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The Cognitive Theories of Maturana and Varela

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Maturana and Varela developed the concept of autopoiesis to explain the phenomena of living organisms. They went further and postulated theories concerning the nervous system and the development of cognition. These theories have radical conclusions concerning human thought, language, and social activity. This paper aims to introduce these ideas and to explore the main implications. It also discusses the application of these cognitive theories in three separate domains—computer systems design, family therapy, and the Law.

KEY WORDS: autopoiesis; cognition; language; law; nervous system; psychotherapy; systems design.

1. INTRODUCTION

The work of Maturana and Varela on the nature of living systems and their cognitive capacities is important and has potentially far-reaching consequences. It is, however, rather inaccessible, using an idiosyncratic vocabulary and making little connection with other literature. An earlier paper (Mingers, 1989) introduced the concept of autopoiesis and its implications and applications. The aim of this paper is similarly to explicate Maturana's cognitive theories, which depend on but are separate from autopoiesis.

Section 2 carries a brief explanation of physical autopoiesis and its main implications as a necessary precursor to Section 3, which describes Maturana's theories concerning the development and nature of the nervous system and cognition. Section 4 discusses the main consequences of the theory, in particular the closure and autonomy of human cognition, the nature of perception and intelligence, and the development of language and conversation as a subject-dependent connotative domain rather than a domain of descriptions of reality. Finally, Section 5 discusses the way these ideas have been taken up in the areas of psychotherapy, the law, and computer systems design. The philosophical

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implications of Maturana's cognitive theories are considered in a separate paper (Mingers, 1990).

2. PHYSICAL AUTOPOIESIS

Maturana and Varela developed the concept of autopoiesis in order to explain the essential characteristics of living as opposed to nonliving systems (Maturana, 1975a, 1980a, 1981; Maturana and Varela, 1980; Varela, 1979, 1980, 1981, 1984; Varela *et al.*, 1974). Maturana and Varela (1987) give a very good introduction. In brief, a living system such as a cell has an autopoietic organization, that is, it is "self-producing." It consists of processes of production which generate its components. These components themselves participate in the processes of production in a continual recursive re-creation of self. Autopoietic systems produce themselves and only themselves; allopoietic systems (e.g., a car) produce something other than themselves. This paper assumes a basic grasp of autopoiesis.

There are two consequences of autopoiesis which are important in understanding Maturana's cognitive theories.

2.1. Structure-Determined Systems

Maturana distinguishes between a system's organization and its structure. *Organization* describes the central relations which constitute a system as a whole and which determine its type. Systems of the same type have the same organization. *Structure* refers to the actual manifestation of a particular example—its actual components and their interactions. Thus all cells have the same autopoietic organization, but there are many different cell structures, and a particular cell changes its structure over time. The important point is that the dynamics of a cell—the changes of state that its structure goes through—are determined by its own structure at that point in time. They are not determined by its interactions with its environment. To an observer it may appear that an event in the environment has brought about a structural change, but in reality the structural change will have been concerned with maintaining autopoiesis. The environmental perturbation can be said only to trigger or select a change of state, not to determine it. Indeed, it is the structure itself which determines what can and what cannot be a trigger.

2.2. Structural Coupling

If a system is so independent of its environment, how does it come to be so well adjusted, and how do systems come to develop such similar structures? The answer lies in Maturana's concept of *structural coupling*. An autopoietic organization is realized in a particular structure. In general, this structure will be plastic, i.e., changeable, but the changes that it undergoes all maintain autopoiesis so long as the entity persists. (If it suffers an interaction which does not maintain autopoiesis, then it dies.) While such a system exists in an environment which supplies it with necessities for survival, then it will have a structure suitable for that environment or autopoiesis will not continue. The system will be structurally coupled to its medium. This, however, is always a contingent matter and the particular structure that develops is determined by the system. More generally, such a system may become structurally coupled with other systems—the behavior of one becomes a trigger for the other, and vice versa. This development of interlocking behaviors forms the basis of the development of language, the subject of much of this paper.

3. THE NERVOUS SYSTEM AND COGNITION

In general usage, cognition refers to the process of acquiring and using knowledge, and as such it is assumed to be limited to organisms with a (fairly advanced) nervous system. The nervous system itself is viewed as a system which has developed to collect knowledge about the environment, enabling an organism to survive better.

Maturana's theories question both these beliefs (Maturana, 1975b, 1978, 1980b, 1988). He began his work with two seemingly unrelated questions: What is the nature of living organisms? and What is the nature of perception and, more generally, what is the nature of cognition and knowledge? A central breakthrough was to see that the two questions are in fact linked. Perception and cognition occur through the operation of the nervous system, which is realized through the autopoiesis of the organism. As we have seen, autopoietic systems operate in a medium to which they are structurally coupled. Their survival is dependent on certain recurrent interactions continuing. For Maturana, this itself means that the organism has knowledge, even if only implicitly. The notion of cognition is extended to cover all the effective interactions that an organism has.

