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Autopoiesis and Knowledge in Self-Sustaining Organizational Systems[1]

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[See Additional Reference for more recent papers on this topic]

Abstract

Knowledge and the communication of knowledge are critical for self-sustaining organizations comprised of people and the tools and machines that extend peoples' physical and cognitive capacities. Humberto Maturana and Francisco Varela proposed the concept of autopoiesis ("self" + "production") as a definition of life in the 1970s. Nicklas Luhmann extended this concept to establish a theory of social systems, where intangible human social systems were formed by recursive networks of communications. We show here that Luhmann fundamentally misunderstood Maturana and Varela's autopoiesis by thinking that the self-observation necessary for self-maintenance formed a paradoxically vicious circle. Luhmann tried to resolve this apparent paradox by placing the communication networks on an imaginary plane orthogonal to the networked people. However, Karl Popper's evolutionary epistemology and the theory of hierarchically complex systems turns what Luhmann thought was a vicious circle into a virtuous spiral of organizational learning and knowledge. There is no closed circle that needs to be explained via Luhmann's extraordinarily paradoxical linguistic contortions.

Keywords: Autopoiesis, Organization Theory, Nicklas Luhman, Social Systems Theory, Self Observation, Karl Popper, Evolutionary Epistemology

Introduction

Knowledge and the communication of knowledge as "information" are critical for self-sustaining organizations and other social-systems comprised of people and the tools and machines that extend the physical and cognitive capacities of people and organizations [1],[2],[3]. However, working with core ideas lifted from often incommensurable fields, are a long way from having a common understanding of organizations, information or knowledge [4],[5],[6]. Beginning with a background in evolutionary biology [7],[8],[9], followed by 25 years in industry working with information and knowledge management problems [10],[11], Hall sought a deeper understanding of organizations than offered by the approaches summarized in the above cited review articles.

An understanding of organizations can be found in a synthesis of Humberto Maturana and Francisco Varela's original concept of autopoiesis ("self" + "production") [12],[13],[14],[15],[16],[17] and Karl Popper's evolutionary epistemology [18],[19],[20],[21]. Autopoiesis defines life as "circularly organized" or "operationally closed" [17] complex dissipative entities with the autonomous capacity to self-produce components they need for life and able to observe themselves to apply self-regulating feedback in the face of perturbations that might otherwise cause them to disintegrate. Karl Popper's evolutionary epistemology [18],[20],[21],[22] defined knowledge as "solutions to problems of life" and accounted for its growth through time as a consequence of an iterated process of speculation followed by the elimination of errors by Darwinian or conscious selection. This easily accounts for the generation and growth of knowledge in autopoietic frameworks [23],[24],[25],[26],[27] in a way that made the original concept of autopoiesis applicable to systems at any level of organization in a complex scalar hierarchy [28],[29], [30],[31] where parameters of systems at different scalar levels of organization meet the criteria for a complex system to be considered autopoietic [75].

This biophysically based approach to understanding organizational knowledge and cognition competes directly with Nicklas Luhmann's esoteric use of autopoiesis in the development of his social systems theory [32],[33],[34],[35], [37],[38] incorporated in European Post Modern organizational theory [39],[40],[41] and second order cybernetics [42],[43], [44],[45]. Here we compare Luhmann's "autopoietic" social systems with the approach we and our colleagues have taken [77] that treats autopoietic organizations as third order biophysical entities above second order multicellular humans in the complex systems hierarchy of the world.

Maturana and Varela's Autopoiesis

Maturana and Varela recognized that living things (i.e., autopoietic systems) are thermodynamically driven assemblies of components that have within them the autonomous capacity to produce all the components they require to continue their existence [75]. Varela et al. [15] gave six properties

(paraphrased here for brevity) considered necessary and sufficient to recognize when a complex system could be considered to be autopoietic, and thus living:

- Bounded (demarcated from the environment)
- Complex (different components within the boundary)
- Mechanistic (system driven by energy dissipation)
- Self-differentiated (system boundary intrinsically produced)
- Self-producing (system produces own components)
- Autonomous (self-produced components are necessary and sufficient to produce the system).

