BIOLOGICAL NATURE OF KNOWLEDGE IN THE LEARNING ORGANIZATION

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Abstract

This paper combines ideas from disciplines ranging from physics, epistemology and philosophy of science to military affairs, to sketch a scientific framework for studying organizational learning, knowledge and memory. Threads are woven from this background into a generic analytical framework that reveals the biological nature of knowledge in learning organizations. There are many epistemological and conceptual difficulties surrounding the concept of autopoiesis, so most of the present work focuses on explaining it in generic terms, establishing an epistemological framework in which the autopoietic status of any kind of complex system can be evaluated, and then deriving generic concepts of memory, learning and knowledge within the autopoietic framework. The autopoietic status of human organizations is then tested in relation to this framework, and some of the direct implications regarding organizational learning and adaptation are highlighted.

Introduction

Humberto Maturana and Francisco Varela invented the term autopoiesis" (literally, "self-production") for their definition of life applicable to complex systems (Maturana 1970; Maturana and Varela (1980, 1987; Varela 1979, 1994; Varela et al 1974). I consider here within a broader structure of evolutionary epistemology based on Karl Popper's mature works (1972 and later), as informed (a) by Howard Pattee's (1965 and later) ideas on the semantics and semiotic epistemology of physical systems and (b) Steven Gould's (2002) theory of multi-level selection and evolution. I will argue that autopoietic entities may exist at several levels in the structural hierarchy (Simon 1962, Salthe 1985, 1993; Gould, 2002) of life from cells to social systems. Specifically, social organizations such as firms have properties transcending those of their individual members (e.g., Nelson and Winter, 1982), justifying their treatment as autopoietic entities (i.e., meeting formal requirements to be considered living in their own rights). Taking guidance from Boyd (1996); I sketch the biological nature of meaning, learning, knowledge and adaptation within the autopoietic organization, and briefly suggest some implications this has for organizational learning and adaptation.

Autopoiesis

Maturana and Varela developed the concept of autopoiesis to define the characteristics of life at the biochemical/cellular level. Varela et al. (1974; quoted verbatim in von Krogh and Roos 1995: p 46) listed six criteria, paraphrased here, that a complex system must meet to be considered autopoietic:

1. *The system is discriminable from its environment*. Components belonging to the system can be discriminated from environmental components by the system and external observers.

2. *The components of the system are determined by the system*. Components belonging to the system are identified as such by processes intrinsic to the system (self-reference).

3. *The system is dynamic*. Interactions and transformation of components belonging to the system are determined by the system.

4. *The system dynamically maintains its identity*. System processes work to maintain the integrity of the system.

5. *The system intrinsically produces its own components*. Components from the internal or external environment are altered or transformed by system processes to make them functionally and identifiably parts of the system.

6. *The components produced by and forming the system are necessary and sufficient to produce the system*: The system's self production is autonomous.

Maturana and Varela aimed to express the minimal properties a system must have to be considered living. As cellular neurobiologists, they recognised that many kinds of "living" entities did not reproduce (e.g., differentiated nerve cells, worker bees, etc.), so they did not include self-reproduction or evolution as part of their definition.

A recurring question is whether systems of higher orders of complexity than cellular (e.g., multicellular organisms, social systems such as firms or organizations, ecosystems, Gaia), can be considered autopoietic. Varela (1979), Maturana (2002) and others say no. However, with relatively minor modifications autopoiesis can be given general utility as a test for life across several orders of complexity including multicellular organisms and social organizations.

There are two categories of difficulties in Maturana and Varela's original definition:

- Their highly self-referential language makes discourse difficult outside a tight paradigmatic community.
- Excluding reproduction and evolution left the concept without an explicit concept of duration through time.

Mingers (2001) and especially Urrestarazu (2004) have opened up the self-referential and paradigmatic vocabulary by restating core concepts in more phenomenological language.

In my view, canonical autopoiesis is too limited to test whether *any* real-world entity is "living", because it does not require that self-regulation and self-production be sustainable. Although the canon stresses the dynamic nature of self-production and self-regulation, because it ignores reproduction and evolution, most authors have not considered requirements for regulation over historical time. Thus, and for many of the same cogent reasons cited by Ruiz-Mirazo and Moreno (2004) in coming to a similar conclusion, I add "sustainability" to Maturana and Varela's criteria.