> A cognitive system is a system whose organization defines a domain of interactions in which it can act with relevance to the maintenance of itself, and the process of cognition is the actual (inductive) acting or behaving in this domain. Living systems are cognitive systems, and living as a process is a process of cognition. This statement is valid for all organisms, with and without a nervous system. (Maturana and Varela, 1980, p. 13)

I argue later that it is better to retain the more conventional use of the term cognition, but first I explicate the development and role of the nervous system and how it leads to the emergence of language and the observer.

3.1. The Nervous System

The nervous system is an evolutionary biological development which increases the range of behavior that can be displayed by an organism—its requisite variety. It does not, in essence, change the nature of operation of an autopoietic system. We can see how nerve cells (neurons) have developed as specializations of ordinary cells. If we consider a single-celled organism such as the amoeba [Maturana and Varela (1987) and Von Foerster (1984) give very readable introductions], it displays behavior, for example, movement and ingestion. It has both a sensory and an effector surface—in fact they are both the same, its outer membrane. Chemical changes in areas of its immediate environment affect the elasticity of its membrane, which in turn allows its protoplasm to flow in a particular direction, thus leading to movement or the surrounding of food.

A neuron is like an ordinary cell that is specialized in two ways. First, it has developed very long extensions, called dendrites, which connect to many other, often distant cells. This leads to a separation of the sensory from the effector sites of the cell and allows for the possibility of transmission. Second, it has developed a generalized response—electrical impulses (although neurons are still affected by chemical changes)—as opposed to the specific physico-chemical sensitivity of different sensory surfaces. This has two vital consequences—the establishment of a universal medium (electrical activity) into which all the differing sensory/effector interactions can be translated and the development of internal neurons which connect only to other neurons, responding to this electrical activity. These interneurons are particularly important as they sever the direct relationship between sensor and effector and vastly expand the realm of possible behaviors of an organism. In humans these have grown to outnumber sensory/motor neurons by a factor of 100,000.

The other main physiological feature of the nervous system is the neuron's method of connection—the synapse. The synapse is the point of near-contact between dendrites and other cells, neurons or ordinary cells. Any particular cell will have thousands of these, each contributing a small amount to the cell's overall activity. A synapse is actually a very small gap across which chemicals called neurotransmitters can flow, triggering an electrical exchange. In effect, therefore, these are the sensory and motor surfaces of the neuron.

There are a number of consequences which I briefly outline. Some are discussed more fully later.

3.1.1. Maintaining Internal Correlations

What is it that the nervous system actually does? Looking at the amoeba, a change in the sensory surface is triggered by the level of a chemical in the environment. This leads to motor changes and the movement of the organism through the environment. The process continues until the concentration is reduced and the balance between sensor and effector returns to the previous level. To the observer, the amoeba has captured a prey. To the amoeba, state-determined structural changes have occurred, restoring an internal balance or correlation between sensory and effector surfaces.

For Maturana, the nervous system functions in precisely the same way. It acts so as to maintain or restore internal correlations between sensory and effector surfaces. That it does so through an incredibly complex system of interacting neurons makes no difference to its fundamental operation. Touching a hot plate stimulates certain sensory neurons. These trigger motor neurons, leading to the contraction of a muscle. This in turn results in withdrawal of the hand and removal of the sensory stimulation. Internal balance is restored.

3.1.2. Organizational Closure

As observers, we see the hot plate and the hand moving away. It appears that the nervous system is an open system, receiving an input from the environment and producing an appropriate response. Yet in view of the previous point, this is mistaken. The nervous system is in a process of continuous activity, the state of its components at one instant determining its state at the next. Thus states of relative neuronal activity are caused by and lead to further states of activity in an uninterrupted sequence. This seems clear for interneurons which connect only to other neurons, but do not the sensory and effector surfaces constitute some kind of open interface to the world? Maturana argues that they do in an interactional sense, but not in an organizational sense.

The sensory surface is triggered by something in its environment and its activity contributes to the activity of the whole. This may lead to motor activity compensating for the disturbance. The result is a further change to the sensory surface, not directly but through the environment. The hand moves, the temperature reduces. Relative activity leads to relative activity. This is equally true for internal sensory and effector surfaces. Excessive internal temperature leads to sweating and eventually restored temperature. In all cases nervous activity results from and leads to further nervous activity in a closed cycle.