The properties of autopoiesis are embodied in the persistent "organization" of the network of dynamic interactions among the components of a system that perpetuates autopoiesis as its instantaneous structure changes continually as matter and energy pass through it [75].

As Maturana expressed it in [13], a living (i.e., autopoietic) entity is defined by the physical interactions of its (molecular) components and not the components themselves, where the autopoietic entity is recognized

> [as a] dynamic molecular entity, [that is] realized as a unity as a closed network of molecular productions in which the molecules produced through their interactions:
> a) recursively constituted the same network of molecular productions that produced them; and,
> b) specified the extension of the network and constituted operational boundaries that separate it as a discrete unity in a molecular space.
> [The autopoietic system is] …a molecular system open to the flow of molecules through it as molecules could enter it and become participants of its closed dynamics of molecular productions, and molecules could stop participating in such molecular dynamics leaving it to become part of the molecular medium in which it existed…. [13]: p. 7
> Living systems are not the molecules that compose and realize them moment by moment, they are closed networks of molecular productions that exist as singularities in a continuous flow of molecules through them. Indeed, the condition of being closed molecular dynamics is what constitutes them as separable entities that float in the molecular domain in which they exist…. [13]: p. 10.
> "…autopoietic systems in the physical space must satisfy the thermodynamic legality of physical processes that demands of them that they should operate as materially and energetically open systems in continuous material and energetic interchange with their medium… [where] ...the physical boundaries of a living system... are realized by its components through their preferential interactions within the autopoietic network... as surfaces of thermodynamic cleavage" [12]: p. 30.

Maturana infers from this,

> the law of conservation of organization (autopoiesis in the case of living systems) and the law of conservation of adaptation, that is operational congruence, with the medium in which a system (a living system in our case) exists. These two laws of conservation are both relational conditions of the realization of living systems that must be satisfied for living to occur at all. [13]: p. 10.

In their writings on autopoiesis, Maturana and Varela emphasized the importance of "circular organization" or "operational closure" [17] whereby negative feedback from self-observation maintained the autopoietic nature of the organization. Some authors, e.g., Luhmann, considered that the operation of feedback from self-observation formed a paradoxically and viciously closed causal chain, where A causes B and B causes A – an issue pursued by second order cybernetics [42],[43],[44]. Nicklas Luhmann went to esoteric extremes in an attempt to work with the apparent paradoxes.

Luhmann's Paradox of Self-Reflection

The way we have used autopoiesis differs greatly from Luhmann's [46],[47]. Thus, we make no claim to fully understand Luhmann's paradoxically convoluted expression. To us his style of recursive self-negation seems semantically vacuous. However, some quotes will help to provide a backdrop for considering the contrasting approach to autopoiesis deriving from evolutionary epistemology.

Luhman highlights the apparently paradoxical nature of an observer trying to understand the development of knowledge at any level of structural organization:

> …we need [paradoxical statements] when we have to distinguish different observers from each other or when we have to distinguish self-observations from external observation, because for the self-observer things may appear as natural and necessary, whereas when seen from the outside they may appear artificial and contingent. The world thus variously observed remains, nevertheless, the same world, and therefore we have a paradox. An observer, then, is supposed to decide whether something is natural or artificial, necessary or contingent. But who can observe the observer (as necessary for this decision) and the decision (as contingent for the observer)? The observer may refuse to make this decision, but can the observer observe without making this decision or would the observer have to withdraw, when refusing this decision, to the position of a nonobserving observer? [38]: p. 80].

