions is necessarily bounded by the ultimate possible interactions of a living system through the properties of its components.

Language

The word *language* comes from the Latin noun *lingua*, which means "tongue," and, in prior usage referred mainly to speech. By extension, however, language is now used to refer to any conventional system of symbols used in communication. A language, whether in its restricted or in its generalized form, is currently considered to be a denotative system of symbolic communication, composed of words that denote entities regardless of the domain in which these entities may exist. Denotation, however, is not a primitive operation. It requires agreement consensus for the specification of the denotant and the denoted. If denotation, therefore, is not a primitive operation, it cannot be a primitive linguistic operation, either. Language must arise as a result of something else that does not require denotation for its establishment, but that gives rise to language with all its implications as a trivial necessary result. This fundamental process is ontogenic structural coupling, which results in the establishment of a consensual domain.

Within a consensual domain the various components of a consensual interaction do not operate as denotants; at most, an observer could say that they connote the states of the participants as they trigger each other in interlocked sequences of changes of state. Denotation arises only in a metadomain as an a posteriori commentary made by the observer about the consequences of operation of the interacting systems. If the primary operation for the establishment of a linguistic domain is ontogenic structural coupling, then the primary conditions for the development of language are, in principle, common to all autopoietic systems to the extent that they are structurally plastic and can undergo recursive interactions.

Linguistic behavior is behavior in a consensual domain. When linguistic behavior takes place recursively, in a second-order consensual domain, in such a manner that the components of the consensual behavior are recursively combined in the generation of new components of the consensual domain, a language is established. The richness attained by a language throughout its history, therefore, depends necessarily both on the diversity of behaviors that can be generated and distinguished by the organisms that participate in the consensual domain, and on the actual historical realization of such behaviors and distinctions. The various failures and successes attained in the attempts to generate a linguistic domain of interactions with chimpanzees illustrate this point (Linden, 1978). In fact, whenever an attempt has been made to couple a sufficiently diversified domain of arbitrary distinctions that both the chimpanzee and the observer could make (such as visual or manual distinctions) to an at least commensurable domain of non-arbitrary distinctions (biologically significant) again common to both, an expanding linguistic domain could indeed be developed. Conversely, when the attempt was to couple two domains of distinctions whose varieties did not match in the chimpanzee and the observer) no expanding linguistic domain could be developed. The sign language of the deaf is another illustration of these points.

Linguistic Regularities

Since I have not mentioned grammar or syntax in this characterization of language, the following comments are necessary.

1. The behavior of an organism is defined in a domain of interactions under the conditions in which the organism realizes its autopoiesis. The result, if the organism is structurally plastic, is its ontogenic structural coupling to its medium through selective interactions determined by its behavior. Which structure, which physiology, is selected in a particular history of interactions in a particular organism, however, is determined by the original structure of the organism at each interaction, and not by the nature of the selecting behavior. As a result, as is well known to biologists, different physiologies can be selected through which the same behavior is enacted in different organisms, or in the same organism at different moments of its ontogeny. Accordingly, the regularities or rules that an observer can describe in the performance of any particular behavior, whether it is courtship, hunting, or speaking by the different organisms that enact it, do not reveal homorphisms in the underlying physiologies. The regularities in the performance of the behavior pertain to the domain in which the behavior is described by the observer, not to the underlying physiology. Therefore, the describable regularities of the linguistic behavior of the members of a consensual domain do not necessarily reflect an identity of the underlying physiologies that generate the linguistic behavior of the different members. Only if the original structures of the consenting organisms had been isomorphic could some isomorphism be expected in the physiology of similarly behaving organisms that participate in a consensual domain. Such a coincidence, however, would be a matter of historical contingency, not of structural necessity.