Another way of saying this is that the nervous system is structure dependent. Its possible and actual changes of state depend on its own structure at a point in time, not on some outside agency. At most, such an agency can act only as a trigger or source of perturbation. It cannot determine the reaction of the nervous system. This can easily be shown by recognizing that it is the structure itself that determines what can be a trigger for it. By definition, only systems with light-sensitive neurons can be affected by changes in light.

Points 3.1.1 and 3.1.2 above apply equally where there is no nervous system. That the amoeba is affected by certain chemicals, and that they lead to a particular changes, is determined exclusively by the structure of the amoeba, not the nature of the chemical. The next two points, however, are particular consequences of the nervous system.

3.1.3. Plasticity

The nervous system is essentially plastic—that is, its structure changes over time. This is because of the interneurons which disconnect the sensory and motor surfaces, severing their one-to-one relation and vastly increasing the range of states open to an organism. It is this which allows changes in behavior, and that which we call learning. This plasticity does not happen mainly to the structure of connections between neurons and groups of neurons, but in the pattern of response of individual neurons and their synapses. Such changes occur both because of the specific activity of interacting neurons and through the general results of chemical changes in the blood supply.

3.1.4. Interactions with Relations

Apart from introducing plasticity, the main effect of the nervous system is that it connects together cells that are physically separate within the organism. One vital result of this is that it allows the organism to interact with respect to the *relations between events* rather than the simple events themselves. An organism without a nervous system interacts only with isolated physicochemical occurrences. However, in organisms that connect many different sensors, neurons develop that are triggered not by single events but by the relations that hold between events occurring simultaneously or, indeed, over time. Von Foerster (1984) gives an excellent illustration of a network of neurons which is structured in such a way that it responds only to the presence of an edge—that is, a sharp discontinuity between light and dark.

This may well be the most important consequence of the nervous system. It enables organisms to interact with the general as well as the particular and leads to the possibility of abstract thought, description, and eventually language and the observer as shown in the next section.

3.2. The Emergence of the Observer

The nervous system allows the relations that occur at the sensory surface to be embodied in a particular pattern of nervous activity. With the growth of the interneurons, this pattern no longer has a direct effect on the motor surface but constitutes a perturbation for the internal nervous system itself. The state of relative nervous activity becomes itself an object of interaction for the nervous system, leading to further activity. This is the basis for a further expansion of the cognitive domain—a domain of interaction with its own internal states as if they were independent entities. This is the beginning of what we term abstract thought.

The widened repertoire of behavior and the potential for change and development constituted significant evolutionary advantage and stimulated an enormous expansion of the internal nervous system. Structurally, this development involved the nervous system projecting itself onto itself: the various sensory surfaces having corresponding areas within the cortex, and these being functionally connected to each other and to various mediating structures. The human brain is vastly more responsive to its own internal structures than it is to its sensory/effect or surfaces.

The next important emergence appears to be that of description and language. Maturana's ideas here are strikingly similar to those of G. H. Mead (1934), although apparently developed independently. The evolutionary developments outlined above lead to organisms with well-developed nervous systems capable of wide-ranging and adaptable behavior. Such organisms are structurally coupled to their environment and to other organisms within it. Complex sequences of mutually triggered behaviors are possible. Always, however, such behavior is ultimately structurally determined within each organism.

Within this context, Maturana distinguishes two types of interaction between organisms. The first is where the behavior of one leads directly to the behavior of the other, for example fight/flight or courtship. The second is less direct. The behavior of the first organism "orients" a second organism, i.e., directs its attention to, some other interaction that the two have in common. The orienting behavior stands for or represents something other than itself. What is important is that the behavior symbolizes something other than itself, and its success depends on the common cognitive domains of the organisms. This leads Maturana to describe the domain of such behavior as a consensual domain, and the interactions as communication.

Orienting behavior is thus symbolic—its significance lies not in itself, but in what it connotes or implies. In a very crude way it is an action that is a *description* of the environment of an organism. It is the basis for the emergence of a new domain of interactions—the domain of descriptions—which in turn forms the basis of language. Initially these symbolic gestures will be closely related, through metaphor and metonymy (Wilden, 1977), to the activity that they connote. However, the nervous system can interact with the corresponding states of neuronal activity as if they were independent entities and thus generate descriptions of descriptions in an endless recursive manner. In this way the symbols become further removed from their origin and the domain of essentially arbitrary signifiers that we call language emerges.

As a result of this process, and a concomitant development of the neocortex, organisms have arisen that can make complex and recursive descriptions of their descriptions and thus they become observers. Moreover, within this linguistic domain a description of the self is possible, and thus descriptions of the self describing the self, and so on. So is born the self-observer and self-consciousness.

