CYBERNETIC COUNTERCULTURES INTENSIVE

Week 3. Approaching Autopoiesis: Maturana and Varela

Reading Autopoiesis

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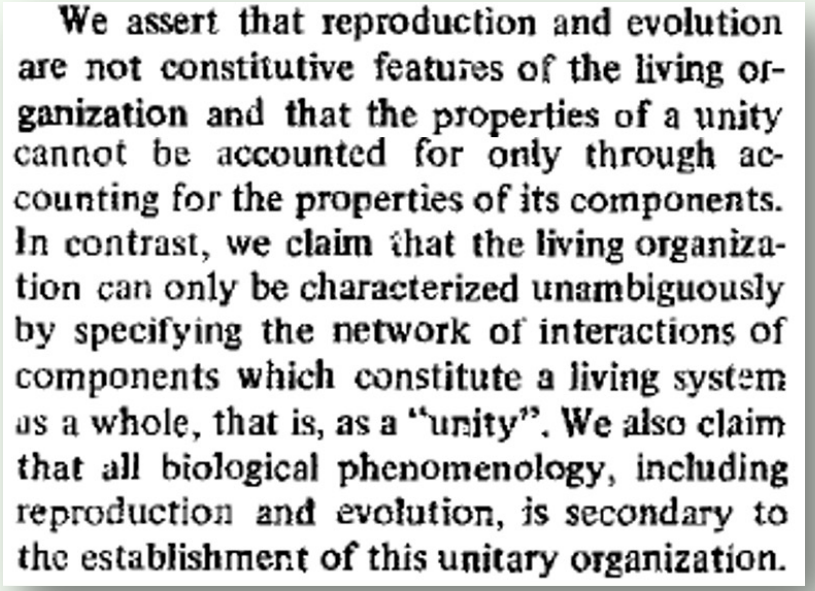
Preface: Why autopoiesis?

The theory of autopoiesis shifts biological thinking toward the *organization* of living systems in relation to their operational dynamics. It radically rethinks the concepts of *self-reference, autonomy, form*, and *cognition.* Its authors foregrounded the way that this line of approach to organismal *unity* was put forward as a necessary supplement to the mainstream programs of that 1970's moment—molecular genetics and bioinformatics in matters of reproduction, and the Modern Synthesis—the marriage of Darwinian natural selection and Mendelian heredity—in matters of evolution. The concept of autopoietic organization was an original application of the cybernetic treatment of form or pattern as independent of specific material realization.



We assert that reproduction and evolution are not constitutive features of the living organization and that the properties of a unity cannot be accounted for only through accounting for the properties of its components. In contrast, we claim that the living organization can only be characterized unambiguously by specifying the network of interactions of components which constitute a living system as a whole, that is, as a "unity". We also claim that all biological phenomenology, including reproduction and evolution, is secondary to the establishment of this unitary organization.

Francisco Varela, from "Preface to the Second Edition of *De Máquinas y Seres Vivos* - Autopoiesis: La organización de lo vivo" (1994; 2011).

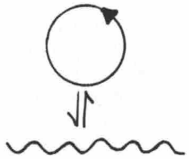
—In this passage, Varela is recollecting how the road to autopoiesis proper ran through Maturana's 1969 papers on organic cognition:

> . . . Humberto made the connection between the circular nature of neuronal processes and the fact that the organism is also a circular process of metabolic changes . . . . So the question under examination was: if we leave the organization of the nervous system to the side for the moment and instead focus on the autonomy of life in its cellular form, what is there to say? This reflection on the circular nature of metabolism in living beings and its relation to cognitive operations, although barely filling a short page in the definitive version of 'Biology of Cognition', would be a focal point from which the development of the idea of autopoiesis would be drawn.

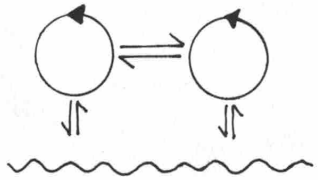
So there are at least two different operational closures coordinated in the autopoietic system. The ultimate closure is the autopoietic organization itself, "the circular nature of metabolism," but among certain organisms, this organization also informs the operational closure of the nervous system in its own right, "the circular nature of neuronal processes."

In these diagrams from *The Tree of Knowledge*, the counter-clockwise circle is an "autopoietic self," while the hatch marks "structurally coupling" that self to the wavy line of the environment indicate the "cognitive self" in its relation to a changing environment sure to be full of neighboring selves of some sort.

Ontogeny is the history of structural change in a unity without loss of organization in that unity. This ongoing structural change occurs in the unity from moment to moment, either as a change triggered by interactions coming from the environment in which it exists or as a result of its internal dynamics. As regards its continuous interactions with the environment, the cell unity classifies them and sees them in accordance with its structure at every instant. That structure, in turn, continuously changes because of its internal dynamics. The overall result is that the ontogenic transformation of a unity ceases only with its disintegration. To abbreviate this situation, when we refer to autopoietic unities, we shall use the following diagram:



Now, what happens when we consider the ontogeny of, not one, but two (or more) neighboring unities in their medium of interaction? We can abbreviate this situation as follows:



—**Identity and Cognition**. The autopoietic closure of living organization accounts for the basic maintenance of *biological identity* (*not* "individuality"). Life as embodiment begins here, as a process unto itself, an organizational unity adjacent and transversal to its thermodynamic contingencies.

—from Francisco Varela, "Patterns of Life: Intertwining Identity and Cognition" (1997):

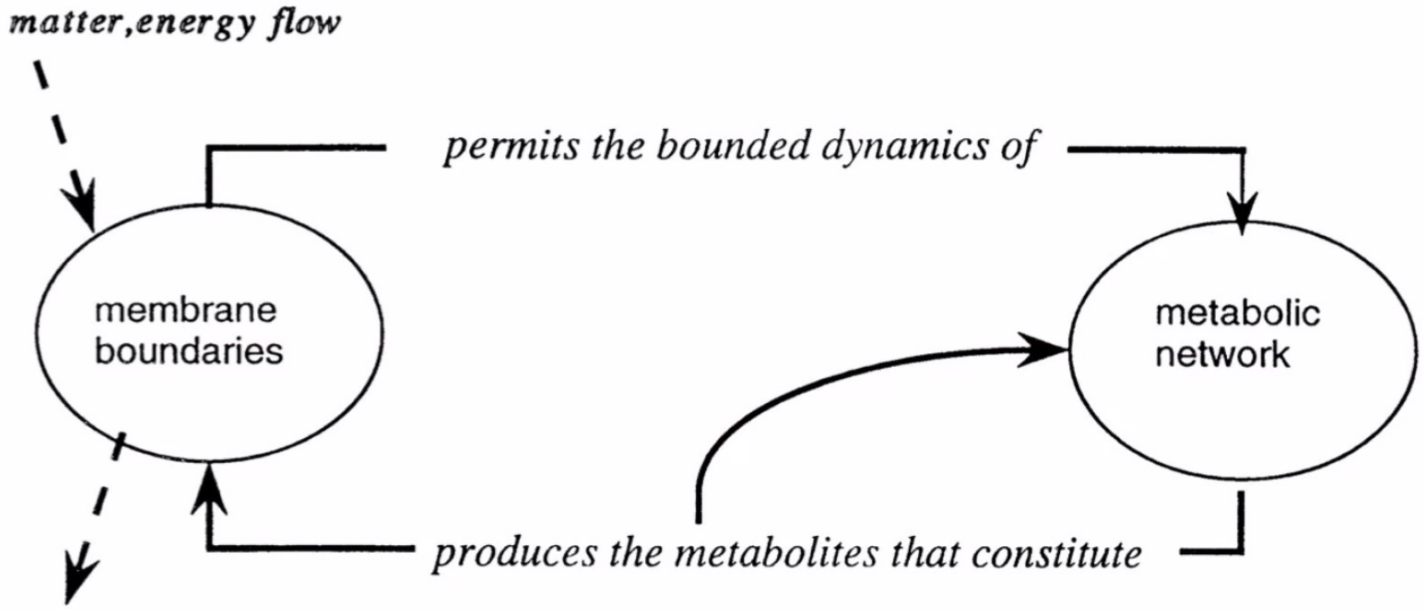


FIG. 2. Outline of the autopoietic closure of the minimal living organization.