2. Every kind of behavior is realized through operations that may or may not be applied recursively. If recursion is possible in a particular kind of behavior and if it leads to cases of behavior of the same kind, then a closed generative domain of behavior is produced. There are many examples: Human dance is one, human language, another. What is peculiar about a language, however, is that this recursion takes place through the behavior of organisms in a consensual domain. In this context, the superficial syntactic structure or grammar of a given natural language can only be a description of the regularities in the concatenation of the elements of the consensual behavior. In principle, this superficial syntax can be any, because its determination is contingent on the history of consensual coupling, and is not a necessary result of any necessary physiology. Conversely, the 'universal grammar' of which linguists speak as the necessary set of underlying rules common to all human natural languages can refer only to the universality of the process of recursive structural coupling that takes place in humans through the recursive application of the components of a consensual domain without the consensual domain. The determination of this capacity for recursive structural coupling is not consensual; it is structural and depends entirely on the operation of the nervous system as a closed neuronal network. Furthermore, this capacity for recursive structural coupling is at work both in spoken and in sign languages of human beings and in the sign and token linguistic domains established with chimpanzees (Gardner & Gardner, 1974; Premack, 1974). Thus, the structure required for a universal grammar un-

derstood as a capacity for recursive structural coupling in the operation of the nervous system is not exclusively human. The contingencies of evolution that led in man to the establishment of spoken language, however, are peculiarly human.

3. For an observer, linguistic interactions appear as semantic and contextual interactions. Yet what takes place in the interactions within a consensual domain is strictly structure-determined, interlocked concatenations of behavior. In fact, each element of the behavior of one organism operating in a consensual domain acts as a triggering perturbation for another. Thus, the behavior of organism *A* perturbs organism *B* triggering in it an internal change of state that establishes in it a new structural background for its further interactions and generates a behavior that, in turn, perturbs organism *A*, which ... perturbs organism *B*, which ..., and so on in a recursive manner until the process stops — either because, as a result of the structural changes of *A* and *B* some behavior is triggered that does not belong to the consensual domain, or because some independent intercurrent interaction occurs that leads them out of the consensual domain.

What happens in a linguistic interaction, therefore, depends strictly on the structural state of the organism undergoing the interaction. For an observer who does not know the structural states of the linguistically interacting organisms, the outcome of a particular linguistic interaction may seem ambiguous, as if the actual syntactic value of a particular linguistic conduct were determined by some internal, not apparent, rule. Yet for each of the actual linguistically interacting organisms there is no such ambiguity. Their internal structure, as the structural background on which their linguistic interactions operate as triggering perturbations, is at any moment determined by their previous interactions and by their previous independent structural dynamics in a non ambiguous manner. Therefore, the context on which the outcome of a linguistic interaction depends is completely determined in the structure of the interacting organisms, even if this is unknown to the observer. The overheard sentence, "They are flying planes," is ambiguous only for the observer who wants to predict the outcome of the interaction with insufficient knowledge of the structural state of the speaking organism. The question in the mind of an observing linguist would be: "How can I determine the superficial syntactic value of the components of the sentence if I do not know its deep structure that determines its effective surface structure, or if I do not know the semantic value of the sentence that, by determining its deep structure, determines its surface syntax?" In fact, this question is irrelevant; it does not refer to the processes that take place in the linguistic interactions and that determine their outcome in the consensual domain. Superficial and deep syntactic structures are features of one descriptions of linguistic utterances, not of the processes of their generation.

4. To understand the evolutionary origin of natural language requires the recognition of a basic biological process that could generate it. So far, this understanding has been impossible, because language has been viewed as a denotative system of symbolic communication. If that were in fact, the way language operates in a linguistic interaction, then its evolutionary origin would demand the preexistence of denotation for agreement on the symbolic values of the arbitrary components of the system of communication. Yet denotation is the very function whose evolutionary origin should be explained. If we recognize that language is a system of generative consensual interactions, and that denotation, as merely a recursive consensual operation, operates only in a domain of consensus and not in the processes through which linguistic interactions take place, then it becomes obvious that language is the necessary evolutionary outcome, in the recursive interactions of organisms having closed, structurally plastic nervous systems, of a selection realized through the behavior generated on the interacting organisms through their structural coupling in a domain of expanding ambient diversity.

