The Logic of Maturana's Biology

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> Context • Maturana's work is not easy to follow. Correct and full understanding of his work has still to be achieved in spite of its importance. **> Problem** • The objective of this paper is to investigate the core logic penetrating Maturana's wide-ranging work and to place his work in the history of western thought. **> Method** • Through intensive reading of his wide-ranging work, I intended to grasp the core biological structure that he advocates, namely, his core logic. **> Results** • Maturana's biology is the biology of structural determinism. It is embodied in a composite entity called a "structure-determined system" with two non-intersecting domains – the domain of interactions and the domain of the composition of components – which can be called the core structure or the core logic of his biology. From the perspective of the history of western thought, Aristotle and Schopenhauer can be regarded as good candidates as the precursors of Maturana's work, and his work can be characterized as an advanced form of Aristotle's hylomorphism, depicted on the horizon of Schopenhauer's world of "Vorstellung" (bringing-forth). **> Implications** • This finding will be useful for understanding Maturana's wide-ranging work and its place in the history of western thought. **> Key words** • Maturana, structural determinism, structure-determined system, non-intersecting, Aristotle, Schopenhauer.

Introduction

The objective of this paper is to investigate the core logic penetrating Maturana's wide-ranging work and place his work in the history of western thought. His work has attracted me for various reasons; the major reasons are: (1) the diversity of his work, (2) the difficulty of comprehending it, and (3) its originality in the history of western thought.

Diversity of Maturana's work

Maturana's work covers a diversity of areas, from chemical molecules, living systems, society, and the biosphere, to the cosmos, or from perception, knowing, language, culture, and education, to human relations and ethics, or from epistemology to ontology. He is a biologist, not a linguist, nor a sociologist, nor a philosopher. My question has been how he, as a biologist, could refer to such a diversity of areas. What made it possible for him to do so? What motivated him to do so? If the core logic that he applied to various areas of his work could be found, it would facilitate correct and coherent understanding of his wide-ranging work.

Difficulty in comprehension

His work is not easy to follow, as many readers have complained (e.g., Glasersfeld 1991; Mingers 1995; Kenny 2007). On the other hand, he too complained about "the frequent mistake of using autopoiesis as an explanatory principle" (Maturana 2002: 34). Why is it so difficult to comprehend correctly what he meant in his work? Maturana himself (1985: 311) said that "it requires a conceptual jump." If this means that there is not a common conceptual framework shared between Maturana and his readers, in other words, if there is a conceptual gap between Maturana and them, what should we do to fill that gap? To find out, it would be useful to find and understand his core logic.

Generally, to understand and appreciate someone's words is to have a vicarious experience of what he or she had in mind at the time that he or she expressed those words (Miura 1976: 27; Tokieda 2007: 46). In order to understand Maturana's work, the reader must have a vicarious experience of what he had in mind at the time that he wrote it. In Maturana's words, having a vicarious experience would mean that the author and his readers would have a common cognitive domain (a common domain of interactions). A fly walking on a painting by Rembrandt does not understand that it is walking on the painting made by Rembrandt, because the fly does not have a cognitive domain for the painting by Rembrandt (Maturana 1980a: 55).

On the other hand, from the side of a describer, in order to have a listener or a reader experience vicariously what he or she describes, two things must be taken into consideration: (1) the contents to be described, and (2) the relation of the describer to the contents. The former can be anything. What I mean by the latter is that the contents may be describer-independent or dependent. Usually we treat them as describer-independent and describe them objectively. This is the case with ordinary sciences. However, in the case of art creation, the relation between a novel writer and the characters in his or her novel, for example, is different from this. The characters, the contents of the novel writer, are dependent on him or her, that is, describer-dependent. This situation is more complicated than the former. It requires of the describer more complex and skillful ways of description, and requires the reader to participate more actively than in the former in order to have a vivid vicarious experience of what the characters and the describer do.

Maturana's contents are describer-dependent. He treats his contents, i.e., the objects of his description, as dependent on a describer, in other words, he treats them as dependent on the describer's biology, operation, consciousness, or subjectivity; generally as observer-dependent or as the objectivity *in parentheses* (Maturana's term "in parentheses" means "dependent on biology, subjectivity, observer et al.," as listed above. In contrast, the term "objectivity *without* parentheses" means "observer-independent

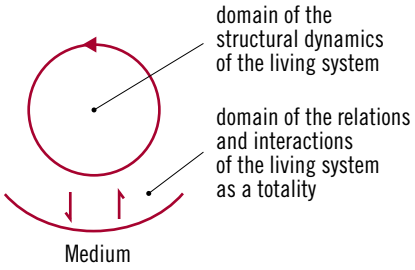

Figure 1: Maturana's core logic, a structure-determined system with two non-intersecting domains. (After Maturana (1995: 149. The original title is "Fig. 7. The organism and its behavior." The term "Medium" in the above figure is mine.)