To summarize Maturana's views so far, autopoietic systems exist structurally coupled to their medium. Their behaviors are implicitly based on presumptions about their environment and are thus cognitive. A nervous system does not alter this basic situation but does permit the emergence of wider realms of interaction culminating in the self-consciousness of humans. Initially, the nervous system severs the direct connection between sensory and motor surfaces, allowing a wider range of changeable behaviors and interactions with relations rather than isolated events. Increasing encephalization (i.e., development of the brain) under evolutionary pressure widens the range of possible behaviors to include abstract thought, orienting behavior, and the domain of descriptions. Finally, descriptions of descriptions and descriptions of self through language generate the observer and self-consciousness. At each stage emerges a domain of new and different interactions—interactions with relations, with internal nervous activity, with descriptions, with descriptions of descriptions, and finally, with self-descriptions. All are made possible by the underlying biology, but none are reducible to it.

> The linguistic domain, the observer, and self-consciousness are each possible because they result as different domains of interactions of the nervous system with its own states in circumstances in which these states represent different modalities of interactions of the organism (Maturana and Varela, 1980, p. 29)

4. CONSEQUENCES OF THE THEORY

4.1. Nervous System and Organizational Closure

As explained in Section 1, an autopoietic system is organizationally closed and structurally determined—its changes of state depend on its own structure at a point in time and are not determined (although they may be selected) by events in the environment. The same is true of the nervous system, even though it itself is not autopoietic. Every state of nervous activity leads to and is generated by other such states. This is true despite its appearing that the sensory/effector surfaces are open to the environment. The correctness of this counterintuitive view is illustrated by a number of examples.

First, consider the studies of color vision in pigeons by Maturana *et al.* (1968). It might be expected that there would be a direct causal relation between the wavelength of light and the pattern of activity in the retina and that this in turn would create the experienced color. In fact, it was not possible to correlate directly light wavelength and neuronal activity. The same nervous activity could be generated by different light situations, while the same wavelength of light could lead to different experiences of color [this is practically illustrated by Maturana and Varela (1987, pp. 16–20)]. However, it was the case that there was a direct correlation between retinal activity and the experience of the subject. In other words, a particular sensory activity always generates the same experience even though it may be triggered by different environmental situations.

Second, consider the sensory and effector surfaces of the nervous system between which lies an environment. Imagine a very simple nervous system, with one sensor connected to one interneuron connected in turn to one effector. If the effector were itself connected directly to the sensor, then the closed circular operation would be apparent. It is not, but neither are the other neurons in this simple system connected *directly* to each other. They are connected across a small gap—the synapse—which, therefore, forms the environment between each neuron. Moreover, each neuron can be seen as having its own effector and sensor surfaces. In principle, therefore, the relations between the sensory and effector surfaces of the nervous system are no different from those between any neurons. What is different is that we, as observers, stand in one environment and not the other, and it is not apparent to us that functionally it is just as if we are standing within one of the synapses.

Third, consider the idea that the environment does not determine, but only triggers neuronal activity. Another way of saying this is that the structure of the nervous system at a particular time determines both what can trigger it and what the outcome will be. At most, the environment can *select* between alternatives that the structure allows. This is really an obvious situation of which we tend to lose sight. By analogy, consider the humming computer on my desk. Many interactions, e.g., tapping the monitor and drawing on the unit, have no effect. Even pressing keys depends on the program recognizing them, and pressing the same key will have quite different effects depending on the computer's current state. We say, "I'll just save this file," and do so with the appropriate keys as though these actions *in themselves* bring it about. In reality the success (or lack of it) depends entirely on our hard-earned structural coupling with the machine and its software in a wider domain, as learning a new system reminds us only too well.

As adults we are so immersed and successfully coupled to our environments that we forget the enormous structural developments (ontogenetic structural drift in Maturana's words) that must have occurred in us, although observing the helplessness of young babies quickly brings this home. It is still easy, however, to imagine that the environment has caused us to become adapted to it, but this is as mistaken as to believe that the existence of treetops caused the development of giraffes.

4.2. Perception and Intelligence

Maturana's approach brings out characteristically novel insights into these domains (Maturana and Guiloff, 1980; Maturana, 1983). In both cases he asks not What is this phenomenon as an entity or characteristic? but What is this as a *process* generating the observed phenomena?