Communication

The task of an observer who faces a problem in communication is either to design a system with emitter and receiver components connected via a conducting element, such that for every distinguishable state produced in the emitter a single distinguishable state is generated in the receiver, or to treat a preexisting system as if it operated like this. Since instructive interactions do not take place in the operational domains that we are considering, the emitter and receiver must be operationally congruent for the phenomenon of communication to occur. In other words, the domain of possible states of the emitter and the domain of possible states of the receiver must be homomorphic, so that each state of the emitter triggers a unique state in the receiver. If the communication system is designed by the observer, this homomorphism is obtained by construction; if a preexisting system is described as a communication system by the observer he or she assumes this homomorphism in his or her description. In fact, every interaction can be trivially described as a communication. Therefore, it must be understood that the current view of communication as a situation in which the interacting systems specify each other's states through the transmission of information is either erroneous or misleading. If this view assumes that instructive interactions take place, it is erroneous; if this view is only meant as a metaphor, it is misleading because it suggests models that imply instructive interactions. Such errors frequently occur in attempts to explain the semantic role of language.

From all these considerations, it is apparent that an established linguistic domain is a system of communication that reflects a behavioral homomorphism resulting from structural coupling. in other words, linguistic communication always takes place after the establishment of an ontogenic structural coupling, and in that sense is trivial because it shows only that the engineer's situation has been established. What is not trivial, however, is what takes place in the process of attaining communication through the establishment of ontogenic structural coupling and the shaping of the consensual domain. During this process there is no behavioral homomorphism between the interacting organisms and, although individually they operate strictly as structure-determined systems, everything that takes place through their interactions is novel, anti-communicative, in the system that they then constitute together, even if they otherwise participate in other consensual domains. If this process leads to a consensual domain, it is, in the strict sense, a conversation, a turning around together in such a manner that all participants undergo nontrivial structural changes until a behavioral homomorphism is established and communication takes place. These precommunicative or anti-communicative interactions that take place during a conversation, then, are creative interactions that lead to novel behavior. The conditions under which a conversation takes place (common interest, spatial confinement, friendship, love, or whatever keeps the organisms together), and which determine that the organisms should continue to interact until a consensual domain is established, constitute the domain in which selection for the ontogenic structural coupling takes place. Without them, a consensual domain could never be established, and communication, as the coordination of noncreative ontogenically acquired modes of behavior, would never take place.

4 Reality

The word *reality* comes from the Latin noun *res*, meaning "thing." The fundamental operation that an observer can perform is an operation of distinction, the specification of an entity by operationally cleaving it from a background. Furthermore, that which results from an operation of distinction and can thus be distinguished, is a thing with the properties that the operation of distinction specifies, and which exists in the space that these properties establish. Reality, therefore, is the domain of things, and, in this sense, that which can be distinguished is real. Thus stated, there is no question about what reality is: It is a domain specified by the operations of the observer. The question that remains is a question in the domain of cognition: It is a question about objectivity. In other words, to paraphrase the questions presented at the beginning, "How is it that we, human beings, can talk about things, describe things, and predict events in terms of things to be observed?"

After all that I have said throughout this chapter, the answer to this question should be unambiguous. Yet let me recapitulate, as an observer, the essence of what I have said.

First, the epistemological analysis of our operation as scientists showed that all scientific statements are necessarily subject-dependent, even these that I am making now as a scientist writing about the problem of objectivity.

Second, the analysis of the organization of the living and the nervous systems showed: *(a)* both are closed systems and, accordingly, do not offer means for the description of an objective reality; and *(b)* that the effective operation of a living system (nervous system included) in the medium in which it is realized (as an autopoietic unity) is the result of its structural coupling to that medium.

Third, the analysis of language showed: *(a)* that language exists in a consensual domain generated by the interactions of closed systems and not in the domain of states of each individual system; and *(b)* that a description always implies an interaction of the system that describes. Let us now as author and reader, adopt the roles of super-observers and answer two questions, which again are reformulations of the questions presented at the beginning:

1. How is it that human beings, being closed autopoietic systems, can talk about things and make descriptions of them?

2. How is it that, if language is behavior in a consensual domain, human beings can use language to predict events to be individually experienced ?