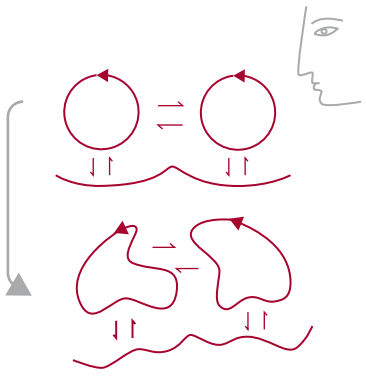

Figure 2: A historically-developed form of Maturana's core logic. This figure shows the observer on the upper right corner and his or her cognitive domain (domain of interactions). The observer, a structure-determined system, observes in his or her domain of interactions two organisms (structure-determined systems) interacting and transforming each other in a historical process, in which they also interact with the niche of the medium that is also a structure-determined system. (After Maturana (1995:155). The original title is "Fig. 10. When an observer sees two organisms in a flow of recurrent interaction that he or she can describe as consensual coordinations of consensual coordinations of behavior, those two organisms operate in language.)

objectivity" or simply "objectivity" in an ordinary sense.). This made his sentences very complicated and difficult to understand. For instance, he wrote: "A space is constituted in the praxis of living of the observer when he or she performed a distinction." (Maturana 1992: 67) By the phrase of "in the praxis of living of the observer" he reminds the reader of the condition of subjectivity, namely of the biological and subjective nature of the content, "a space" in this case. In order for the reader to have a vicarious experience of what Maturana wrote through reading his complicated sentences, it would be necessary to acquire the core logic that penetrates his wide-ranging work.

Core logic

Figure 1 depicts what I abstracted as Maturana's core logic, namely, his basic being, a structure-determined system with two non-intersecting domains. Although the two domains in the figure are named according to a particular case of the system, i.e., a living system, this scheme is generally applied to all the system. Later I will explain the architecture of the system in more detail.

Developed logic

Figure 2 shows a historically-developed form of his core logic. There, the observer, the two organisms, and the medium are all structure-determined systems. By putting the organisms and the medium into a historical process, Maturana develops his core logic of the structure-determined system, namely, he lets biological phenomena (for example, language) arise from them in the domain of interactions of the observer. Maturana's biology is the biology in which a structure-determined system (the observer) observes the operations of other structure-determined systems (the organisms and the medium in the case of Figure 2) in the historical processes.

These two figures are fundamental and very useful images for interpreting Maturana's sentences and making vivid vicarious experiences of them. It seems to me that they are the indispensable images that Maturana himself keeps in mind every time he writes his paper.

My assertion that Maturana's core logic consists in his basic being, the structure-determined system with two non-intersecting domains, can be supported by his statements. In his interview with Poerksen (Poerksen 2004: 62), Maturana said "I could only give up my views if the structural determinism of living systems were no longer in force." His structural determinism (which I will explain later) is embodied in his structure-determined system with two non-intersecting domains. He also said in the interview with Poerksen (Maturana & Poerksen 2004: 187) that "I would prefer to call myself a biologist who is trying very hard to keep two different domains separate: the domain of the internal dynamics of a system and the domain of the interactions of that system." These two domains are those given in Figure 1 above as the two non-intersecting domains of the structure-determined system.

From the perspective of the history of Western thought

Many philosophers, among others, Aristotle and Schopenhauer, helped me in my attempts to understand correctly Maturana's work. For Aristotle, his notions of substance (a basic being: matter (dynamis, potentiality), form (energeia, actuality at work; or entelecheia, actuality in in-goal-state), and their composite) and hylomorphism, and his method of science were all useful in understanding Maturana's work. Aristotle applied his notions of substance and hylomorphism to various areas of his study as Maturana applied his own core logic to his wide-ranging work. As I explain later, Maturana's basic being, a structure-determined system, can be said to be an advanced or expanded form of Aristotle's hylomorphism, which says that "ordinary physical objects are complexes of matter and form" (Shields 2007: 57).

As for Schopenhauer, I learned much from his doctoral thesis *Ueber die vierfache Wurzel des Satzes vom zureichenden Grunde – Eine philosophische Abhandlung*" (Schopenhauer 1997). His well-known book *Die Welt als Wille und Vorstellung* (1966) was based on this dissertation. His "world of Vorstellung"[1] is the same as Maturana's domain of interactions (domain of cognition) of the observer and his "immediate object"

1| The word "Vorstellung" can be translated as "presentation," "bringing-forth," or "representation" according to the context. I choose "bringing-forth" in this paper.