7. *The self-produced system is self-sustaining over time*. The system is able to continue producing itself to survive through a period of time.

Homeostasis and Cognition

In a real-world physical sense, homeostatic self-sustainment invokes the dissipative dynamics (metabolism) needed to combat entropic tendencies towards disintegration over time that requires access to potential energy gradients to support the dissipative processes. In the physical world, homeostatic mechanisms are driven by flux(es) of energy and materials. (Prigogine 1955; Priogine et al. 1972; Morowitz 1968; Ruiz-Mirazo and Moreno 2004).

Homeostasis is the cybernetic "capability of a system to hold its critical variables within physiological limits in the face of unexpected disturbance or perturbation" (Beer 1981: 337–341). Beer notes that autopoiesis is a special kind of homeostasis "...in which the critical variable held steady is the system's own organization". Constitutive (structurally coupled) cybernetic processes embodied within the system itself provide self-regulation (e.g., Reiner 1968) in the face of perturbations. This is also roughly Pattee's (1995) concept of "semantic closure" - where the autonomous system uses symbolically encoded "knowledge" derived from experience to maintain its regulative capacity. If perturbations exceed the adaptive capacity of the system's self-regulation, it fails to constrain internal disturbances and "dis-integrates" (i.e., dies).

Maturana (1970) defined "cognition" as the operation of organizationally closed networks of processes: "A cognitive system is a system whose organization defines a domain of interactions in which it can act with relevance to the maintenance of itself, and the process of cognition is the actual (inductive) acting or behaving in this domain." [p. 13]

Cognition in a self-sustaining system thus comprises homeostatic processes within the system responding to perturbations in order to maintain the entity's capacity for self-maintenance and self-sustainment.

The Physical Epistemology of Autopoietic Cognition

Paradigmatic Issues

There are several paradigms of knowledge, and discussions of knowledge or knowledge-related phenomena are fraught with the potential for incommensurable and irrational discourse (Kuhn 1970, 1983; Hall 2004, 2004a). The major knowledge paradigm used in the knowledge management discipline derives from Michael Polanyi (1958, 1966), or Polanyi via Sveiby (1997), or Nonaka (1991; Nonaka and Takeuchi 1995). Polanyi focused primarily on "personal" knowledge that was often tacit in a way that does not encompass many of the kinds of meaning and knowledge of interest here.

Karl Popper (1972, 1974, 1974a, 1982, 1994, Popper and Eccles 1977), extends the concepts of knowledge in ways that inform the development of organizational knowledge theory. Popper's epistemology is more appropriate to studies of organizational knowledge than Polanyi's, but only a few authors addressing the KM discipline, including Firestone and McElroy (2003, 2003a, 2003b), Blackman et al. (2004), Capurro (2004), Gaines (2003), Moss (2002) and myself (Hall 2003, 2003a) reference Popper's ideas.

Karl Popper's Three Worlds and Evolutionary Epistemology

Popper (1972) divides existence and products of cognition into three ontologically related domains called "worlds". I cast my summary in my own terminology:

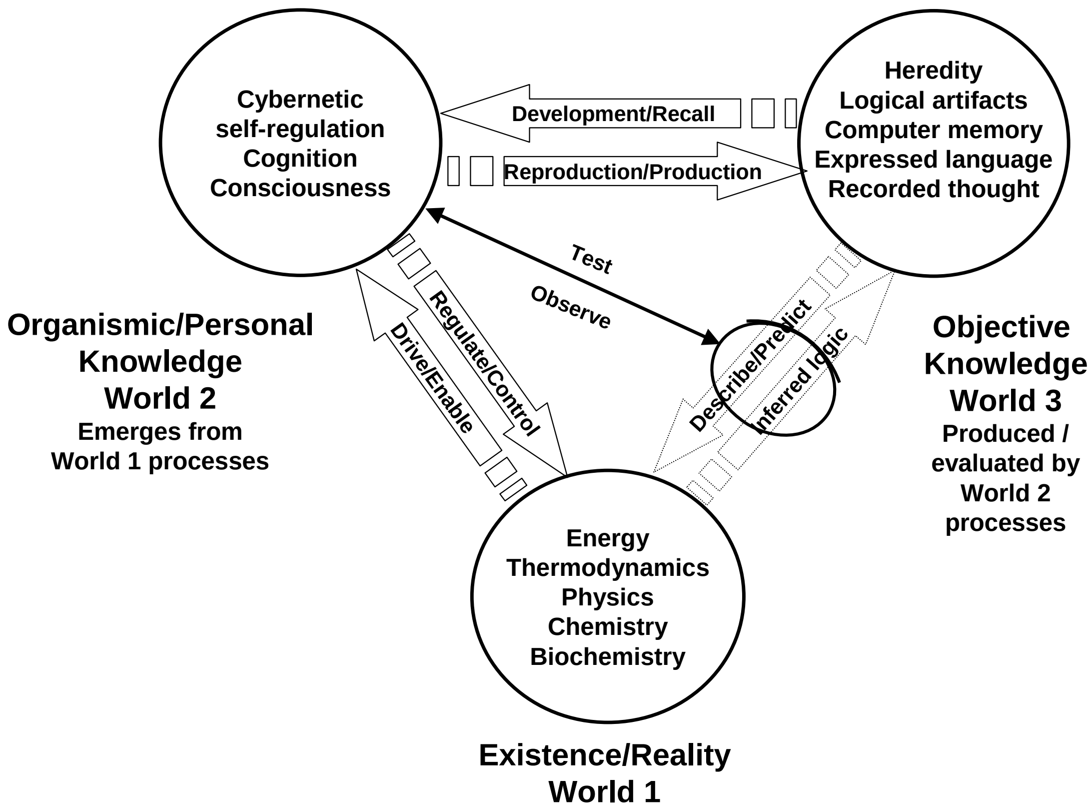

Figure 1. Graphical representation of three worlds of knowledge (from Hall 2003).

- World 1 (W1) is dynamic physical reality governed by universal laws of physics and chemistry, i.e., the world of phenomena and the ultimate "truth" knowledge of the material world tries to represent.
- World 2 (W2) comprises cognition and (eventually) consciousness of discriminable entities formed within W1. Cognitive entities semantically represent and anticipate W1 to maintain their existence in the face of W1 perturbations or change.
- World 3 (W3) comprises persistent logical content produced by cognition e.g. experience-based heredity as semantically encoded in selected nucleotide sequences of DNA molecules, logical content of computer memories encoded in bit patterns, contents of manuscripts, books, libraries, etc. encoded in language. Such logical content is at the same time objective, intangible, and transcendent. The same content exists and can persist independently, both from the cognition that produces it and its original physical carrier in W1 (i.e., the same logical content often can be transcribed from one physical medium to another without losing its meaning).

Relative to his three worlds, Popper (1972: 108–109) states that there are

"...two different senses of knowledge or of thought: (1) knowledge or thought in the subjective sense, consisting of a state of mind or of consciousness or a disposition to behave or to react . . . and (2) knowledge or thought in an objective sense, consisting of . . . problems, theories, and arguments as such. Knowledge in this objective sense is totally independent of anybody's claim to know; it is also independent of anybody's belief, or disposition to assent; or to assert or to act. Knowledge in the objective sense is knowledge without a knower: it is knowledge without a knowing subject."

Extending Popper's concepts, I equate knowledge in W2 to be something akin to a diffuse property of the whole cybernetic system - what Kauffman (1993) and Rocha (1997) call attractor basins. W3 is the domain of semantically encoded artefacts of knowledge able to passively persist for a time "outside" of the dynamic activities of the cybernetic system (Pattee 1995, 2001; Rocha 1997; Rocha and Hordijk 2004; Etxeberria 2004). In the specifically human W3, knowledge was first encoded linguistically.

These senses of knowledge correspond to the vernacular "tacit" and "explicit" (Nickols 2000). Explicit knowledge is the primary focus of Popper's epistemology; and it is, of course, explicit knowledge that information technology is best able to process and manage. By contrast Polanyi (1958, 1966) focuses on personal knowledge, which Popper places in W2.