Luhmann's social systems theory reduces social systems to organizationally closed networks of self-producing "communications":

> The system disposes over internal and external causes for the production of its product, and it can use the internal causes in such a way that there results sufficient possibilities of combining external and internal causes.
> The work which is produced, however, is the system itself or more exactly: the form of the system, the difference between system and environment. This is exactly what the concept of autopoiesis is intended to designate…. The concept of autopoiesis, then, necessarily leads on to the difficult and often misunderstood concept of the *operative closure of the system*…. It is … the necessary consequence of the trivial (conceptually tautological) fact that no system can operate outside of its boundaries. This leads to the conclusion - which forms the first stage of a clarification of the concept of society - that we are dealing here (that is, if we want to use the form-concept of system) with an *operatively closed autopoietic system*. ([35]: p. 70 – Luhmann's italics)

> …[W]hich is the operation which produces the system of society?… My proposal is that we make the concept of communication the basis and thereby switch sociological theory from the concept of action to the concept of system. This enables us to present the social system as an operatively closed system consisting only of its own operations, reproduced by communications from communications. With the concept of action external references can hardly be avoided. … Only with the help of the concept of communication can we think of a social system as an autopoietic system, which consists only of elements, namely communications, which produce and reproduce it through the network of precisely these elements, that is, through communication. ([35]: p. 71).

Using arguments deriving from Spencer Brown's Laws of Form [49], Luhmann claims the network of communications is its own boundary, and that people and their actions are formally external to and not part of the networks [48],[39]:

> A system is the form of a distinction, possesses therefore two sides [sic]: the system (as the inside of the form) and the

> environment (as the outside of the form). Only the two sides together constitute the distinction, constitute the form, constitute the concept. … *The boundary between system and environment separates the two sides of the form, marks the unity of the form and is for this reason not to be found on either side of the form. The boundary exists only as an instruction to cross it - whether from inside to outside or from outside to inside.* [35]: p 69 my italics.

Here, we understand Luhmann to be saying that the boundary of a system is intangible; as some kind of distinction or separation between physical reality and ghostly connections of a network of intangible communications realized in some imaginary phase space orthogonal to the real world's dimensions – an argument developed from Spencer Brown's Laws of Form [49] relating to the imaginary part of a complex number. In this sense, perhaps one could argue that the "boundary" represents an epistemic cut [50] between the ghostly network and the physical world.

> The distinction between the problem of truth and the problem of reference thus leads to a distinction of distinctions, namely, to the distinction between the distinction true/untrue and the distinction self-reference/external reference. The two distinctions are located at right angles to each other. They have no mutually unbalancing effects. That is, self-referential observations and descriptions, as well as those of external reference, can be both true and untrue. ([36]: p. 65)

However, to Maturana self-observation was only "apparently" paradoxical (e.g., Maturana, Biology of Cognition, in [14]; [51]), but he lacked the epistemological framework and vocabulary to clear the fog. Because Luhmann and his followers accepted that self-observation of autopoietic self-maintenance and self-production was viciously paradoxical, they performed extraordinary linguistic and logical contortions in an attempt to work within the circle. However, Karl Popper's evolutionary epistemology turns the apparently vicious circle of self-observation and self-criticism into a virtuous spiral [52], [53], clarifying many aspects of Maturana and Varela's also recursive writing.

Popper: There is No Vicious Circle

To Popper, knowledge of the external world consisted of constructed solutions to problems of life; or at least claims, tentative theories, or tentative solutions [18],[19],[21],[22] relating to the world. Although Popper's primary concern was human cognition and knowledge, he presented a broadly based ontology of three worlds and the roles of knowledge applicable to all living things [18][1].

World 1 ("W1" - physical events and processes) is dynamic physical reality and everything in it, including physiology.

World 2 ("W2" - cognition) is the domain of embodied behavior, mental states and psychological processes within minds, dispositional and tacit knowledge. W2 encompasses active processes and subjective results of cognition. Cognition produces knowledge embodied in living things as, "dispositional" or "situational" knowledge (propensities to act in certain ways in response to particular situations). This bears some resemblance to Polanyi's "tacit" knowledge [55],[56]. By extension, W2 includes the embodiment of all kinds of cybernetically self-defined and self-regulated dynamic processes [12],[13],[14],[16],[57]. In other words, W2 contains the semantic significance or meaning of cognitive processes and their results, while the physical dynamics of the matter involved in the processes remains always in W1. The survival knowledge (i.e., solutions to problems of the world) the autopoietically living entity requires to maintain its existence must be expressed in W2 as cybernetic "control information" [58].