(the object not-mediated via Vorstellung, that is, our body) corresponds to Maturana's domain of composition of components of the observer (domain of structural dynamics in Figure 2), and hence, Schopenhauer's system of philosophy can be taken as a kind of hylomorphism (Imoto *in press*).

Schopenhauer says about the distinction between ordinary sciences and philosophy (Schopenhauer 1966 Volume 2: 5) that the former assumes the objective world as positively and actually existing, but for the latter, consciousness alone is immediately given, hence the basis of philosophy should be limited to the facts of consciousness. Maturana's biology is an observer-dependent or subject-dependent science, or more strictly the science that is dependent on the subject's consciousness, as suggested before. His biology is the science that is limited to the facts of consciousness, that is, the facts of experiences. Maturana actually says (Maturana & Poerksen 2004: 196; see also Maturana 1973) that "science is not a domain of objective knowledge but a domain of subject-dependent knowledge, defined and determined by a methodology." According to the criterion of Schopenhauer, Maturana's biology is philosophy, or, if anything, an extraordinary science.

Thus, from the perspective of the history of western thought, Aristotle and Schopenhauer can be regarded as good candidates as the precursors of Maturana's work. It may be possible to say that his work can be characterized as an advanced form of Aristotle's hylomorphism, depicted on the horizon of Schopenhauer's world of Vorstellung (bringing-forth). The similarity, however, does not deny Maturana's originality, which I will explain below.

Maturana's research career

Maturana's research career can be roughly divided into three periods: the first from 1954 to 1960, the second from 1960 to 1970, and the third after 1970. The work in the third stage contains a diversity of work as mentioned above. The work in the first stage was in neuro-anatomical and -physiological studies in vision. His papers were published in such popular and prestigious science journals as *Nature* and *Science*. They were ordinary scientific papers written in the attitude of objectivity, so they are not difficult to read and understand if readers have objective knowledge proper to those areas. But this is not the case with his work in the third stage. The papers from this stage were not published in well-known science journals. The reason is clear: such journals only deal with papers written objectively and subject-independently. During the second stage he transformed himself from an ordinary biologist to an extraordinary one. His worldview, ontology, and epistemology changed from the ordinary commonsensical framework to one that could be thought of as extraordinary by almost all contemporary biologists or natural scientists in general, and even by some external-realist philosophers.

Shifts in ontology and epistemology

In ontology, he changed his worldview from the commonsensical external-realist framework to the internal-realist one, or from the view "from without" to the view "from within," as mentioned above in relation to Schopenhauer. It could be said that he became a self-conscious biologist instead of an object-conscious one. In relation to his 1970 paper "Biology of cognition," he expressed his transformation as follows:

> "In a sense [the paper] has been my way to transcendental experience: to the discovery that matter, metaphorically speaking, is the creation of the spirit (the mode of existence of the observer in a domain of discourse), and that the spirit is the creation of the matter it creates. This is not a paradox, but it is the expression of our existence in a domain of cognition in which the content of cognition is cognition itself. Beyond that nothing can be said." (Maturana 1980b: xviii)

The matter is the creation of the spirit, the spirit is the creation of the matter that the spirit creates, and the content of cognition is cognition itself; beyond that nothing can be said – this all is an explicit expression of the facts of consciousness as I referred to in relation to Schopenhauer. Ontologically Maturana became an internal realist instead of an external one.

Remarkable in Maturana is his transformation in epistemology, theory of knowledge. It turned out to arise as the change in his way of explanation. He changed the way of explaining from his and our long-accustomed causal and reductionist methods to his new method of explanation that uses what he calls a "generative mechanism," which would give rise to the phenomena to be explained through its operation. This is the place where his "conceptual jump" that I noted above occurred, and this change was the main reason why I found it difficult to follow and understand his work from the third stage. This epistemological change of Maturana's is related to his distinction of the two non-intersecting domains of the structure-determined system, which I will discuss again.

The change in ontology from the external-realist view to the internal-realist one is not so difficult to attain. Even I, a veterinary physician and pathologist, could reach the internal realist view through my own study of perception (Imoto 2004). But the idea of the change in the way of explanation did not explicitly come upon me, which must have also been the case with other scientists and philosophers. Maturana derived his new epistemology from his basic being, the structure-determined system, especially from the non-intersectional nature of its two domains. This is the reason why he puts particular emphasis on the non-intersectional nature of these domains, as shown in the interview with Poerksen that was cited before.

Aristotle's substance

In order to understand Maturana's basic being, the structure-determined system with two non-intersecting domains, it is useful to compare it with Aristotle's basic being, substance, particularly in the case of the living system.