It may be debated whether Popper would agree with the way I have used his 1972 words to establish a generic three "worlds" framework. However, to formulate a generic epistemology appropriate to all levels of hierarchical complexity, as will be elaborated elsewhere, it particularly suits me to place the symbolically encoded logical content of heredity and computer memory in the same ontological category as content expressed in human language (i.e., in W3).

The value of a "belief" held in W2 (i.e., a cognitively constructed disposition - Popper 1963) to a primitive cognitive entity depends on how adequately the belief "represents" W1. This adequacy is tested in action. If the entity's belief about reality facilitates survival in W1, it has a positive value. If the belief is inadequate, the entity dies (i.e., dis-integrates) along with its belief. In time, entities holding adequate beliefs that survive the consequences of acting on them increase. Thus, for Popper, knowledge is a belief or theory about reality that can be acted on. Whether the belief is "true" can never be proven, if by "proven" we mean "justified as certainly true", but selection by the environment will work to eliminate erroneous knowledge.

Language and writing allow humans to symbolically articulate their W2 beliefs and share the resulting claims as objective W3 hypotheses inferring aspects of W1. These claims can be "scientifically" criticised on the basis of logic and evidence external to the knowing individual. The contents of the linguistically expressed claims are W3 objects, subject to evaluation by W2 cognitive processes—i.e., through subjective or intersubjective criticism. This allows errors to be eliminated consciously, before they cause their carriers' deaths. The relative epistemic values of such artefacts of knowledge are determined by the degree to which they can be or have been criticised and tested, and the results of this criticism.

Popper called this his evolutionary theory of knowledge growth. Conjectures criticised by attempts to refute them (or capable of such criticism) are qualitatively more valuable, in the sense that they do (or can) provide demonstrably more adequate representations of W1, W2, and W3 objects, and their interactions, than claims that have not been (or cannot be) so tested. As new claims are made and criticised to refute and remove clearly inadequate ones, our store of evaluated and tested claims grows in quality and quantity, improving our understanding of reality over time.

Popper (1972) elaborated this idea in his "general theory of evolution" (Popper 1972: pp. 241-245). It bears consideration for its unexpected insights into the origins and development of knowledge in a framework of evolving cognitive entities, but due to space considerations, I provide only a few highlights:

1. All organisms are constantly involved in solving problems of existence ("All Life Is Problem Solving" - the title of a posthumously published book of his essays, Popper, 1999).
2. All problem solving proceeds by trial and error: "new reactions, new forms, new organs, new modes of behavior, new hypotheses, are tentatively put forward and controlled by error-elimination" (Popper 1972: p. 242).

3. "Error-elimination may proceed either by the complete elimination of unsuccessful forms (the killing-off of unsuccessful forms by natural selection) or by the (tentative) evolution of controls which modify or suppress unsuccessful organs, or forms of behaviour, or hypotheses." (p. 242).

4. "Using '**P**' for problem, '**TS**' for tentative solutions, '**EE**' for error-elimination", Popper expresses what he calls his "tetradic schema" (e.g., Popper 1994: 12):

$$\mathbf{P_1 \dashrightarrow TS \dashrightarrow EE \dashrightarrow P_2}$$

where $\mathbf{P_1}$ is an existentially objective survival problem the entity faces, **TS** is a tentative solution (elsewhere it is expressed as **TT** - or tentative theory), **EE** is a process or circumstances for eliminating errors that tests the tentative solution and eliminates it if it doesn't "work", and $\mathbf{P_2}$ is a somewhat changed objective problem the entity faces after having solved or failed to solve $\mathbf{P_1}$.

In other words, although the problem solving process is continually iterated, the cycle is not quite closed. Each iteration is to some degree informed by memories of what survived prior iterations, and the problem is thus somewhat changed as a consequence of this information. For most living things other than self-conscious humans, the tentative solution is expressed in the objective body and behavior of the individual - who survives or dis-integrates based on the success of that expression..