Superobserver's Answer to the First Question

Human beings can talk about things because they generate the things they talk about by talking about them. That is, human beings can talk about things because they generate them by making distinctions that specify them in a consensual domain, and because, operationally, talking takes place in the same phenomenic domain in which things are defined as relations of relative neuronal activities in a closed neuronal network. In other words, for us as super-observers, it is apparent that human beings can talk about only that which they can specify through their operations of distinction, and that as structure-determined systems, they can only make distinctions that their structural coupling to their medium (other organisms included) permits. Accordingly, the changes of state that human beings or their instruments undergo in their interactions constitute the specification and description of the things entered as elements in their consensual domains, and this occurs under conditions in which their changes of state are determined by their structures and their structures are the result of their structural couplings. Obviously, this result is possible because, although every internal or external interaction of an organism is mapped in the relations of relative neuronal activities of its nervous system, where they cannot be distinguished as individual experiences, they can be distinguished socially in terms of behavior within a consensual domain. As a consequence, although descriptions ultimately always imply interactions of the organism through its components, language permits descriptions of entities in as many different domains as can be defined consensually, however removed from actual interactions they may seem to an observer, because linguistic descriptions always take place as consensual distinctions of relations of relative neuronal activities in the talking organisms, and consensual distinctions always imply interactions between organisms through their components. Thus, talking human beings dwell in two non-intersecting phenomenal domains: the domain of their internal states and the domain of their interactions in the consensual domain. Since these two domains are non-intersecting, neither can be reduced to the other, even though an observer can establish a homomorphism between them. This is obvious for me as a super-observer because I am external to both. For the human being talking, however, all that exists is his or her domain of experiences (internal states) on which everything is mapped, and the human being operates through experiences as if a phenomenal reduction had taken place. Yet, if he or she could be led to become a super-observer, he or she would accept the legitimacy of these multiple, nonintersecting phenomenal domains in which he or she can operate without demanding reductionist explanations.

In synthesis, although many spaces can be described through language, no space can be described that cannot be mapped onto the changes of state of the linguistically interacting organisms through the interactions of their components. Therefore, the ultimate and basic space that a composite unity can describe in a consensual domain is the space in which its components exist; the space in which its components exist determines the ultimate domain of interactions through which a composite unity can participate in the generation of a consensual domain. Thus, the human domain of descriptions is both bounded and unlimited. It is bounded, because every description that a human being makes necessarily implies an interaction through his components; it is unlimited, because through the operation of the nervous system the person can always recursively refine new phenomenic domains through the consensual specification of new unities composed through the coupling of old ones. In general, then, the ultimate space that the components of a composite system define is for such a system its ground space. Men, in particular, specify their ground space, the space which they define as composite unities by describing their components through their interactions through their components, as *the physical space*. As a consequence the human cognitive domain, the human domain of descriptions, is necessarily closed: every human assertion implies an interaction. That about which man cannot talk he cannot speak.

Superobserver's Answer to the Second Question

First, it is apparent that if, for the organisms that possess a natural language, to enact it is to realize their autopoiesis through their behavior in a consensual domain, then effective linguistic interactions between organisms (linguistic interactions that lead to their continued operation within the consensual domain without loss of autopoiesis) are necessarily an expression of *(a)* their reciprocal structural coupling; and *(b)* the changes in relations of relative neuronal activities in their respective nervous systems as determined by their structures and selected by their interactions.

Second, from the perspective of an observer, it is apparent that the relations of relative neuronal activities that take place in the nervous system of an organism that participates in a consensual domain result either from its structural coupling to the other members of the consensual domain, and represent (for the observer) external interactions, or from the recursive structural coupling of the nervous system to its own structure, and represent (for the observer) internal interactions. Relations of the first kind correspond to things distinguished in a consensual, social, domain; whereas relations of the second kind correspond to things distinguished in a private, personal domain that may or may not intersect with the social domain. The first correspond to experiences that pertain to a consensual reality, the second to experiences that pertain to a private, individual reality. In these circumstances, since a prediction is the realization in a consensual domain of a state in a model, and since the operation within a consensual domain as well as all the external and internal interactions of an organism involving its nervous system are equally realized as configurations of changing relations of relative neuronal activities in its nervous system, a prediction cannot but correspond to a configuration of relations of relative neuronal activities to be obtained if certain operations (other relations of relative neuronal activities) are realized. If the operations to be realized arise from relations of relative neuronal activities that correspond to external interactions, then the prediction belongs to the domain of consensual reality; if the operations to be realized arise from relations of relative neuronal activities that correspond to internal interactions, then the prediction belongs to the domain of private reality. In either case, however, predictions are realized as actual experiences, that is, as actual states of the organisms obtained through the realization of the operations that constitute the predictions if the organisms operate within the domains of structural couplings in which the predictions are made. In other words, the realization of a prediction in a consensual domain is a necessary result of the structural coupling that constitutes the consensual domain. Only if it implies operations outside the consensual domain in which it is made is a prediction not fulfilled. The operation of a structure determined system is necessarily perfect; that is, it follows a course determined only by neighborhood relations in its structure and by nothing else. It is only in a referential domain, such as the domain of behavior, that an observer can claim that an error has occurred when his or her expectations are not fulfilled because, contrary to them, the operation of the organism reveals that it is not structurally coupled to the medium in which he or she observes it and in which he or she predicts its behavior.