In his *De Anima (On the Soul)* Aristotle says the following about substance:

> "We say that substance is one kind of what is, and that in several senses: 1) in the sense of matter […], and 2) in the sense of form or essence […], and 3) thirdly in the sense of that which is compounded of both. Now matter is potentiality, form

Figure 3: Aristotle's composite substance.

actuality [entelecheia, the being in in-goal-state] […]. Among substances are by general consent reckoned bodies [things] and especially natural bodies; for they are the principles of all other bodies. Of natural bodies some have life in them, others not; […]. It follows that every natural bodies which has life in it is a substance in the sense of a composite. Now given that there are bodies of such and such a kind, viz. having life, the soul cannot be a body; for the body is the subject [substratum] or matter, not what is attributed to the soul. Hence, the soul must be a substance in the sense of the form of a natural body having life potentially within it. But substance is actuality, and thus soul is the actuality of a body as above characterized." (*De Anima*, II-1, 412a6–22; notes in brackets are mine)

In short, for Aristotle, a living system is a composite of matter and form, or of potentiality and actuality (as entelecheia), and the soul is the entelecheia as the principle of life. This situation is represented by the following figure.

In Figure 3, the circle is the form of a living system with the arrow head indicating the soul's living actuality, including the matter inside the circle. This figure does not include the domain of interactions and the medium, compared with Figure 1 for Maturana's basic being. Indeed, according to Shields (2007: 84), Aristotle resists the suggestion that organisms derive their ends from the larger environment in which they find themselves; and as the soul is the form and the entelecheia as the principle of life, and the word "entelecheia" means "en telos" (the in-goal-state), thus, for the organism, its formal and final and even efficient causes are one and the same, or at least co-incide, which suggests that the level of the organism is itself the right place to stop. For Aristotle, the domain of interactions and the medium are not necessary to define the living system, according to his teleological worldview. This gives a great difference between Aristotle's and Maturana's basic beings.

Having said that, how does Aristotle's substance work in the medium? Aristotle's term "form" has two modes of existence; one is "energeia," the other "entelecheia." (De Anima II-5: 417a10–417b9) Energeia is the mode of being at work. So, even if Aristotle did not mention the domain of interaction, the substance at work in the mode of energeia should be regarded as being in the domain of interactions.

Maturana's structure-determined system with two non-intersecting domains

The notion of the "domain"

In advance of explaining the structure-determined system, the term "domain" should be explicated. As far as I know, there is no direct definition of the term "domain" by Maturana himself. But, the following quote is enough to define it.

"A space is constituted in the praxis of living of the observer when he or she performs a distinction. The constitution of a space brings forth a phenomenal domain as the domain of distinctions of the relations and interactions of the unities that the observer distinguishes as populating that space." (Maturana 1992: 67)

From this quote, the "domain" is defined as a part of the space constituted with the relations and interactions of unities or their components that are brought forth by the distinction of the observer. (Note here that for Maturana relations themselves can be treated as unities.)

Maturana's structure-determined system

Maturana explains the structure-determined system as follows:

"A system is a composite entity that exists simultaneously both as (*a*) a collection of components interconnected in a way such that if one acts on one of them one acts on all, and (*b*) as a singular entity that operates as a whole in a medium or domain of interactions that contains it and makes possible its operation or existence as a totality. These two manners of existence or of operation of a system cannot be reduced one to the other; they occur in two non-intersecting phenomenal or operational domains. This double existence is a condition of constitution of systems in general, regardless of the nature of their components or the nature of the domain in which they exist as totalities." (Maturana 2005: 82; emphasis in the original)

In Figure 1, the domain *(a)* in the above quote is called the domain of the structural dynamics of the living system, and the domain *(b)* the domain of the relations and interactions of the living system as a totality, applied to a particular case, i.e., the living system. This distinction of the two domains, however, is applicable to all systems as such.

Each domain of the system is variously named according to the contexts to be explained. The domain represented by the arrow-headed circle in Figure 1 is called the domain of composition of components, of components, of internal dynamics, of structural dynamics, or the domain of anatomy and physiology, according to the kinds of context. I will use the term "domain of composition of components" or simply "domain of composition" in this paper. The domain represented by the reciprocal arrows in Figure 1 is also called variously, for example, the domain of interactions, behavior, actions, doings, or existence. I will use "domain of interactions" here. The term "niche" points to the same domain as the domain of interactions when it is seen from the side of the medium (Maturana 1970: 10) or it can be said that the niche is the domain of interactions of the medium seen as a structure-determined system.

In contrast to Aristotle's composite basic being (Figure 3), Maturana's positing of the domain of interactions is noteworthy. He says that "an entity is an entity if it has a domain of interactions" (Maturana 1970: 8) and treats a system as a unit of interactions (ibid.). By doing this, he included the domain of interactions into the system, or in other words, he internalized the niche and hence the medium. Thus, he enlarged the boundary of Aristotle's hylomorphic being, and, hence, expanded the notion of hylomorphism. His core logic became an advanced form of Aristotle's hylomorphism.