—Varela would come to define the self as "a meshwork of selfless selves"—organismal, neurological, immunological. In this scheme, the operational closure of the *nervous system* enables the emergent unity of cognition in its coupling to the autopoietic identity of the organism.

—from Francisco Varela, "Patterns of Life: Intertwining Identity and Cognition" (1997):

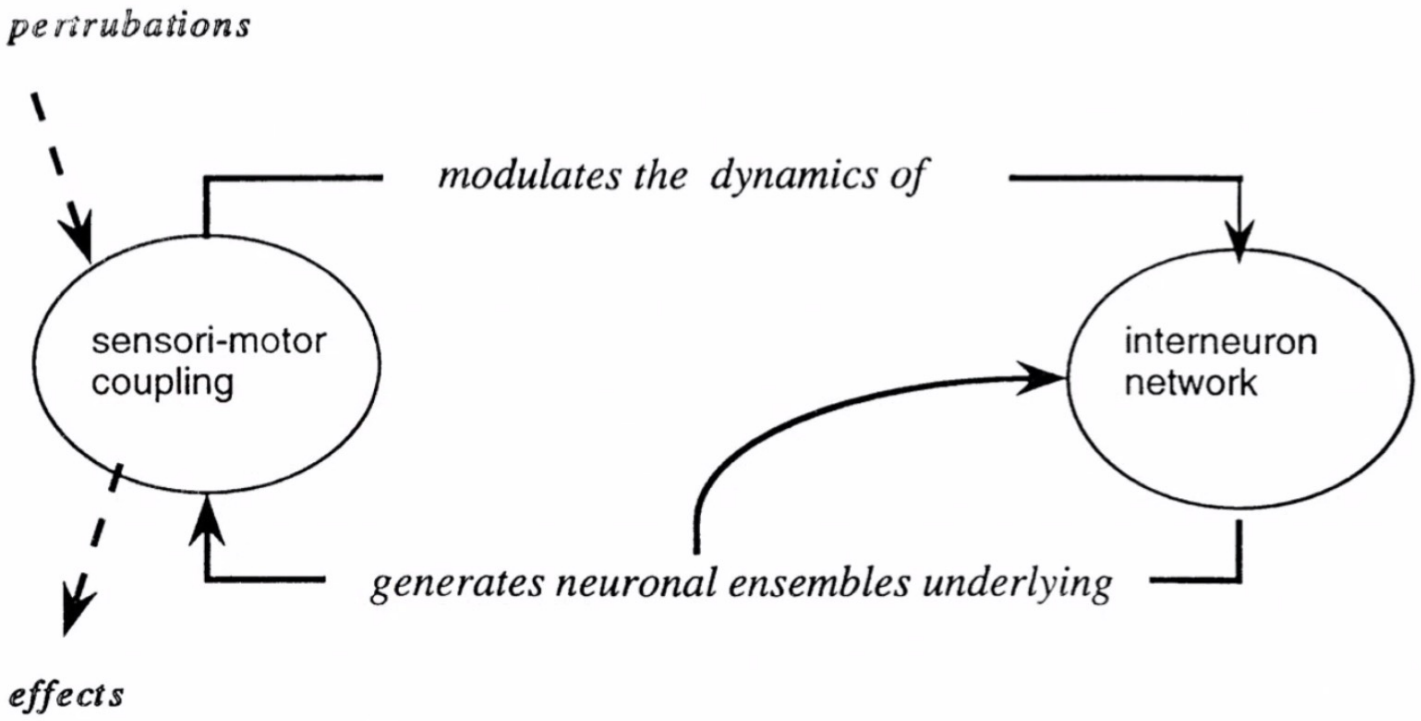
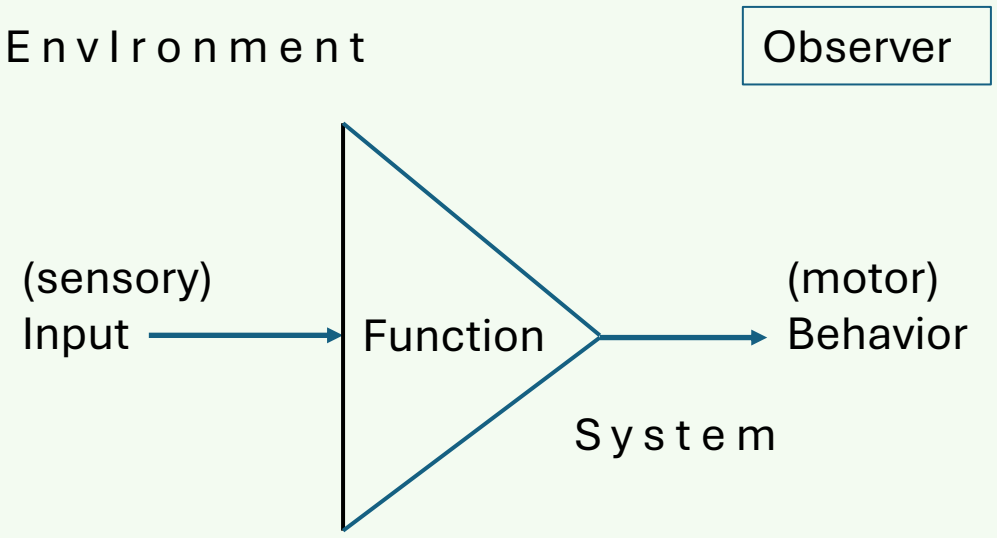
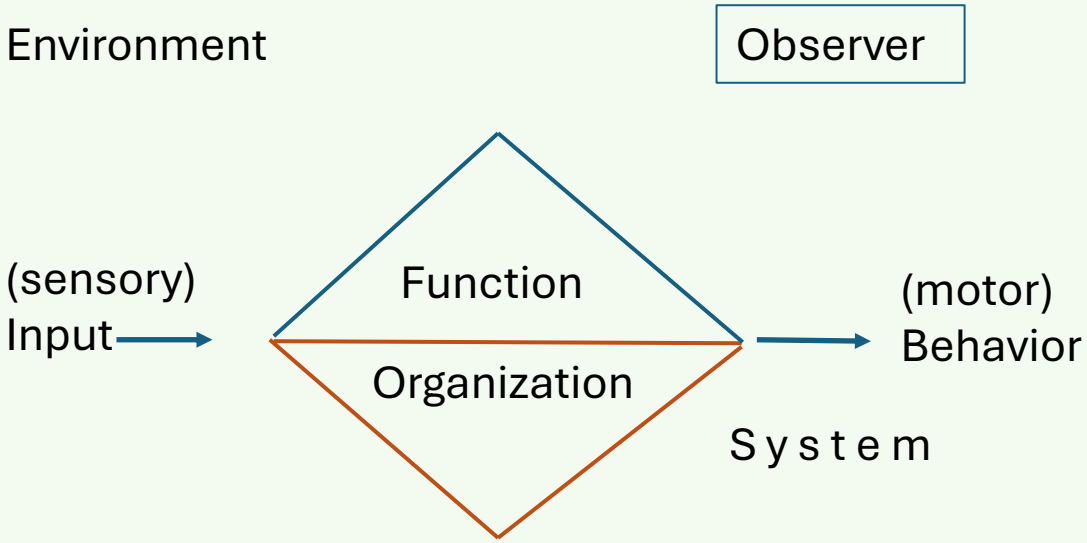