Observer's Reduction to Actual Agent

These answers made by a human observer in the role of superobserver also apply to his or her own operation as an observer, because the operation of an observer is an operation in a second-order consensual domain. Accordingly, although we have played the role of superobservers in order to reveal the manner of operation of linguistic interactions, no human being can effectively operate as an absolute superobserver, because of the closure of his domain of descriptions. This, however, does not weaken the argument, which remains fully valid after collapsing the superobserver into the observer, because it is based only on relations proper to a second-order consensual domain that permit an observer to play such a role: the role of a second-order observer, the observer of the observer in its medium.

We live in a domain of subject-dependent realities, and this condition is the necessary result of our being structure-determined, closed, autopoietic systems. Yet we are not like the chained men in the cave of Plato's *Republic* who saw only the shadows of objective entities that could, at least in principle, be conceived as having an absolute reality. We are more like pharmacologists describing biologically active substances by means of the changes of state of their biological probes. There is no similarity between the changes of state that a female rabbit undergoes and the hormone that brings them about; nobody claims that there is. However, strictly, for a long time and in the absence of other methods, many substances have been characterized by the changes of state of the biological probes that revealed them. Furthermore, other methods are not effectively different from the pharmacological one. This is not a novelty. Yet it is not frequently realized, and it is less frequently taken seriously in the domain of science, that we human beings operate in our cognitive domain like the pharmacologist and that we can only operate in this way by using ourselves as biological probes with which we specify and describe the domains of reality in which we live. That we should be living systems is obviously not a necessary condition, but it is an existential condition that determines how our domains of reality are generated; because in us, as in all living systems, all operations are subordinated to the invariance of our autopoiesis.

5 Conclusion

The extent of what an organism can do is determined by its organization and structure, and all that an organism can do constitutes its cognitive domain. The way we (human beings) determine knowledge shows that implicitly or explicitly we accept this to be the case: We ask a question in a given domain and, as an answer we expect an action, or the description of an action, in the same domain. The fact that we usually demand that human beings should be aware of their knowledge — that is, that they should be observers — does not change the matter. Our cognitive domain is bounded and unlimited in the same manner in which our domain of reality is bounded and unlimited. Knowledge implies interactions, and we cannot step out of our domain of interactions, which is closed. We live, therefore, in a domain of subject-dependent knowledge and subject-dependent reality. This means that if the questions, "What is the object of knowledge?" or "What is the objective reality of an object?" are meant to be answered by an absolute observer, then they are meaningless, because such an absolute observer is intrinsically impossible in our cognitive domain. In fact, any knowledge of a transcendental absolute reality is intrinsically impossible; if a supposed transcendental reality were to become accessible to description then it would not be transcendental, because a description always implies interactions and, hence, reveals only a subject-dependent reality. The most we can say, therefore, is that the observer generates a description of the domain of reality through his or her interactions (including interactions with instruments and through instruments), and that the observer can describe a system of systems (a system of consensus) that leads to the emergence of systems that can describe: observers. As a consequence, because the domain of descriptions is closed, the observer can make the following ontological statement: The logic of the description is isomorphic to the logic of the operation of the describing system.