By internalizing the domain of interactions, he also established the seat for the mind of the observer. Because the observer observing is an observer of his or her domain of interactions (Maturana 1970: 8), his or her mind or consciousness consists in his or her domain of interactions. Thus Maturana says that "the mind is not in the head, the mind is in the behavior" (Maturana 1985: 311), namely in the domain of interactions. This domain is tantamount to Schopenhauer's world of Vorstellung (bringing-forth) as mentioned before.

The organism as a structure-determined system has two modes of operations in totality in the domain of interactions or in the domain of sensory-effector correlations when it has a nervous system: the first-order description and the second-order description (Maturana 1970: 27–28), which I call horizontal and vertical coordinations, respectively (Imoto *in press*). Horizontal coordinations are the interactions of the organism with its medium; vertical coordinations are the interactions with its own internal states that are originally derived from the horizontal coordinations and then recursively coordinated through the nervous system as if they were another independent domain of interactions. The vertical recursive mode of coordinations is prominently developed in human beings due to the corresponding development of the nervous system, through which the nervous system of the human being becomes a "languaging brain" that makes possible our thinking and monologue.

Now we have all the tools necessary to correctly understand and interpret Maturana's wide-ranging work: the observer, the structure-determined system with its two non-intersecting domains, two modes of operations, history (time, historical processes), and the medium (space), as shown in Figure 2.

Structural determinism

Structural determinism is Maturana's most important tenet, as he said, "I could only give up if the structural determinism of living systems were no longer in force." (Poerksen 2004: 62). The structural determinism is explained based on his core logic, the architecture of the structure-determined system with two non-intersecting domains.

Thus his structural determinism says that "all that takes place *in* it [the system], or happens *to* it at any instant, is determined by its structure at that instant." (Italics are mine; Maturana 2002: 15)

The prepositions "in" and "to"

When we read this sentence about structural determinism, it is important, at first, to take note of the use of the prepositions "in" and "to." The preposition "in" in "in it" points to the domain of composition, and the preposition "to" in "to it" to the domain of interactions. Although Maturana has never spoken in any of his works about this subtle distinction between "in" and "to" when he defines structural determinism, it is a very important distinction because each of these prepositions points to a different domain of the structure-determined system. Sometimes he uses "with," such as "a structure determined system – that is, a system in which all that happens *with* it and *to* it is determined at every instant by the way it is made (its structure) at that instant" (Maturana 2002: 5–6), or "we, as living systems, are structure-determined systems, and all that happens *in* us or *with* us is determined in our structure and in our structural dynamics (Maturana 2007:109). As these examples show, the meaning of the preposition "with" sounds ambiguous; it can be taken as connoting the meaning of "in" on the one hand, and that of "to" on the other hand.

The meaning of structural determinism

In relation to the above explanation of "structural determinism," he usually adds the comment that "nothing external to the system can specify what happens in it, but only triggers a change in its structure, determined by its structure" (Maturana 2000: 461). These explanations of structural determinism can be rephrased by taking into consideration the distinction of the two domains, as follows: all that takes place in the domain of composition, or all that happens to the domain of interactions, at any instant, is determined by the domain of composition at that instant, and the changes (or external things) that happen in the domain of interactions trigger changes in the domain of composition, determined by the domain of composition. This speaks about the determinate nature of the domain of composition over the domain of interactions and, at the same time, about the indeterminate or modulatory nature of the domain of interactions over the domain of composition.

In relation to this point, Karl Marx's insight into the relation between production and consumption is very illuminating. In *The Grundrisse*, he wrote:

> "With a single subject, production and consumption appear as moments of a single act. The important thing to emphasize here is only that, whether production and consumption are viewed as the activity of one or of many individuals, they appear in any case as moments of one process, in which production is the real point of departure and hence also the predominant moment. Consumption as urgency, as need, is itself an intrinsic moment of productive activity." (Marx 1978: 231)

In this quote, "a single subject" is comparable to the structure-determined system, "production" to the domain of composition, and "consumption" to the domain of interactions. Production and consumption are the two moments of one process of a single subject, and the former, as the real point of departure, is a predominant moment over the latter. This relation is just the same as described above for the relation between the two domains of the structure-determined system.

Thus the relation that Maturana calls "non-intersecting" between the two domains of the structure-determined system is explained like this: both domains are relatively independent of each other and nonetheless inseparable, with the primacy of the domain of composition over the domain of interactions. The mode of existence of each domain is different, hence, non-intersecting.