His analysis of perception was introduced in Section 4.1. The process of perception does not consist in our grasping or representing an objective world external to us. Rather, it involves the operations of a closed neuronal network which has developed a particular structure of sensory/effector correlations through a history of structural coupling. For the observer who sees the organism and its environment in apparent harmony, it seems that the organism must be responding to perceived changes in the environment. But the internal situation is rather like a robotic production line. Each robot is programmed to perform its own specific actions in orchestration with the others. While these actions coordinate, there appears to be purpose and communication, but as soon as they become unsynchronized, the resulting ludicrous spectacle reveals how fragile is this illusion.

Similarly, intelligence is normally seen as an objective property of a person or animal, like weight or strength, which can be measured in an objective way by, for example, solving problems or puzzles. Maturana argues that we must ask how behavior which observers call intelligent is generated. His answer is that it must be the result of a history of structural coupling with the environment and/or other organisms and that, therefore, *any* behavior that is successful within a domain of structural coupling is intelligent behavior. Intelligence is neither a property of the organism, or some part of the organism, nor directly observable. The word intelligence connotes the structure resulting from coupling in various domains and it is manifest only in particular instances of coupled or consensual behavior.

There are a number of implications. First, all cultures, as consensual domains of biologically successful behavior, imply equivalent although not identical intelligence in their members. Second, intelligence in general cannot be measured and certainly cannot be compared across cultures. IQ tests reflect only a subset of a particular culture and can record only the extent of an organism's coupling to that particular domain and, thus, to the observer (test creator) who specifies it. They cannot therefore measure the organism's potential for structural coupling in other domains or in general. Third, specific intelligent is not heritable, for it is developed in the ontology of a particular organism's coupling. At most one can say that the general capacity for coupling in a particular domain (e.g., the linguistic) is genetically dependent.

4.3. Language as a Consensual Domain

Just as it is mistaken to believe that the nervous system operates by manipulating the environment, it is equally mistaken to view language as denotative, that is, objectively indicating and pointing to an external world. Linguistic behavior is connotative. The observed communication of meaning and the practical efficacy of language do not reside in the words and terms themselves but reflect similarities in the organisms' structures developed through their history of interactions.

As explained in Section 3.2, organisms which interact recurrently with each other become structurally coupled. They develop behaviors which reciprocally trigger complementary behaviors, and their actions become coordinated so as to contribute to their continued autopoiesis. Moreover, the particular behaviors or conducts are divorced from that which they connote—they are symbolic and thus essentially arbitrary and context dependent. They "work" only to that extent that they reflect agreement in structure, and this is what Maturana means by a domain of *consensual* action. They rely on a consensuality (rather than explicit consensus) between those involved (Harnden, 1990).

The consensual domain is thus a domain of arbitrary and contextual interlocked behaviors. Much animal behavior involves coordinating actions of this type, e.g., courtship and nest-building. Some may be instinctive, e.g., the dance of bees, but most is learned through the structural drift of the organism through its life. This learned consensual behavior Maturana terms *linguistic*, although it is not yet language. It is distinguished by its symbolic nature—i.e., that the action stands for something other than itself. For an observer, such coordinating conducts can be seen as a description of some feature of the organism's environment.

Linguistic acts by themselves do not constitute language. For Maturana, the process of using language, or "languaging," can occur only when the linguistic behaviors themselves become an object of coordination. This in turn can happen only when the nervous system has developed in such a way that it can interact with its own symbolic descriptions. Thus linguistic behavior is the consensual coordination of action. Languaging is a recursion of this, i.e., the consensual coordination of consensual coordinations of action.

Once this level of abstraction has been reached—i.e., the description of a description, the entire space of language is opened up, as are the observer and the self-conscious self-observer. In his early work Maturana talked of descriptions and descriptions of descriptions, but now he refers to consensual coordination of action. This emphasizes his view that language is not essentially a descriptive domain but always an activity, embedded in the ongoing flow of actions.

Having uncovered the generation of human language, let us move to the level of its day-to-day use. Maturana (1988) has developed an elegant description of languaging around the concept of a conversation—that is, an ongoing coordination of actions in language among a group of structurally coupled observers. For the individual, such a conversation is actually a meshing or braiding of language and mood (or emotion). The linkage between these distinct domains occurs because they are both embodied in the body of the observer. Although often ignored in discussions of language and meaning, in real conversations our mood or "emotioning" is an ever-present background to our use of language. It conditions our stance or attitude—Are we happy or sad, caring or self-concerned, deferential or confident, angry or upset?—and thereby the course of our conversation. In turn, what we say, and what is said, may trigger in us changes of mood. For Maturana a conversation is an inextricable linking of language, emotion, and body in which the nervous system is the medium in which all intersect.