Apparently all that remains is the observer. Yet the observer does not exist alone, because his existence necessarily entails at least an other being as a necessary condition for the establishment of the consensual domain in which he exists as an observer. However, what is unique to each observer and makes each observer stand alone, is, on the one hand, his or her experiences, which remain necessarily secluded in his or her operational closure, and, on the other hand, the observer's ability through second-order consensuality to operate as external to the situation in which he or she is, and thus be observer of his or hers circumstance as an observer.

Postscript: Creativity and Freedom

Much of what I have said has been intuitively accepted by philosophers since antiquity, but until now no one had proposed an explanation that could show the biological nature of the phenomena of cognition and reality. This chapter is such an explicit attempt (see also Maturana, 1970, 1974). Furthermore, until now, it had not been shown that there is no contradiction between the subject-dependent nature of our reality and our effective operation in a socially valid and seemingly objective physical world. Since a description always implies an interaction, and since the describing systems describe their components via their interactions through their components, there is a constitutive homomorphism between descriptions, and behavior in general, and the operation of the systems that describe. Therefore, we literally create the world in which we live by living it. If a distinction is not performed, the entity that this distinction would specify does not exist; when a distinction is performed, the created entity exists in the domain of the distinction only, regardless of how the distinction is performed. There is no other kind of existence for such an entity.

In this context, then, what are creativity and freedom?

Answers to these questions have been entangled in a frequent confusion of determinisms with predictability, and in the belief in the objective occurrence of the phenomenon of choice. That a system is structure determined means that it is deterministic and that in its operation choice is out of the question, but it does not mean that it is necessarily predictable. Determinism is a feature of the operation of a system, while predictability and choice are expressions that reflect the state of knowledge of the observer. If the system observed and the medium in which it is observed are known, then the system does not appear to encounter alternatives in its interactions, because it and its medium form for the observer a single predictable system; if the system or the medium are unknown, then the system appears to encounter alternatives in its interactions, because system and medium constitute operationally independent systems for the observer who cannot predict their course: in such a case the observer projects his or her own uncertainty on the system by claiming that it must make a choice. An unknown system is, for the ignorant observer, a chaos, however deterministic it may appear to the knowing observer who sees it as a structure-determined system. Once this is understood, it becomes apparent that a novelty, the new, is always an event viewed in a frame of reference from which it could not have been predicted by an observer.

When an organism enters into an interaction that arises from a contingency, that is, from an encounter with an operationally independent system (which could be part of the organism itself), the ensuing triggered changes of state of the organism could not have been predicted by an observer of the operation of the organism alone. For the observer, the organism performs a novel distinction and specifies a new reality. This is creativity: the generation by an organism of distinctions (unexpected for an observer) through its interactions with systems to which it is not structurally coupled (operationally independent systems), and to which it may become structurally coupled as a result of the interactions. Since the structure of an organism (its nervous system included) is under continuous change as a result of its autopoiesis in an operationally independent medium, organisms are, at least potentially, in the position of undergoing a continuous change in their structural couplings anal hence, of continuously encountering independent systems and thus of undergoing continuous changes of state unpredictable from their perspective alone. Creativity, then, is a necessarily widespread feature in living systems.

If an organism exists in a domain that does not determine all its interactions, so that it can undergo interactions with independent systems, there is freedom in the domain of existence of the organism. The organism is free even if its operation is deterministic, and if it can generate second-order consensual domains, it can, as an observer, recursively generate operationally independent consensual entities as a recursive observer of its circumstance. This has been well understood throughout the history of mankind. If a human being can observe the social system that he creates with his behavior, he may dislike it and reject it, and thus become a source of change, but if he can only undergo interactions specified by the social system that he integrates, he cannot be an observer of it and his behavior can only confirm it. Accordingly, all coercive political systems aim, explicitly or implicitly, at reducing creativity and freedom by specifying all social interactions as the best means of suppressing human beings as observers and thus attaining political permanence. To obtain this ultimate goal, however, the typically human mode of creativity must be completely suppressed, and this, as long as there is any capacity to establish such second-order consensual domains as the use of language requires, is impossible.

Every human being, as an autopoietic system, stands alone. Yet let us not lament that we must exist in a subject-dependent reality. Life is more interesting like this, because the only transcendence of our individual loneliness that we can experience arises through the consensual reality that we create with others, that is, through love.

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