Applications of Maturana's core logic in his work

He applies his core logic (Figure 1), together with its developed one including horizontal and vertical coordinations (Figure 2), to a diversity of areas, with the awareness that he himself is a structure-de-

termined system with two non-intersecting domains.

When it is applied to the living system, the notions of autopoiesis, structural coupling, organization and structure, simple and composite unities, conservations of organization and adaptation, natural drift and linage formation, the biosphere, and the cosmos, are all made possible. When it is applied to human beings, it makes it possible for him to explain the phenomena of distinction, perception and cognition, language, emotion, self-consciousness, culture, society, ethics, the origin of humanness, and so forth. He also applies his core logic to the way of explanation, and even to the writing style of his papers

Why did he cover such diversity of subject-matters? What motivated him to do so? The answer should be this: he became an extraordinary scientist in the sense of Schopenhauer's criterion noted above. He was transformed from an objective, external-realist scientist into a subjective, internal-realist one. Since almost all our knowledge so far has been made by objective, external-realist people as objective knowledge, it would be natural that he was driven to re-write all objective modes of our knowledge from his new worldview of subjectivity or objectivity in parentheses. The book *The Tree of Knowledge* is the fruit of such his efforts as an internal-realist scientist. In the preface of that book, he wrote: "It is a complete outline for an alternative view of the biological roots of understanding." (Maturana & Varela 1992: 11)

Maturana's method of explanation

Since there is little room here to discuss every aspect of his wide-ranging subject matters, I will take one topic, his method of explanation, which is the expression of his newly acquired epistemology as mentioned above. For Maturana, a pair notion of question and answer, or explanandum and explanans, makes a unity or a whole, namely, a structure-determined system with two non-intersecting domains. Indeed, he says that "*the notion of structural determinism is at the same time the conceptual and the operational fundament of all explanations*." (Maturana 2002: 20. italics in original) Questions lie in the domain of interactions, and answers in the domain of composition of components. Questions or phenomena to be explained are the properties observed in the domain of interactions, and answers or generative mechanisms are the organizations in the domain of composition of components.

With regard to his distinction above, there are two important statements in his 1970 work, "The biology of cognition."

1. "A cognitive system is a system whose organization defines a domain of interactions" (Maturana 1970: 13). This statement is another expression of his structural determinism. 2. "The great hindrance in the understanding of the living organization lies in the impossibility of accounting for it by the enumeration of its properties; it must be understood as a unity" (Maturana 1970: 5). This statement speaks of his need for the organization that lies in the domain of composition in the unity as a structure-determined system. Thus he turned himself to create the notion of the living organization known now as the autopoietic organization.

Besides Aristotle and Schopenhauer, I learned much from Hegel, especially from his *Phenomenology of Spirit* and *Science of Logic*. In the Preface of the former book, Hegel wrote the two well-known statements: (1) "everything turns on grasping and expressing the True, not only as *Substance*, but equally as *Subject*," and (2) "The true is the whole. But the whole is nothing other than the essence consummating itself through its development" (Hegel 1977: 10–11). The first statement of Maturana in the immediately preceding paragraph sounded to me as if it reflects Hegel's first statement because the domain of interactions is the place where the subject is as the mind, as noted before. The second statement of Maturana in the same paragraph sounded to me as if it reflects Hegel's second statement because for Maturana the truth is in the whole developed in its historical process that is reflected in his core and developed logics mentioned before. Particularly, this second aspect is very important when we consider Maturana's "scientific explanation," which comprises four steps as follows:

> "1. The description of what an observer must do to experience the experience to be explained.
> 2. The proposition of a generative mechanism such that if it is allowed to operate the result would be that the observer experiences the experience that he or she wants to explain, presented in point 1.
> 3. The deduction from all the operational coherences implicit in point 2 of other possible experiences for the observer, as well as of what he or she should do to live them.
> 4. The realization of what has been deduced in point 3, and if it happens as deduced, point 2 becomes a scientific explanation." (Maturana 2002: 21)

Why does the observer need to proceed to points 3 and 4, instead of stopping at point 2 in Maturana's method of scientific explanation? It is because the experience or phenomenon to be explained found in point 1 is a particular or a species, and, on the other hand, the generative mechanism proposed at point 2 is related to the general or the genus. The phenomenon to be explained in point 1 is only one of all the phenomena that the generative mechanism would produce in its operation. The phenomenon observed at point 1 does not exhaust all possible phenomena. That is why the observer needs to proceed further to points 3 and 4 to try to list and exhaust all possibilities and make a presumptively-general mechanism at point 2 a truly-general one. As quoted above from Hegel, "The true is the whole."

The following quote illustrates well the "particular-general issue" of Maturana's method of scientific explanation.