As Winograd and Flores (1987) have recognized, this view is strikingly similar to the phenomenology of Heidegger (1962). He, too, argues that in relating to the world, in existing in the world, our basic attitude is always a practical one of doing, acting, having some aim in mind. Our consciousness (although we may not generally *be conscious of this*) is characterized by our *state of mind* or mood and by our *understanding* of our situation which may be articulated in language. Generally, we are immersed in our daily tasks and *do not notice* most of the world as such. In using language within a conversation, we bring out particular objects and highlight particular properties in the light of our concern at the time.

> Communication is never anything like a conveying of experiences, such as opinions or wishes, from the interior of one subject into the interior of another. Dasein-with [the process of being with others—J.M.] is already essentially manifest in a co-state-of-mind and a co-understanding. (Heidegger, 1962, p. 205)

It is important to note that the driving force behind these developments is the their evolutionary advantage through enabling cooperative and coordinated activity. Thus language itself is ultimately rooted in cooperative practical activity, and its effects, rather than the abstract exchange of meaning and ideas. It also emphasizes that language is itself an activity and of course is not restricted to verbal actions alone.

It is interesting to compare this with Habermas's analysis of language. For Habermas, too, language is a practical activity which arises out of the need for the social coordination of action. This has important consequences for the underlying nature of language, namely, that for utterances to be practically successful, they make, at least implicitly, certain claims as to their validity. Over and above being *comprehensible*, they must be *true* in their description of the external world, *right* according to the norms of the social world, and *truthful* in their expression of the subjective world of the speaker. Habermas, although accepting the intersubjective nature of language, remains wedded to the denotative view of language and communication.

5. APPLICATIONS OF THE COGNITIVE THEORIES

In this section I examine briefly the practical importance of Maturana's cognitive ideas by describing some of the diverse areas in which they are being applied. In particular, I consider impacts within psychotherapy, the implications for computer systems design, and an autopoietic view of the Law. In exploring these applications somewhat uncritically, I do not wish to suggest either that I fully endorse them or that they are not the subject of much debate in their respective domains.

5.1. Psychotherapy

Psychoanalysis and psychotherapy include myriad different approaches, one of which is family therapy. The latter is characterized by therapists who work with families rather than individuals, seeing the symptoms manifested by the individual as being related to the interactions of the family as a system. This approach stems from a basic systems perspective and has developed to reflect changes within the systems movement itself.

Early work (e.g., Jackson, 1957) was based on first-order cybernetics, viewing the family as a self-stabilizing system using ideas such as feedback and homeostasis. The root metaphor saw the family as a smoothly functioning machine and the therapist as a "mechanic" able to repair such systems (Hoffman, 1988).

A major shift occurred during the 1970s based on the work of Gregory Bateson (1973, 1979), who can be seen as forming a bridge between the objectivism of first-order cybernetics and the constructivism of Maturana's second-order cybernetics. First, Bateson emphasized the importance of circular and reciprocal chains of mutual causality rather than the linear thinking such as A causes B. The family was therefore seen as a system of symmetrical and complementary behaviors and interactions, and notions such as hierarchy, power, and control were abandoned. Second, there was a shift away from the metaphors of energy and matter toward information, context, and meaning. Meaning was no longer objectively given, but transformed and modified by context and transmission. Sequences of interactions were repetitive and circular and could be split up or punctuated in different ways. This pointed to the importance of the therapist as punctuator and definer of reality, as part of the system rather than an independent objective observer.

This approach was most formalized in what is known as the Milan method developed by Palazzoli, Boscolo, Cecchin, and Prata (Campbell and Draper, 1985). This can be described by three terms—*hypothesizing*, *circularity*, and *neutrality*. Systemic hypotheses are generated by the therapists involving circular relations among all family members. These are then investigated by questioning individuals about the differences and relationships between other family members. The therapist strives to remain neutral—that is, not siding with any individual in the family.

This Batesonian approach is itself now being superseded by the more radical ideas of Maturana and Varela, under the rubric of a "constructivist" or "bringing-forth" paradigm (Kenny and Gardner, 1988; Goolishian and Winderman, 1988; Hoffman, 1988, 1990; Mendez *et al.*, 1988; Varela, 1989). The approach is now strongly subjectivist in the sense that there can be no objectively correct outside description of the family's reality. The family and its members construct, through their linguistic interactions and conversations, the reality that they experience. All such realities are equally valid, although not necessarily equally desirable, and there can be no outside privileged viewpoint. The essential unit of analysis is the conversation (in Maturana's sense of ongoing *activity*) and families are constituted by a network of recurrent conversations within the consensual linguistic domain generated by their members. Such an organization is structure determined and will react to perturbations in an autonomous manner. Families come for help when the realities produced by their particular conversations are unpleasant or distressing. This is because, Maturana argues (Mendez *et al.*, 1988), many conversations attempt to impose one person's characterizations and expectations on another rather than accepting the different worlds that we individually bring forth.