5. Popper notes that there may be multiple tentative solutions to a problem, and all are filtered through the **EE** process (Figure 2). To emphasise the tetradic schema's recursiveness, I have changed Popper's $\mathbf{P_1}$ to $\mathbf{P_n}$ and $\mathbf{P_2}$ to $\mathbf{P_{n+1}}$. I have also drawn in a return loop to remind readers that the schema itself is iterated endlessly in a not quite closed cycle. Having successfully completed a cycle (or generation of selection), the problem situation is changed by prior solutions, and the new tentative solutions may not be the same.

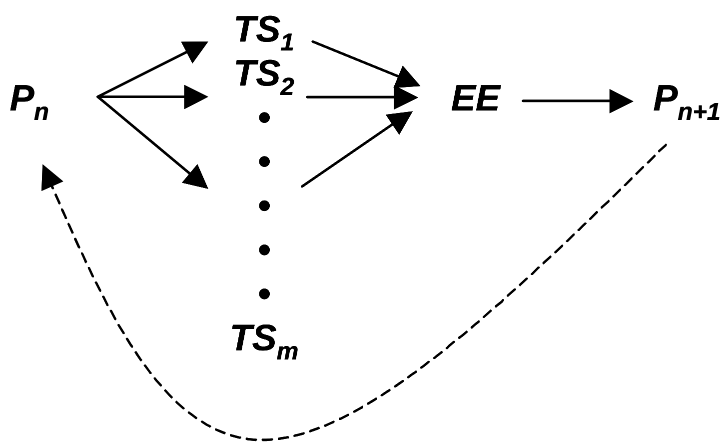

Figure 2 Popper's "general theory of evolution", as modified from Popper 1972 (p: 242 - originally presented in the second Arthur Holly Compton Memorial Lecture, Washington University, 19 Apr. 1965)

6. "Our schema allows for the development of error eliminating controls (warning organs like the eye; feed-back mechanisms); that is, controls which can eliminate errors without killing the organism; and *it makes it possible, ultimately, for our hypotheses to die in our stead.*" (Popper 1972: p. 244 - my italics)

Thus,

"Long before criticism there was growth of knowledge--of knowledge incorporated in the genetic code. Language allows the creation and mutation of explanatory myths, and this is further helped by written language. But it is only science which replaces the elimination of error in the violent struggle for life by non-violent rational criticism, and which allows us to replace killing (world 1) and intimidation (world 2) by the impersonal arguments of world 3." (Popper 1972: p. 84)

Working completely independently from Popper, Howard Pattee developed a biophysical explanation that informs Popper's three worlds and evolutionary epistemology.

Semantic Closure, Symbols And The Origin Of Semiotic Controls

Since the 1950s, Pattee studied the relationship between the physical world, life and knowledge (1965, 1969, 2001), followed by his student Luis Rocha (1997, 1998, Rocha and Hordijk 2004) and others. As discussed above, difficulties in analysing the autopoietic status of complex systems are understanding the self-referential "circular organization" required for autopoiesis, and separating the autopoietic system as an "observer" from what it "observes". Joining Popper and Pattee's epistemologies offers conceptual tools to apply autopoietic concepts to all kinds and orders of complex systems.

Polanyi (1968) outlines fundamental epistemological issues relating to self-referential material systems (i.e., cybernetic systems) and defines the physical concept of a "semantic" relationship that serves as a starting point for Pattee's and Rocha's contributions.

Pattee stresses that for a self-referential system to physically control something within itself, that something has to be observed and measured. The "knowledge" of what response is required must then be triggered by the act of observation and fed back as control information to constrain that which is to be controlled. Pattee calls this self-referent relation "semantic closure". In Polanyi's (1968) terms, syntactic rules establish the boundary conditions, and the boundary conditions constrain the dynamics of the physical processes.

Pattee (2001) is very clear that the required "knowledge" must originate through evolutionary processes of trial and error elimination in living systems. Pattee also states that for an organized entity to be called an "observer" it must have the property of semantic closure. Figure 3 maps Pattee's concepts to Popper's three worlds (Figure 1).