> "The question, 'What is a social system?' cannot be answered by simply describing a particular one because we do not know the significant relations that we must abstract when characterizing its organization. The question must be answered by proposing a system which, if allowed to operate, would generate a phenomenal domain indistinguishable from the phenomenal domain proper to a natural social system." (Maturana 1980b: xxiv)

By describing or listing the properties of one particular social system we do not know what the social system in general is. Instead, we should abstract significant relations as a generative mechanism to explain what the social system is. This is what Maturana said in the above quote. Note that this is the same method that was used for the understanding of the architecture of the living system.

In passing, then, what is the generative mechanism for the social system? For Mat-

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Seiichi Imoto has worked as a veterinarian (DVM, PhD) majoring in internal medicine and pathology since 1973. In 2000, he began to study philosophy, seeking for different ways of thinking. He was lucky enough to encounter Maturana's work but it was very difficult to follow; there was in it indeed a way of thinking that was very different from his long-accustomed scientific way of thinking.

urana (2002: 14), autopoiesis is possible only in the molecular domain, not in the supramolecular domain, i.e., the social system; therefore, social autopoiesis cannot explain what the social system is. Now he asserts that the significant relation for the social system is *love*, as a desire for an ethical coexistence with other beings in the social domain of interactions (Maturana & Verden-Zöller 2008: 7).

Emergent properties and Maturana's two non-intersecting domains

For Maturana, structural determinism that is embodied as a structure-determined system with two non-intersecting domains is a fundamental ground of his work, hence, his core logic, without which all his work will be demolished.

As noted before, Maturana, in his interview with Poerksen (Maturana & Poerksen 2004: 187), strongly emphasized the significance of the non-intersectional nature of the two domains of the structure-determined system. This may suggest, however, that there is controversy on this issue.

Maturana disagrees with the notion of *emergence* or *emergent properties*. According to O'Connor and Wong (2006), emergent properties are roughly characterized as follows:

> "emergent entities (properties or substances) 'arise' out of more fundamental entities and yet are 'novel' or 'irreducible' with respect to them. (For example, it is sometimes said that consciousness is an emergent property of the brain.)"

Maturana disagrees with this notion because "it obscures the fact that systems exist as composite in two non-intersecting operational (phenomenal) domains." (Maturana & Verden-Zöller 2008: 167) He has been toiling hard for years to elucidate the non-intersectional nature of the two domains of the structure-determined system by using the metaphor of the instrumental flight in absolute darkness (Maturana 1970: 51) or the concepts of simple and composite unities (Maturana 1992: 67), by contrasting the state of molecular autopoiesis with that of the organism in totality (Maturana 2002: 15), or through the arguments of double or triple look (Maturana & Poerksen 2004: 62 & 155).

In the section on "the meaning of structural determinism" in this paper I expressed the non-intersectional nature of the two domains as "relatively independent each other and nonetheless inseparable, with the primacy of the domain of composition over the domain of interactions." To put it concisely, "non-intersecting" is "inseparable but non-overlapping." It may be said further in a Hegelian dialectic sense that the domain of composition of components contains many contradictory oppositions, for example, metabolism and anabolism, and processes toward life and death, and they are all sublated into synthesis in the domain of interactions. The modes of existence of the domain of composition of components and that of the domain of interactions are different.

Recently he summarized his view of the system as "systemic laws" in Spanish (Dávila & Maturana 2008). Some of them can be found in his papers written in English. Regarding the non-intersecting nature of the two domains of existence of a system, he states as follows:

> "Systemic Law 3: 'The result of a process does not ever participate in its genesis.' We frequently forget this when we wish to see a purpose in a process, and we argue as if its result were an argument for its occurrence." (Maturana 2008: 84)

This systemic law says that the result of a process takes place in the domain of interactions, and the process of its genesis lies in the domain of composition of components, whose difference, Maturana complains, the notion of emergence obscures.

And at the same time, he warns us against teleological explanations, frequently caused by confusing the two domains or by ignoring the different modes of existence in the two domains.

How did Maturana arrive at the notion of the dual domains of existence?

How did Maturana arrive at the notion of the dual domains of existence of a system? Of course it came from his studies of the operations of the living system and the nervous system, particularly in the second stage of his research career. But how?

With respect to the operation of the living system, its features such as reproduction, heredity, growth, irritability, or our abilities such as thinking and reasoning, do not tell us what the invariant organization common to all living systems is, although we can recognize living systems as living when we encounter them.