The role of therapy and the therapist is now very different. Change cannot be imposed or taught from the outside since the family is structure determined; it can occur only when the structures of the individual members change so that they can no longer realize the same conversations. To do this the therapist must become part of the ongoing conversation of the family and discover the recurrent pattern of actions which characterize it. Then the therapist must interact with the individuals in ways that do not involve or confirm this pattern in order to try to generate structural changes which will lead to the disintegration of the previous family identity and the enactment of a new one.

5.2. Computer Systems Design

Maturana's theories have been imported into computer systems through the work of Winograd and Flores (1987). In this excellent book they assimilate the phenomenology and hermeneutics of Heidegger and Gadamer, Searle's theory of speech acts, and Maturana's cognitive theories to produce a critique of the traditional objectivist, rationalist approach to computer systems design and artificial intelligence (AI). In its place, they suggest an approach based on conversations and commitments.

The main outlines are as follows. First, cognition and thought is not an isolated, separate mental function but our normal everyday activity—our "being in the world." It is embodied in the patterns of behavior which are triggered by our interactions and which have developed through our structural coupling. "Thinking" is not detached reflection but part of our basic attitude to the world—one of continual purposeful action. Second, knowledge does not consist of representations, in individuals' heads, of objective independent entities. Rather, we make distinctions through our language in the course of our interactions with others, continually structuring and restructuring the world as we coordinate our purposeful activities. Third, that which is said does not occur de novo but is grounded in our past experiences and tradition—the history of our structural couplings.

Fourth, the most important dimension of our actions as humans is language, but we must change or view of language away from seeing it as representational and denotative toward seeing it as (social) action through which we coordinate our activity. Languaging takes place in conversations which become the central unit of analysis. Such conversations are networks of distinctions, requests, and commitments, valid with respect to their acceptance by others rather than their correspondence to an external reality.

Finally, the view of "problems" which computers can help "solve" must change. Problems are not objective features of the world, but the result of breakdowns within our structural coupling to objects or to others. When our activities do not succeed or our coordinations fail, our routine operation is disrupted and a "problem" occurs. This is always against a particular background, for a particular individual or group and the nature of the problem become defined only through the attempts to repair it.

These ideas lead to a distinctive view both about the development of information systems in organizations and about the nature of computers and AI. Organizations are seen as networks of recurrent and recursive conversations between individuals and groups of individuals (cf. the family above). The conversations consist of speech acts involving mainly requests, promises, commitments, and declarations coordinating general activities and the conversations themselves. Information systems should be designed to be part of and facilitate this communicative and coordinating process. They must be open and flexible, reflecting the changing distinctions and conversations generated within a domain rather than imposing an external and unchanging straitjacket.

Equally, Winograd and Flores suggest that the whole objectivist thrust of computing/AI is misdirected. Developing systems to do more and more complex calculations or better process chunks of reified "information" or "knowledge'' will not lead to more human-like cognitive abilities. For this, one would need something radically different—a system, capable of significant structural change, which was able to develop its own readinesses and distinctions through a history of interactions in a domain which was of significance for its own operation.

5.3. The Law

In both the domains described above, the emphasis was on the cognition and behavior of the people involved in a situation, but the application of autopoiesis to the law has quite a different focus—the law as an abstract, yet real system quite separate from legal actors. It has developed largely through the application of autopoiesis to the social world (Luhmann, 1986, 1987a,b; Teubner, 1987, 1990).

In essence, the approach is to take the original definition of autopoiesis as a system of self-production and apply the model, with certain necessary changes, to the legal system. The central question is, therefore, Of what does such an autopoietic legal system consist? What are the elements and components which both produce and are produced by themselves in a circular process of self-production? The answer that Luhmann proposes follows from his earlier work on social systems.

These he characterizes as composed essentially of *communications*—that is, events that involve a combination of utterances, information, and understanding (Luhmann, 1986). A social system is a recursive reproduction of such communications. The legal system is a subsystem of society and shares in its constitution. It therefore consists of a recursive reproduction of *legal communicative acts*, that is, legally valid communicative acts which in some way have legal consequences. Such acts change or develop the legal structure of expectations and thereby bring forth further legal acts. What is to count as a legal act is of course determined purely by the legal system, thus creating the autonomy and closure typical of autopoietic systems.