World 3 ("W3" - objectively persistent products of knowledge) is the domain of persistently codified knowledge, where encoded content can exist objectively, independent from a knowing entity. Popper defined W3 to include knowledge in the objective sense, which includes "the world of the logical contents of books, libraries, computer memories, and suchlike" ([18]: p. 74) and "our theories, conjectures, guesses (and, if we like, the logical content of our genetic code)" ([18]: p. 73), while the physical structure of the codified content remains always in W1. W2 mediates between W1 and W3.

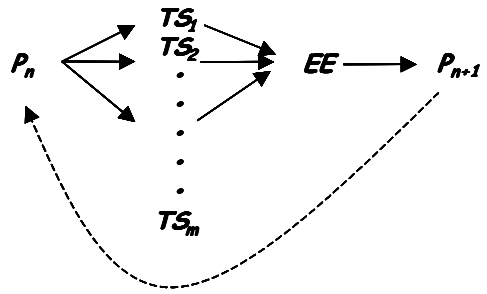

Figure 1. (after Popper 1972: pp. 243). P_n is a problem situation the living entity faces in the world, TS_m represent a range of tentative solutions (or theories in self-conscious, articulate individuals) the entity may embody or propose in W2 to solve the problem. ***EE*** represents a process of natural selection imposed by W1 on the entity or criticism and error elimination in W2 that selectively removes those solutions that don't work in practice. ***Pn+1*** represents the now changed problem situation remaining after the first one is solved. As the entity iterates the process, it constructs an increasingly accurate representation of external reality.

Donald T. Campbell [59],[60],[61],[62],[63] and Karl Popper [54],[18],[20],[21],[22] formulated evolutionary epistemology. According to Campbell, living things built knowledge through processes of "blind variation and selective retention". Popper called his most comprehensive explanation a "general theory of evolution" (Figure 1). In many places he abbreviated this to a "tetradic" schema: $\boldsymbol{P_1 \rightarrow TS \rightarrow EE \rightarrow P_2}$, where ***TS*** referred to "tentative theories".

As Maturana noted, autopoietic entities are thermodynamically dissipative systems open to exchanges of matter and energy with their environments [12],[13] and must conserve their adaptation to their external environment "for living to occur at all" ([13]: p. 10). Popper's evolutionary epistemology explains the iterated process by which this adaptation evolves and is maintained. The process is cyclical and based on prior states of the autopoietic entity but it is not closed in a paradoxically vicious circle. Because cognition is a causally driven physical process, all references to the self and the self's environment relate to the state of the world in earlier times [64]. Thus, along the time axis, all references to internal or external states are open spiral processes (Figure 2) [52],[53]. Evolutionary epistemology also preserves and explains the nature of the structural coupling between the external environment and the autopoietic system (i.e., as the differences between P_n and P_{n+1}) that concerns second-order cybernetics.

[1] As interpreted by Hall [23],[24],[25].

Thus, Luhmann's elaborate and paradoxically convoluted explanations of autopoietic social systems are not needed.

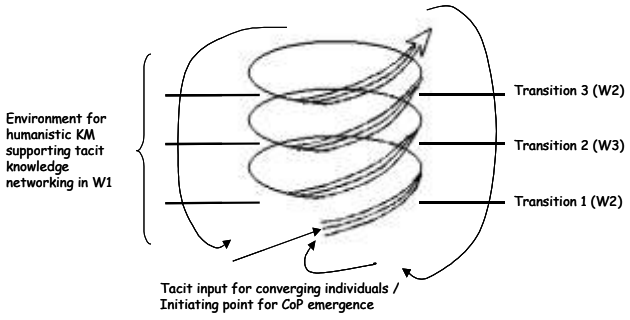

Figure 2. Nousala's virtuous spiral (from [52])

Many Human Organizations are Autopoietic

Using the theory of complex systems [28],[29],[30],[31] in a scalar hierarchy, contra [65],[66],[67], we have argued that many human organizations have the necessary properties to be considered autopoietic [23],[24],[25],[26],[75],[77]. The failure of many workers (i.e., external observers) to recognize the autopoietic nature of organizations is their failure to understand the importance of selecting an appropriate focal level for observing the system of interest (Figure 3).