> "In 1960 I asked myself 'What should happen in the manner of constitution of a system so that I see as a result of its operation a living system?' […] I was proposing that *the relation between the internal dynamics of the system and the result of that internal dynamics in the domain in which I observed it*, would tell me what the system was. *I had to create the system to know it*." (Maturana 2002: 5, my emphasis)

This quote shows why and how he created the system with two non-intersecting domains. When I, as a veterinary physician, diagnose a patient animal using some diagnostic name, I first examine the animal for symptoms with various diagnostic tools, and then select the most appropriate diagnostic name from among some differential diagnostic candidates. The mechanism of the disease so diagnosed is in the domain of internal dynamics, namely, in the domain of composition, and the symptoms from which my diagnosis is derived are in the domain of interactions. So I may say I had known of the existence of those two domains, but I treated them causally; I could not take them as non-intersecting.

Another factor that led Maturana to the insight into the non-intersectional nature of the two domains can be derived from his insight into the operational mode and functional organization of the nervous system. Similarly to the case of the living system, he considered that "enumeration of the transfer function of all nerve cells would leave us with a list, but not with a system capable of abstract thinking, description, and self-description." (Maturana 1970: 6) Then comes his idea that "only conduct itself can be considered as the functional unit of the nervous system." (Maturana 1970: 19) Through this idea, he could set the domain of sensory-effector correlations as the domain of interactions and the central nervous system as the domain of composition of components, which made it possible for him to explain humans' mental phenomena such as conceptual thinking, language, and self-consciousness.

Recent BCI technology

Although this finding about the nervous system was based on Maturana's own neuroanatomical and -physiological studies of vision (cf. Maturana, Uribe & Frenk 1968), it must have been a quite strange idea at the time in 1970. Even now it might be treated as strange, but recent BCI (brain-computer interface) or BMI (brain-machine interface) technologies (e.g., Serruya et al. 2002; Wu et al. 2004) have begun to prove the validity of Maturana's idea of the nervous system with two non-intersecting operational domains, and, hence, the validity of his idea of the living system with two non-intersecting domains of existence (Imoto *in press*), although Maturana's work is still not known among researchers in these fields.

In the tradition of hylomorphism

Hylomorphism is a middle way between the two extremes of materialism and idealism, and also different from dualism – Platonic or Cartesian (Shields 2007: 285 & 402). It deals with a hylomorphic (matter-form or body-mind) composite system as a composite. It does not treat matter and form or body and mind altogether separately. Maturana expanded Aristotle's traditional hylomorphism by including the domain of interactions in it, and recent BCI or BMI technologies can be regarded as included with Maturana's expanded hylomorphism. If researchers in those fields pay attention to Maturana's work on the structure-determined system with two non-intersecting domains, they will get a deeper insight into their technologies, and hence, the system in general.

Conclusion: "The power of the pharmacologist"

Maturana's biology is the biology of structural determinism. It is embodied in a composite entity that is called a structure-determined system with two non-intersecting domains: the domain of interactions and the domain of composition of components. This architecture of the structure-determined system can be called the core logic of Maturana's biology. Only through seeing and taking into consideration this logic of his biology will we be able to understand correctly the diversity of his work and overcome the difficulty that we feel when we read his work.

From the perspective of the history of western thought, Aristotle and Schopenhauer can be regarded as good candidates as the precursors of Maturana's work, and his work can be characterized as an advanced form of Aristotle's hylomorphism, depicted on the horizon of Schopenhauer's world of Vorstellung (bringing-forth).

Interestingly, in two papers Maturana wrote about the bioassay once used by pharmacologists (Maturana 1978, 1983). In the final section of his 1983 paper "What is it to see?" he wrote about "The power of the pharmacologist":

> "In those days one could distinguish and describe (that is, perceive) estrogens in the urine of a pregnant female [rabbit] with the changes of state of the ovaries of a rabbit, and one could characterize the properties of the ovaries of a rabbit (that is, know them) with the urine of a pregnant female." (Maturana 1983: 268)

The estrogens in the urine are the result of the molecular processes in the ovaries of the rabbit used as a biological probe. The former phenomenon (the estrogens in the urine) is in the domain of interactions of the rabbit, and the latter phenomenon in the ovaries of the rabbit in its domain of composition. They are non-intersecting. So, this can also be an example of the operation of a structure-determined system with two non-intersecting domains.

From this pharmacologist's standpoint, each of us turns out to be a molecular biological probe, namely, a molecular structure-determined system. Through the molecular changes of state in our domain of composition of components, we experience, in the domain of interactions, the world brought forth through the molecular changes in the former domain.

In this perspective, Maturana says that "living systems are components or participant elements of a systemic, structure-determined biosphere and cosmos (Maturana & Verden-Zöller 2008: 204). This is the reason why we can see and understand the biosphere and the cosmos as we see and understand them. Each of us is a molecular biological probe as a molecular structure-determined system, resonating with other molecular structure-determined systems, including other persons, as one of the molecular components of the cosmos.

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Received: 21 January 2011
Accepted: 24 June 2011