FIG. 3. Outline of the operational closure of the nervous system.

Systemic Forms



Let's back up for a second to review our understanding of systemic forms. Last week we drew this abstract general-system template from the opening sections of "Behavior, Purpose, and Teleology." What stands out here is its strict linearity: input→output, cause→effect, stimulus→response, all in a line.



In light of the theory of autopoiesis, we must augment this general system description with a recognition of the *formal organization* that underlies material function and manifest behavior. However, for Maturana and Varela, biological *organization* is not to be read as "information" but rather as the form assumed by the emergent recursion of properties that define the *unity* of an autopoietic system.

Other authors will connect this "mathematical" mode of cybernetic refinement concerning arrangement, order, and relation to information theory. It is also parallel to the linguistic structuralism of that moment.

Wiener's discourse of *pattern* and Bateson's discourse of *difference* are similarly formal-informatic concepts. In the BCL/*Whole Earth* milieu, this is the discourse of *form*, as in Spencer-Brown's *Laws of Form* and Varela's "Calculus for Self-Reference."

Recall for instance that in "What is Cybernetics?" when Wiener turns to the question *what is communication?* his first point concerns the *separation* of the formal aspect of pattern from the materiality of its medium:

> One of the most interesting aspects of the world is that it can be considered to be made up of patterns. A pattern is essentially an arrangement. **It is characterized by the order of the elements of which it is made, rather than by the intrinsic nature of these elements**.

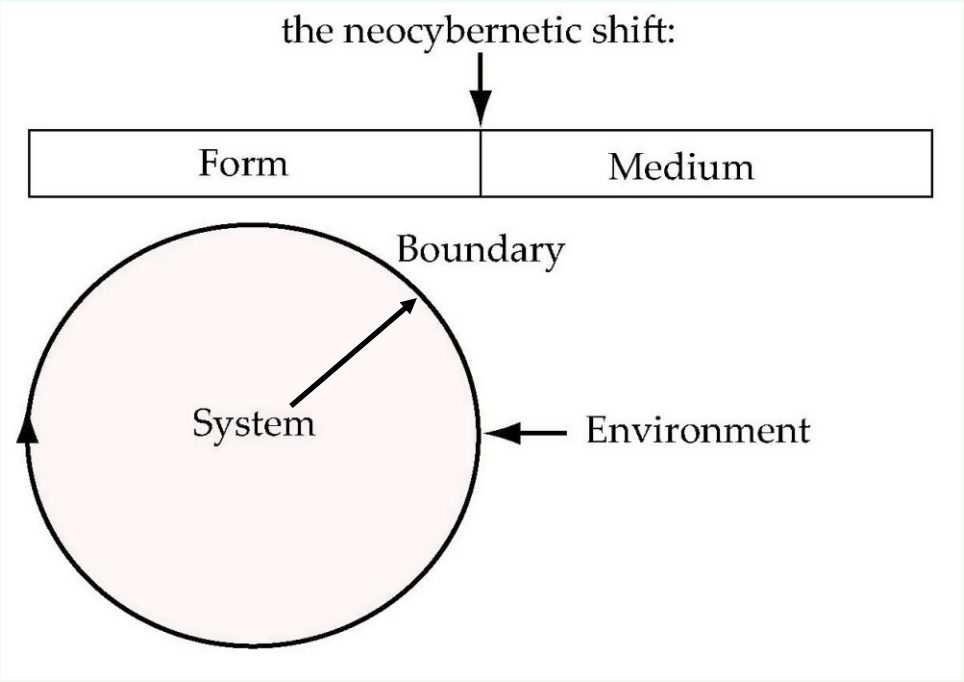
This placing of *form* prior to *matter* renders cybernetics liable to idealistic constructions ("mind over matter"). However, the autopoietic organization is not *noumenal* but *operational.* It is bootstrapped anew with every living system that manages to come into existence.

The neocybernetic shift observes the relation to form as *recursive*: Multiple forms can emerge from a medium, material or otherwise, enough to constitute a new medium, from which new kinds of form can now come forth. Alternatively, different kinds of mediums can arise to the same form. Here there is no metaphysical separation between the ideal and the real. In autopoiesis all is in process.

Dr. Bruno on System and Form

classical Western epistemology:

Subject	Object
Form	Matter



Here is the autopoietic version of the form/medium distinction:

". . . a complex system is defined as a unity by the relations between its components which realize the system as a whole, and its properties as a unity are determined by the way this unity is defined, and not by particular properties of its components. It is these relations which define a complex system as a unity and constitute its organization. Accordingly, the same organization may be realized in different systems with different kinds of components as long as these components have the properties which realize the required relations."

—This proviso allows the theory of autopoiesis to account for all life forms irrespective of differences in their material composition. The autopoietic organization is a *pattern* repeated in "the **relations** between . . . components which realize the system as a whole."

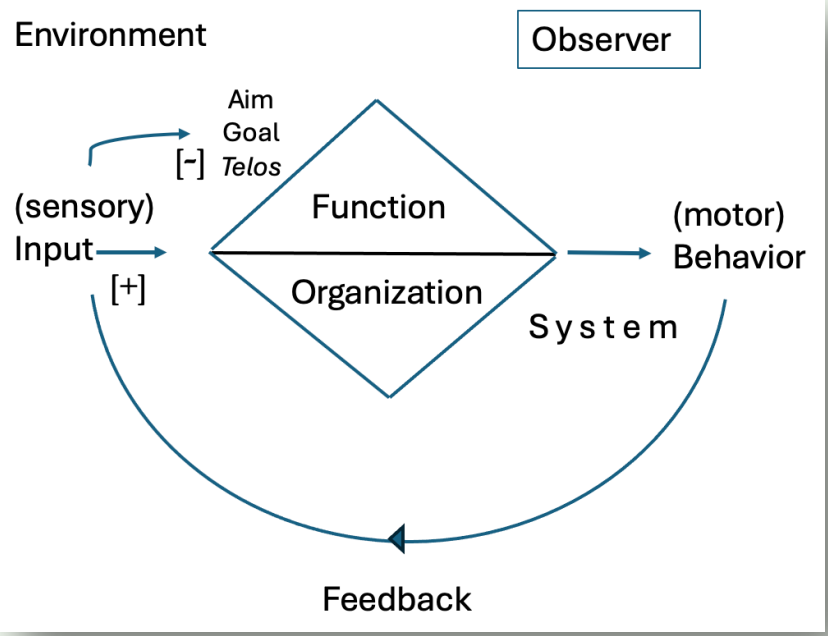
analyzable whole endowed with constitutive properties which define it as a unity, or else as a complex system that is realized as a unity through its components and their mutual relations. If the latter is the case, a complex system is defined as a unity by the relations between its components which realize the system as a whole, and its properties as a unity are determined by the way this unity is defined, and not by particular properties of its components. It is these relations which define a complex system as a unity and constitute its organization. Accordingly, the same organization may be realized in different systems with different kinds of components as long as these components have the properties which realize the required relations. It is obvious that with respect to their organization such systems are members of the same class, even though with respect to the nature of their components they may be distinct.