We can easily see and recognize boundaries of systems at the human scale with our unaided eyes. We need powerful microscopes to see systems at the cellular level comprised of macromolecular subsystems, but through magnification we can still easily see and recognize system and subsystem boundaries with our eyes. It is much more of a conceptual leap for us to "see" the boundaries of the larger scale systems in which individual humans like ourselves form subsystem components.

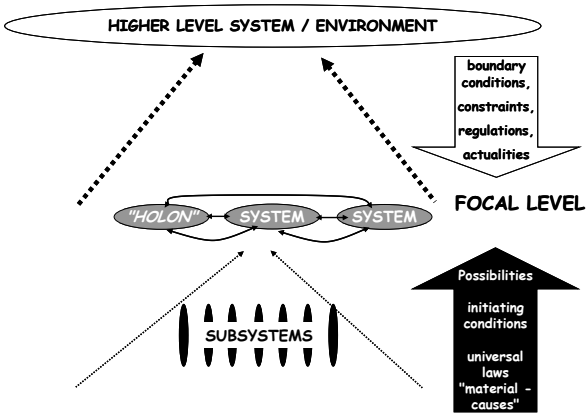

Figure 3. Establishing a level of focus on a system in a hierarchically complex world. (From [26]).

Hall argued that some human economic organizations are third order autopoietic entities in their own rights [23],[24], [25],[26],[75]. The human and organizational economy abstracts real energy fluxes. Organizations sell products and procure energy and resources. Individuals belonging to organizations use organizational salaries to purchase their own requisites for living. Thus measurements and observations of cash flow are reasonable abstractions of these energy flows from source to sink as high value resources are used to produce products and dissipated in the form of labor and distribution. Thus, complex dynamics may evolve at a level of complexity involving human economic interactions.

Large economic organizations certainly meet requirements to be considered autopoietic. They are:

- *Bounded*. The entity's components are self-identifiably tagged): Members of the organization are typically identified with badges, and sometimes even uniforms. 'Human resource systems" in the organization track memberships, associations, etc. to identify members, with boundaries further identified by walls and fences, often monitored by receptionists and security guards.
- *Complex*. Individual people are certainly autopoietic entities in their own rights, but they can work together in networks of interaction to form and maintain the organizational structure of a higher order entity.
- *Mechanistic*. Money tokenizes power over energy and material resources needed for corporate existence. Cash accounting, payrolls, internal processes and procedures, etc. incentivize, measure and regulate the interactions of organization members to benefit the continued survival and growth of the organization.
- *Self differentiated*. System boundaries internally determined by rules of association, employment agreements, oaths of allegiance to organizational rules, deeds, etc., that determine who belongs to the organization and what property it owns.
- *Self producing*. Processes exist to recruit, induct and train new members and to build or procure plant, equipment or other resources the organization requires.
- *Autonomous*. As long as the organization maintains enough capital to avoid takeover or disintegration in the face of economic/environmental perturbations, well-established organizations survive independently of the membership of any particular individuals in the organization.

Discussion and Conclusions

If organizations are autopoietic, it is proper to consider the nature of organizational cognition and knowledge. Nelson and Winter [68] described several aspects of organizational structure they considered to be "organizational tacit knowledge" (i.e., W2 knowledge in Popper's sense) in economic competition, such as routines, formal procedures, plant and equipment layout, jargons, organizational networks, etc. [27],[69]. These conclusions have been reflected in studies of organizational knowledge management in practice [71],[72], [53],[73],[76] ,[78],[79].

These studies only scratch the surface of what is possible using insights from studying organizations as autopoietic (or potentially) autopoietic entities. Such ease of applicability is not apparent from Luhmann's use of autopoietic ideas.

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