Such a system is quite different both from a traditionally defined legal system and from physical autopoietic systems. Compared with the former, it is defined purely in terms of communicative acts and therefore excludes people—judges, juries, barristers, criminals; organizations—the courts, legislatures, prisons; and even laws and statutes. All of these are part of the environment of the system. In contrast with the latter, it consists of the production of events rather than physical things. In a cell, for example, chemicals are produced, exist for a duration, and then participate in further production. The same chemicals are constantly reproduced. Events, however, are produced at a point in time—they have a duration but only that of their actual occurrence. They do not exist after their occurrence. When completed, their very absence calls for another event or else the system will no longer exist. Moreover, the next event cannot be a repetition of the first, but must be a different event.

Legal acts involve expectations, in particular, expectations about right and wrong as defined purely in terms of legal norms (i.e., legal/illegal). Luhmann suggests that these expectations have two dimensions—normative and cognitive. Cognitively, expectations generally refer to events outside the system, and if they turn out to be wrong, they need to be changed. Normatively, expectations are within the system; they are defined by the system and can be changed only by it. So, for example, it is expected that people will pay taxes. If a particular person is found not paying taxes, the cognitive expectation will be incorrect and will change, but the normative expectation that it is right to pay taxes will not change. The normative expectation can be changed only by a legal communication within the system. The system is therefore normatively closed but cognitively open.

There are important consequences of this characterization. First, the legal system is radically autonomous. It defines what are legal acts and all legal acts must be part of the system—"only the law can make law" (Kennealy, 1987). This is an unusual conception of autonomy. Usually autonomy of law would be seen as a relative concept concerned with the extent to which the legal system was open to pressure from other sections of society. For an autopoietic legal system, however, autonomy is complete and the question of the causal origin of change does not occur. The system is in a continual state of change defined by its own structure in compensation for disturbances in its environment.

Second, this autonomy implies significant closure with respect to its environment. Changes in the legal system will be determined by its own structure, not by some outside agency, and so it is not possible to control the system in a purposeful way. Its reaction to perturbations may well be unpredictable. Also, the system itself determines what it can and cannot interact with or be triggered by. The observer may see the legal system within a complex environment of economic, political, and social systems, but the autopoietic legal system defines a much smaller niche of possible interactions—those communicative acts which are legal and yet exist in other systems, e.g., the payment of a fine. The legal system (and other autopoietic systems) defines its own reality.

A number of problems with this approach can also be identified, although they cannot be discussed fully here. First, is the translation of autopoiesis from the physical domain sound? Can we properly talk of the production of events by events? Could we map out a network of particular events and processes constituting a particular legal system in the same way that we can map out the cell? What about the boundary? There is no equivalent to the boundary of a cell here, just a distinction between legal and nonlegal communications. Second, how can we explain the history of change of the legal system? How can it be both autonomous and constrained by society? How can we explain the coevolution of the legal and other systems? (Teubner, 1987; Kennealy, 1987; Heller, 1987). It seems to me that this is much less of a problem. Maturana's more recent ideas on structural coupling between systems and coontogenetic drift (Maturana and Varela 1987), not referred to by the legal theorists, addresses precisely these questions.

6. CONCLUSION

Maturana has constructed a comprehensive and consistent explanation of living and cognizing organisms from the basic processes of the cell to the complexities of language and self-consciousness. In so doing he generates a radical view of cognition in which the world we experience is a subject-dependent creation constrained only by our basic autopoiesis and our structural couplings. Language is seen as a domain of essentially arbitrary and consensual distinctions developed through a history of mutual coordinations of action. It does not and cannot describe an independent and objective world. We construct the objects of our discourse in our discourse. This leads to a view of the social world as constituted by recurrent conversations—interactions between structurally coupled organisms intertwining language, emotion, and the body in diverse but equally valid domains or, indeed, realities.

This weltanschauung has been picked up within discourses such as family therapy, the law, and computer design. Family therapy and computer design are particularly close to Maturana's recent work seeing the family and organizations, respectively, as networks of recurrent, self-defined conversations which create the reality experienced by their members. Work with the law draws more heavily on the basic concept of autopoiesis but again emphasizes the closed, self-defining, nature of the resulting system.

This paper has been largely expository and uncritical, but in reality the work is highly contentious and should be seen as challenging and stimulating. There are many open questions worthy of further research. Are there other domains where the ideas may be applied such as accounting or organizational theory? Is it legitimate to transfer the concept of physical autopoiesis to non-physical systems? Are organizations and societies autopoietic or merely organizationally closed? It is best seen as a metaphor rather than reality? Is Maturana's epistemology—that we have no access to an independent world so should suspend claims concerning objectivity—justified or should we work with the belief that there is an independent if unknowable reality? Does the concentration on individual or group constructions ignore wider constraints such as power and structural inequalities based on class, sex, and race? Hopefully questions such as these will, in time, find answers.

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