3. Autopoietic Organization

It is apparent that we may define classes of systems (classes of unities) whose organization is specifiable in terms of spatial relations between components. This is the case of crystals, different kinds of which are defined only by different matrices of spatial relations. It is also apparent that one may define other classes of systems whose organization is specifiable only in terms of relations between processes generated by the interactions of components, and not by spatial relations between these components. Such is the case of mechanistic systems in general, different kinds of which are defined by different concatenations (relations) of processes. In particular this is the case of living systems whose organization as a subclass of mechanistic systems we wish to specify.

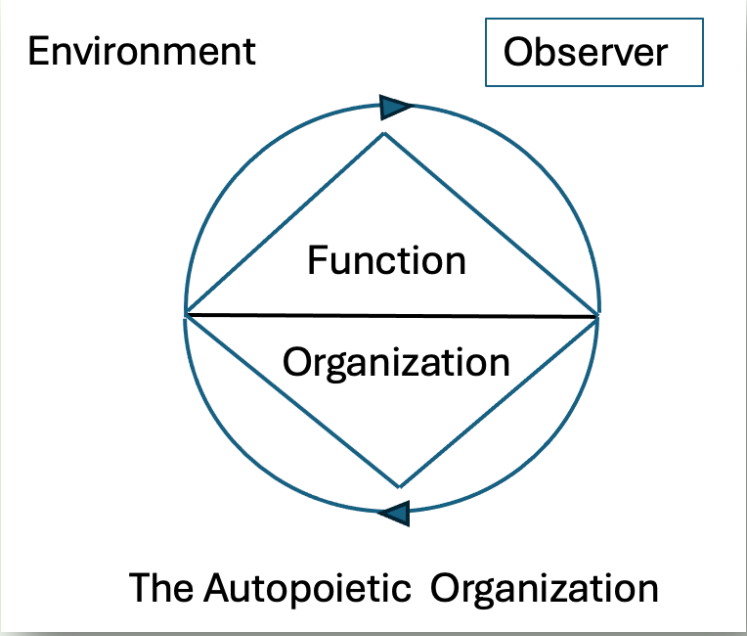
The autopoietic organization is defined as a

We learned from Wiener's cybernetics that negative feedback—



--is a uniform *behavior* shared by organisms and artifacts.

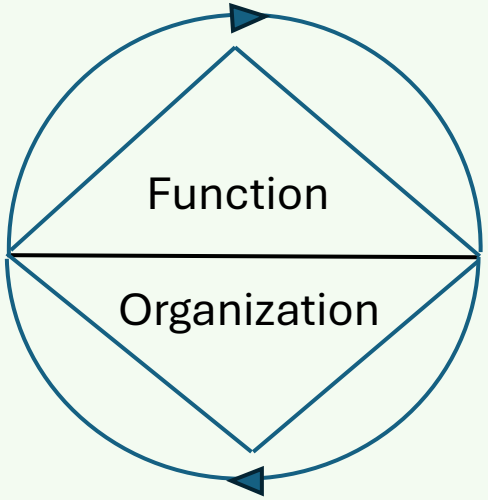
Maturana and Varela assert that self-production through operational recursion--



--is an *organization* unique to, or definitive of, living systems.

Environment

Observer

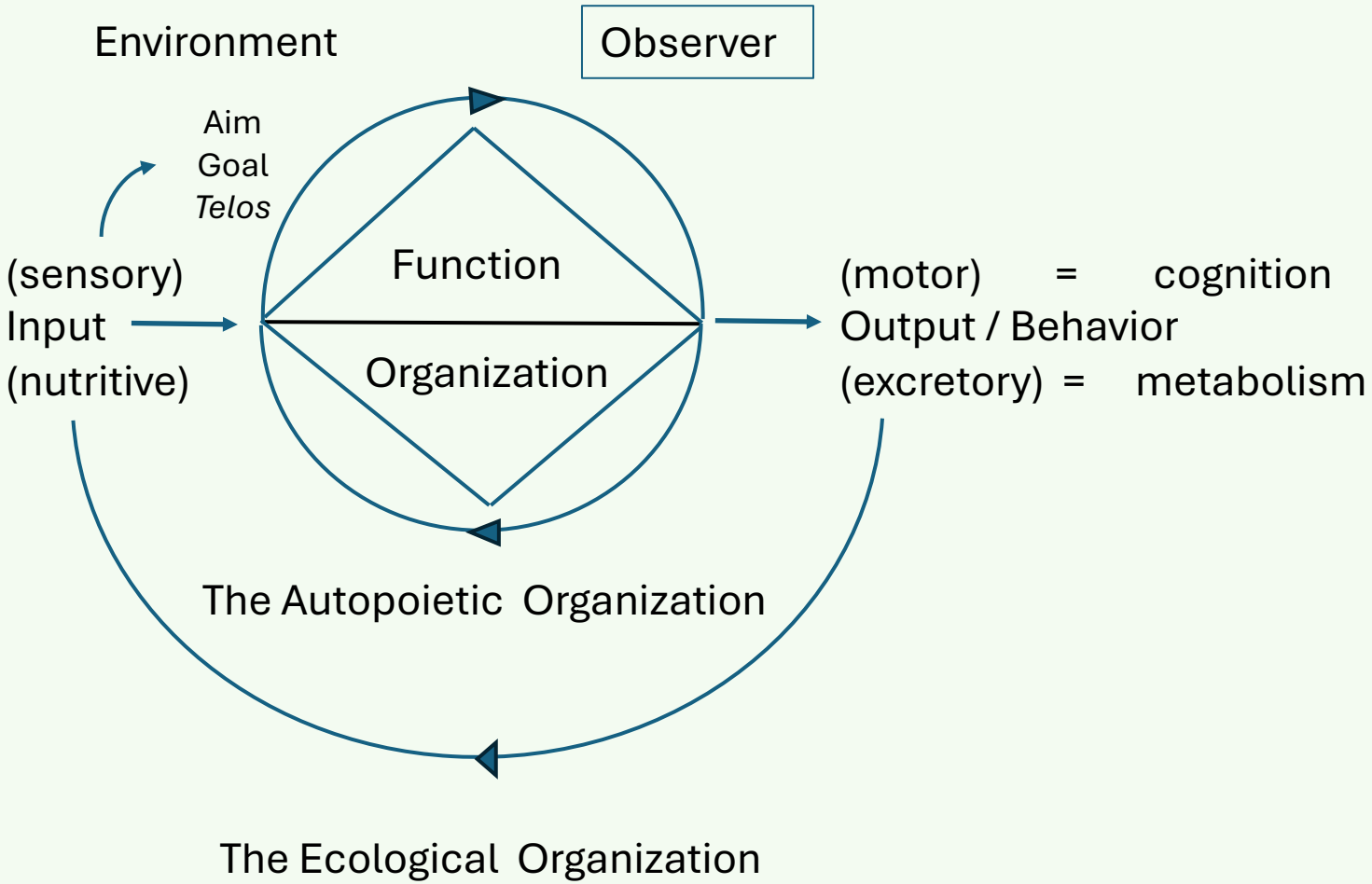


The Autopoietic Organization

"In terms of their functional organization living systems do not have inputs and outputs, although under perturbations they maintain constant their set states."
—Maturana and Varela, *Autopoiesis and Cognition* (51)

BC] *Function* would be the dynamics of metabolism, while *organization* includes the formation of the cell membrane, the physical boundary that marks off and maintains the structure of the system.

But living systems entail their environments, and vice versa. Biology is also ecology.



The Text of Autopoiesis

BioSystems 5 (1974) 187–196, NORTH-HOLLAND PUBLISHING COMPANY, AMSTERDAM

BioSystems 5 (1974)

AUTOPOIESIS: THE ORGANIZATION OF LIVING SYSTEMS, ITS CHARACTERIZATION AND A MODEL

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We formulate the organization of living organisms through the characterization of the class of autopoietic systems to which living things belong. This general characterization is seen at work in a computer simulated model of a minimal case satisfying the conditions for autopoietic organization.

1. Introduction

Notwithstanding their diversity, all living systems must share a common organization which we implicitly recognize by calling them "living". At present there is no formulation of this organization, mainly because the great developments of molecular, genetic and evolutionary notions in contemporary biology have led to the overemphasis of isolated components, e.g. to consider reproduction as a necessary feature of the living organization and, hence, not to ask about the organization which makes a living system a whole, autonomous unity that is alive regardless of whether it reproduces or not. As a result, processes that are history dependent (evolution, ontogenesis) and history independent (individual organization) have been confused in the attempt to provide a single mechanistic explanation for phenomena which, although related, are fundamentally distinct.

We assert that reproduction and evolution are not constitutive features of the living organization and that the properties of a unity cannot be accounted for only through accounting for the properties of its components. In contrast, we claim that the living organization can only be characterized unambiguously by specifying the network of interactions of components which constitute a living system as a whole, that is, as a "unity". We also claim that all biological phenomenology, including reproduction and evolution, is secondary to the establishment of this unitary organization. Thus, instead of asking "What are the necessary properties of the components that make a living system possible?" we ask "What is the necessary and sufficient organization for a given system to be a living unity?" In other words, instead of asking what makes a living system reproduce, we ask what is the organization reproduced when a living system gives origin to another living unity? In what follows we shall specify this organization.

2. Organization

Every unity can be treated either as an un-

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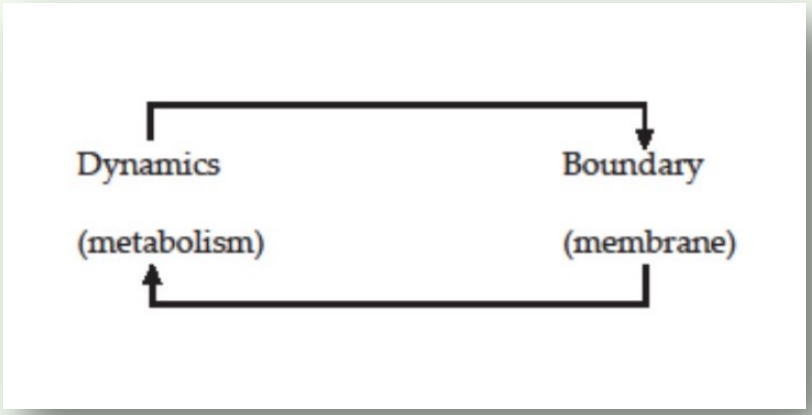

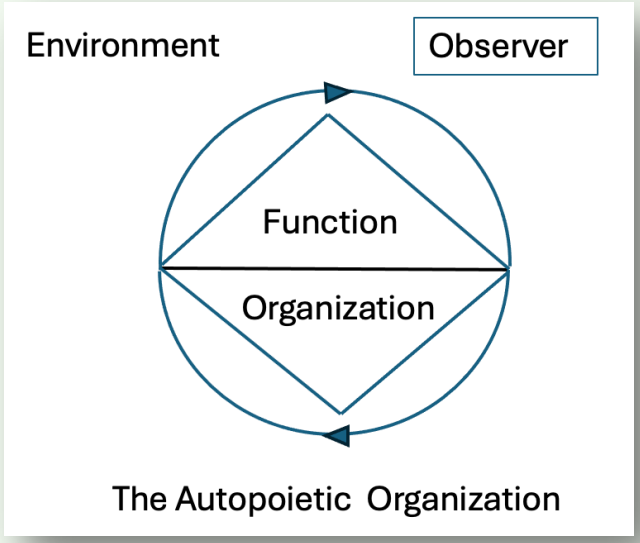

The Autopoietic Organization

"The autopoietic organization is defined as a unity by a network of productions of components which (i) participate recursively in the same network of productions of components which produced these components, and (ii) realize the network of productions as a unity in the space in which the components exist. Consider for example the case of a cell: it is a network of chemical reactions which produce molecules such that (i) through their interactions generate and participate recursively in the same network of reactions which produced them, and (ii) realize the cell as a material unity. Thus the cell as a physical unity, topographically and operationally separable from the background, remains as such only insofar as this organization is continuously realized under permanent turnover of matter, regardless of its changes in form and specificity of its constitutive chemical reactions."

Autopoiesis and autonomy = self-production and in-dependence

"The class of systems that exhibit the autopoietic organization, we shall call **autopoietic systems**. **Autonomy is the distinctive phenomenology resulting from an autopoietic organization**: the realization of the autopoietic organization is the product of its operation. . . . **An autopoietic system has a domain in which it can compensate for perturbations through the realization of its autopoiesis, and in this domain it remains a unity.**

In contradistinction, mechanistic systems whose organization is such that they **do not produce the components and processes which realize them as unities** and, hence, mechanistic systems **in which the product of their operation is different from themselves, we call allopoietic**."

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4. Autopoiesis and Allopoiesis

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Autonomy is the distinctive phenomenology resulting from an autopoietic organization: the realization of the autopoietic organization is the product of its operation. As long as an autopoietic system exists, its organization is invariant; if the network of productions of components which define the organization is disrupted, the unity disintegrates. Thus an autopoietic system has a domain in which it can compensate for perturbations through the realization of its autopoiesis, and in this domain it remains a unity.

In contradistinction, mechanistic systems whose organization is such that they do not produce the components and processes which realize them as unities and, hence, mechanistic systems in which the product of their operation is different from themselves, we call allopoietic. The actual realization of these systems, therefore, is determined by processes which do not enter in their organization. For example, although the ribosome itself is partially composed of components produced by ribosomes, as a unity it is produced by processes other than those which constitute its operation. Allopoietic systems are by constitution non-autonomous insofar as their realization and permanence as unities is not related to their operation.

5. Autopoiesis: The Living Organization

The biological evidence available today clearly shows that living systems belong to the class of autopoietic systems. To prove that the autopoietic organization is the living organization, it is then sufficient to show, on the other hand, that an autopoietic system is a living system. This has been done by showing that for a system to have the phenomenology of a living system it suffices that its organization be autopoietic (Maturana and Varela, 1973).

Presently, however, it should be noticed that in this characterization, reproduction does not enter as a requisite feature of the living organization. In fact, for reproduction to take place there must be a unity to be reproduced: the establishment of the unity is logically and operationally antecedent to its reproduction. In living systems the organization reproduced is the autopoietic organization, and reproduction takes place in the process of autopoiesis; that is, the new unity arises in the realization of the autopoiesis of the old one. Reproduction in a living system is a process of *division* which consists, in principle, of a process of fragmentation of an autopoietic unity with distributed autopoiesis such that the cleavage separates fragments that carry the same autopoietic network of

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6. A Minimal Case: The Model

We wish to present a simple embodiment of the autopoietic organization. This model is significant in two respects: on the one hand, it permits the observation of the autopoietic organization at work in a system simpler than any known living system, as well as its spontaneous generation from components; on the other hand, it may permit the development of formal tools for the analysis and synthesis of autopoietic systems.

The model consists of a two-dimensional universe where numerous ○ elements ("substrate"), and a few ★ ("catalysts") move randomly in the spaces of a quadratic grid. These elements are endowed with specific properties which determine interactions that may result in the production of other elements ⊡ ("links") with properties of their own and also capable of interactions ("bonding"). Let the interactions and transformations be as follows:

SCHEMA I

[1] Composition: ★ + 2 ○ → ★ + ⊡

[2] Concatenation (Bonding): ⊡–⊡–…–⊡ + ⊡ → ⊡–⊡–…–⊡ (n; n+1)

n = 1, 2, 3, …

[3] Disintegration: ⊡ → 2 ○

Interaction [1] between the catalyst ★ and

"… **In living systems** the organization reproduced is the autopoietic organization, and reproduction takes place in the process of autopoiesis; that is, the new unity arises in the realization of the autopoiesis of the old one. … Yet, **although self-reproduction is not a requisite feature of the living organization, its occurrence in living systems as we know them is a necessary condition for the generation of a historical network of successively generated, not necessarily identical, autopoietic unities, that is, for evolution.**"

BC] Or, reproduction of any sort is contingent upon active autopoiesis, that is, the continuation of life per se. At the same time, the ultimate persistence of autopoiesis as a system form is contingent on its reproduction, its incessant self-replacement. For its part, biological evolution is contingent upon reproduction with variation. **Autopoiesis is the conserved organization amidst the diversification of the biosphere.**

In his "Preface" composed in 1994, Varela discusses the computer model of autopoiesis at the end of the 1974 article: "it anticipated what twenty years later would become the explosive field now called artificial life and cellular automata":

in addition to a succinct presentation of the idea of autopoiesis, the intent of the article was to clarify the concept through instancing a minimal case of autopoiesis. Toward the end of 1970 we had come to the conclusion that a simple case of autopoiesis would require two reactions: one of polymerization of membrane elements, the other, the 'metabolic' generation of monomers. The latter had to be a reaction catalysed by a third pre-existing element in the reaction. Once we had designed this reaction scheme, the next obvious step was to test a simulation of this minimal case (which soon came to be called the Protobe in our discussions) using cellular (or *tessellated* as they were called then) automata, that had been introduced in the 1950s especially by John von Neuman. With the collaboration of Ricardo Uribe of the School of Engineering, the simulation rapidly provided the results that our intuition had led us to expect: the spontaneous emergence in this artificial bi-dimensional world of units which self-distinguished by means of the formation of a 'membrane', and which showed a capacity of self-repair.

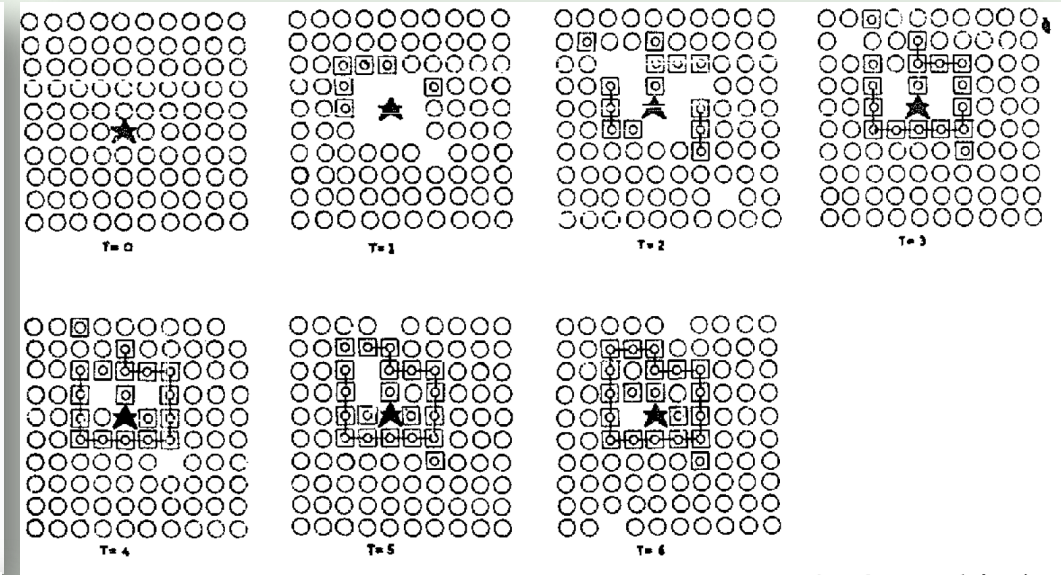

Fig. 1. The first seven instants (0→6) of one computer run, showing the spontaneous generation of an autopoietic unity. Interactions between substrate ○ and catalyst ★ produce chains of bonded links ⊠, which eventually enclose the catalyst, thus closing a network of interactions which constitutes an autopoietic unity within this universe.

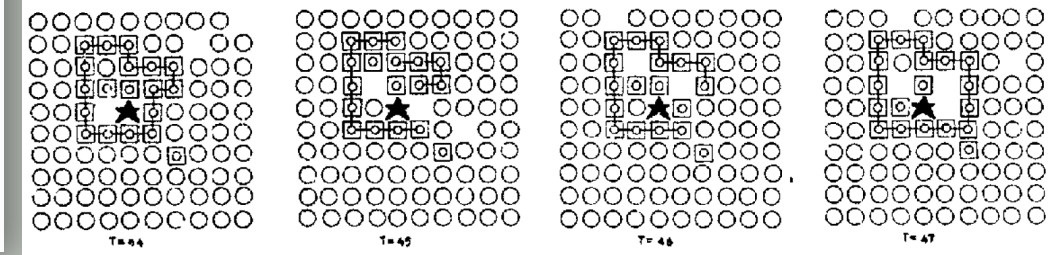

Fig. 2. Four successive instants (44–47) along the same computer run (Fig. 1), showing compensation in the boundary broken by spontaneous decay of links. Ongoing production of links re-establishes the unity under changes of form and turnover of components.

Now, *Autopoiesis and Cognition* retains the preface by Stafford Beer that was already prepared for the 1975 BCL typescript edition. Beer is famous for his work with the Allende government on Project Cybersyn, a systems approach to monitoring and guiding the national economy, recently the subject of a nine-part podcast by Evgeny Morozov called "The Santiago Boys." Here Beer makes a large claim for the theory insofar as it

> solves the problem of identity which two thousand years of philosophy have succeeded only in further confounding. . . . There is no need to postulate a mystical something which ensures the preservation of identity *despite* appearances. The very continuation is "it".

evolving world; if we are to educate people to live in that world; if we are to legislate for that world; if we are to abandon categories and institutions that belong to a vanished world, as it is well-nigh desparate that we should; then knowledge must be rewritten. *Autopoiesis* belongs to the new library.

IN PARTICULAR

The authors first of all say that an autopoietic system is a homeostat. We already know what that is: a device for holding a critical systemic variable within physiological limits. They go on to the definitive point: in the case of autopoietic homeostasis, the critical variable is ***the system's own organization***. It does not matter, it seems, whether every measurable property of that organizational structure changes utterly in the system's process of continuing adaptation. *It* survives.

This is a very exciting idea to me for two reasons. In the first place it solves the problem of identity which two thousand years of philosophy have succeeded only in further confounding. The search for the 'it' has led farther and farther away from anything that common sense could call reality.

Their 'it' is notified precisely by its survival in a real world. You cannot find it by analysis, because its categories may all have changed since you last looked. There is no need to postulate a mystical something which ensures the preservation of identity *despite* appearances. The very continuation is 'it'.

HUMBERTO R. MATURANA and FRANCISCO J. VARELA

AUTOPOIESIS AND COGNITION

The Realization of the Living

With a preface to 'Autopoiesis'

by

Sir Stafford Beer

Autopoiesis: The Organization of the Living **was originally published in Chile under the title *De Maquinas y Seres Vivos*, © 1972 by Editorial Universitaria S.A.**

D. REIDEL PUBLISHING COMPANY

DORDRECHT : HOLLAND / BOSTON : U.S.A.

LONDON : ENGLAND

1980

Meanwhile, this edition was nicely produced with an excellent editorial preface as well.

EDITORIAL PREFACE

This is a bold, brilliant, provocative and puzzling work. It demands a radical shift in standpoint, an almost paradoxical posture in which living systems are described in terms of what lies outside the domain of descriptions. Professor Humberto Maturana, with his colleague Francisco Varela, have undertaken the construction of a systematic theoretical biology which attempts to define living systems *not* as they are objects of observation and description, nor even as interacting systems, but as self-contained unities whose only reference is to themselves. Thus, the standpoint of description of such unities from the 'outside', i.e., by an observer, already seems to violate the fundamental requirement which Maturana and Varela posit for the characterization of such systems – namely, that they are autonomous, self-referring and self-constructing closed systems – in short, *autopoietic systems* in their terms. Yet, on the basis of such a conceptual method, and such a theory of living systems, Maturana goes on to define cognition as a biological phenomenon; as, in effect, the very nature of all living systems. And on this basis, to generate the very domains of interaction among such systems which constitute language, description and thinking.

The radical shift in standpoint here requires an imaginative leap and the abandonment at the outset of the standard characterizations of living systems in terms of function or purpose, or of organism-environment relations, or of causal interactions with an external world, or even in terms of information, coding and transmission. In effect, Maturana and Varela propose a theoretical biology which is topological, and a topology in which elements and their relations constitute a closed system, or more radically still, one which from the 'point of view' of the system itself, is entirely self-referential and has no 'outside', Leibnizian for our day.

The work demands and deserves careful reading. It is technical, formal, difficult, philosophical and boldly imaginative. It is rigorously constructed, and insofar as it is a theoretical biology, it remains uncompromisingly abstract and formal. Yet it smells of the medical laboratory and of the working domain of the neurophysiologist. Where the interpretation of the formal theory maps it into the domain of the nervous system, the insights and suggestions for further interpretation are exciting indeed. And we expect nothing less, here and to come.

HUMBERTO R. MATURANA AND FRANCISCO J. VARELA

Autopoiesis and Cognition

> So long as ideas of the nature of living things remain vague and ill-defined, it is clearly impossible, as a rule, to distinguish between an adaptation of the organism to the environment and a case of fitness of the environment for life, in the very most general sense. Evidently to answer such questions we must possess clear and precise ideas and definitions of living things. Life must by arbitrary process of logic be changed from the varying thing which it is into an independent variable or an invariant, shorn of many of its most interesting qualities to be sure, but no longer inviting fallacy through our inability to perceive clearly the questions involved.
>
> Henderson, ***The Fitness of the Environment***

AUTOPOIESIS

The Organization of the Living

INTRODUCTION

A universe comes into being when a space is severed into two. A unity is defined. The description, invention and manipulation of unities is at the base of all scientific inquiry.

In our common experience we encounter living systems as unities that appear to us as autonomous entities of bewildering diversity endowed with the capacity to reproduce. In these encounters autonomy apears so obviously an essential feature of living systems that whenever something is observed that seems to have it, the naive approach is to deem it alive. Yet, autonomy, although continuously revealed in the self-asserting capacity of living systems to maintain their identity through the active compensation of deformations, seems so far to be the most elusive of their properties.

Autonomy and diversity, the maintenance of identity and the origin of variation in the mode in which this identity is maintained, are the basic challenges presented by the phenomenology of living systems to which men have for centuries addressed their curiosity about life.

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These considerations of *distinction* are right out of Spencer-Brown's *Laws of Form*: we will pick up this topic in Week 5 with Heinz von Foerster.

Distinctions

The act of indicating any being, object, thing, or unity involves making an *act of distinction* which distinguishes what has been indicated as separate from its background. Each time we refer to anything explicitly or implicitly, we are specifying a *criterion of distinction*, which indicates what we are talking about and specifies its properties as being, unity, or object.

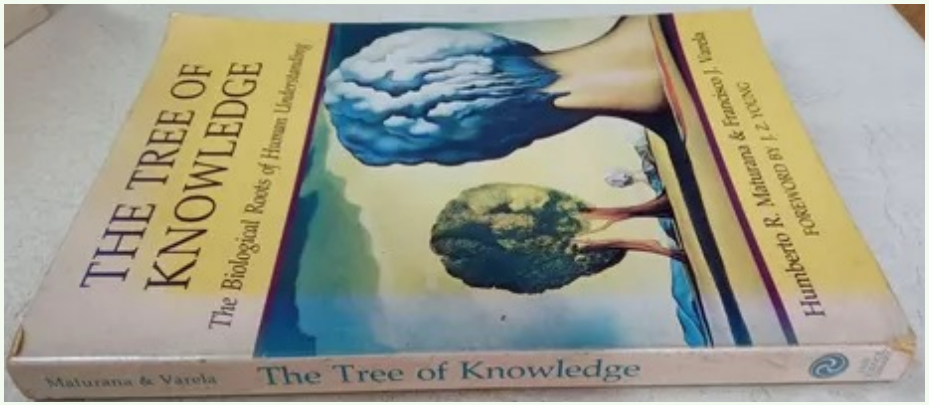
This is a commonplace situation and not unique: we are necessarily and permanently immersed in it.

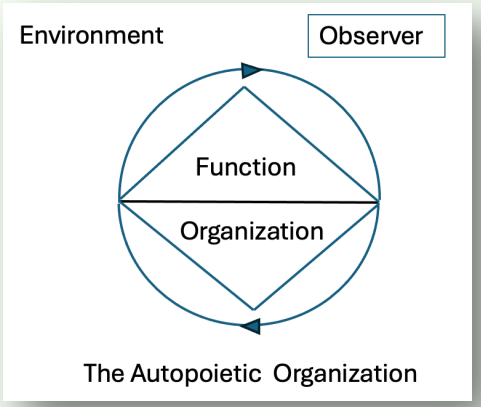
Unities

A *unity* (entity, object) is brought forth by an act of distinction. Conversely, each time we refer to a unity in our descriptions, we are implying the operation of distinction that defines it and makes it possible.

—from Maturana and Varela, *The Tree of Knowledge: The Biological Roots of Human Understanding*, 2nd ed.

Autopoiesis and Cognition begins with a kind of origin story in which the "universe" arrives each time a living system enters into a cognitive relationship with its environment. In von Foerster's idiom, this is to say that every living system "constructs its reality" with each selection it makes among its afforded environment of differences.





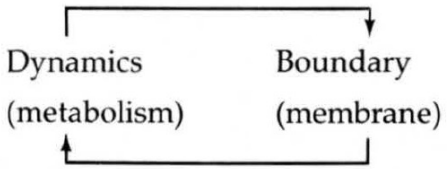
Tree] The mechanism that makes living beings autonomous systems is autopoiesis . . . Their only product is themselves, with no separation between producer and product. The being and the doing of an autopoietic unity is inseparable.

> —Cellular autopoiesis is the feedback not of information but of organization. The living organization is the being, its functioning is the doing. Organization and function are inseparable but still distinct.

Tree] **Autopoietic unities specify biological phenomenology as the phenomenology proper of those unities with features distinct from physical phenomenology.** This is so, not because autopoietic unities go against any aspect of physical phenomenology—since their molecular components must fulfill all physical laws—but because the phenomena they generate in functioning as autopoietic unities depend on their organization and the way this organization comes about, and not on the physical nature of the components.

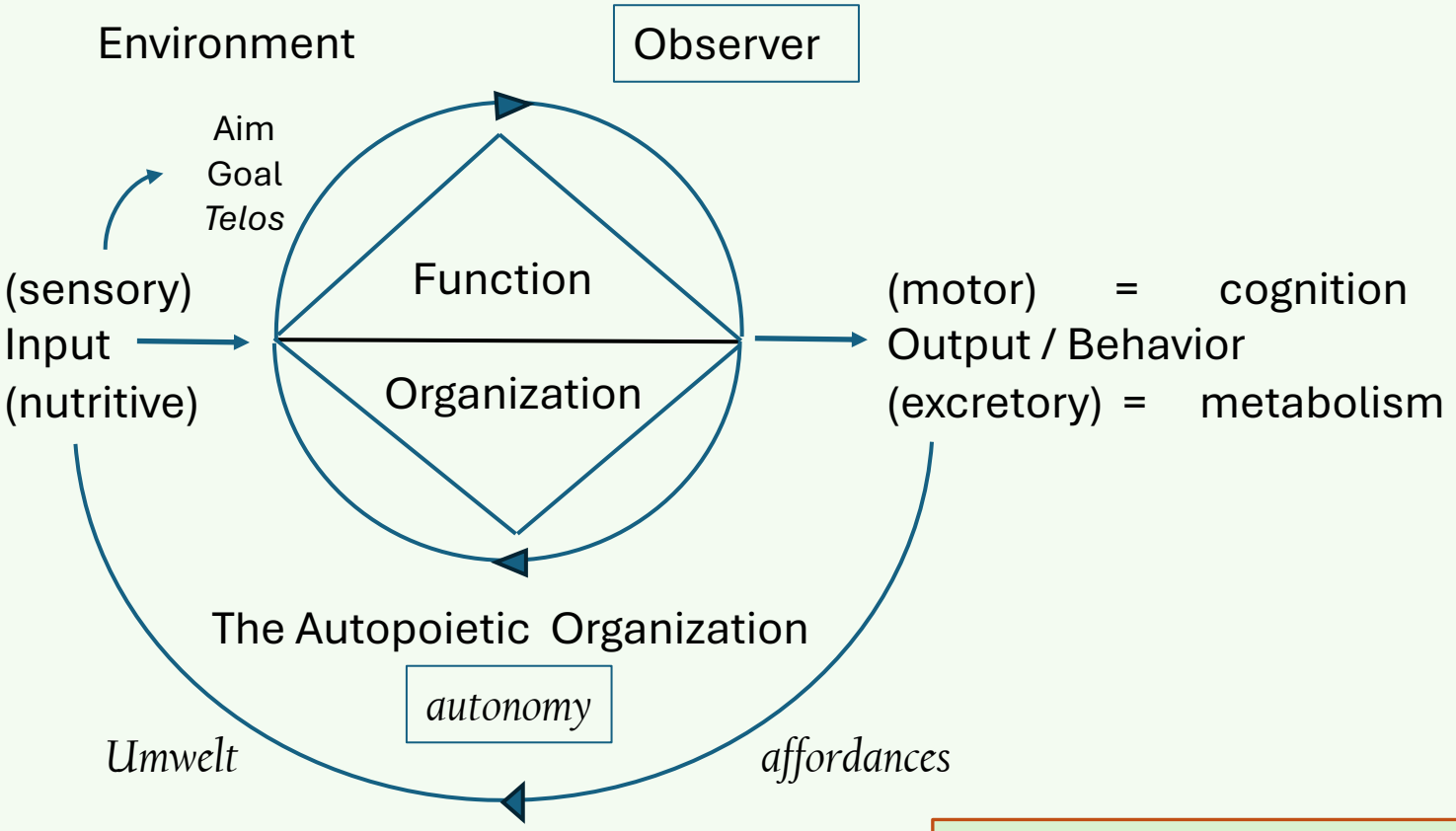
> —This last statement resonates with the epistemological constructivism regarding the "interior construction" of knowledge we will review in von Foerster's work. Here we have the "interior construction" of autopoietic forms. Put another way, **a living system is itself a *cognitive* process of distinguishing elements (such as molecules coming from the environment), then sorting and arranging them into relations effective in maintaining autopoiesis.**

What we have, then, is a unique situation as regards relations of chemical transformations: on the one hand, we see a network of dynamic transformations that produces its own components and that is essential for a boundary; on the other hand, we see a boundary that is essential for the operation of the network of transformations which produced it as a unity:



Note that these are not sequential processes, but two different aspects of a unitary phenomenon. It is not that first there is a boundary, then a dynamics, then a boundary, and so forth. We are describing a type of phenomenon in which the possibility of distinguishing one thing from a whole (something you can see under the microscope, for instance) depends on the integrity of the processes that make it possible. Interrupt (at some point) the cellular metabolic network and you will find that after a while you don't have any more unity to talk about! The most striking feature of an autopoietic system is that it pulls itself up by its own bootstraps and becomes distinct from its environment through its own dynamics, in such a way that both things are inseparable.

Living beings are characterized by their autopoietic organization. They differ from each other in their structure, but they are alike in their organization.



And the ecological organization is Gregory Bateson's map and territory.