For me, the point where life begins is defined by canonical autopoiesis with the added criterion that the dynamic system must sustain its existence over time by responding adequately to perturbations (Popper's "problems"). Following Pattee, this is where semantic closure is first achieved. At that point the survival knowledge is embodied in the system's cybernetic structure - probably in the form of structural dispositions able to respond differentially to perturbations (i.e., to "classify" or decide), to shift the system's dynamic behavior into one of several different attractor basins (Kauffman 1993) or eigenbehaviors (Rocha 1998 - after von Foerster). This concept is key to understanding the relationship between the constructed nature of knowledge within an autopoietic system and observations of the external world (Rocha 1998). With semantic closure, the newly autopoietic system begins to form a W2.

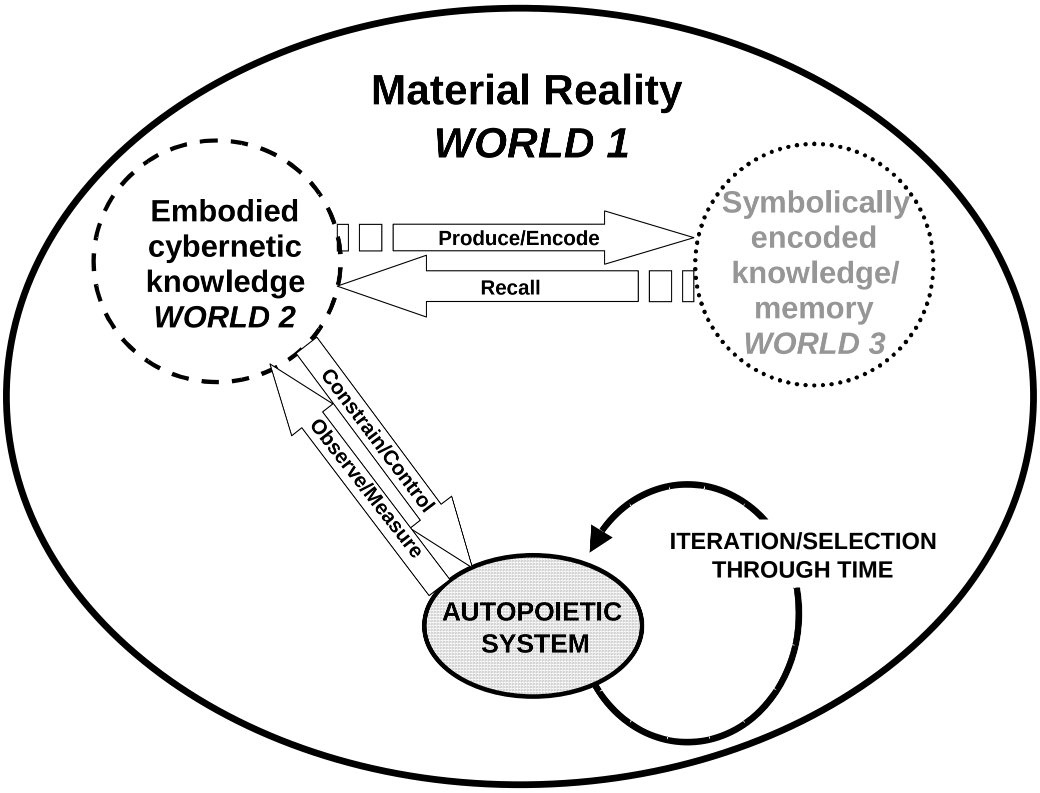

Figure 3. Mapping of Pattee's concepts of semantic closure and symbolic knowledge to popper's three worlds as illustrated in Figure 1.

A situation may be reached where a self-sustaining autopoietic system can feed surplus self-production into material growth and reproduction. Initially, reproduction may result from passive fragmentation caused by perturbations, where sufficient cybernetic self-regulatory and self-productive capacity is retained in some fragments to continue the historical thread of autopoiesis. Once the thread begins to vary and reproduce, selective elimination of less well controlled and efficient "spearheads" will result in evolution (Popper 1972). Continued selection will favor the establishment of coding systems to preserve and reproduce survival knowledge in more efficient formats than provided by the overall disposition or constitution of cybernetic networks. The establishment of a semantic separation between passively persistent codified "knowledge" and dynamic processes regulated by the code is where W3 begins to emerge.

Pattee's (1995) "epistemic cut" names the need to clearly distinguish between "knowledge" embodied or encoded in physical structures and the material world itself. Where the cut is placed in a hierarchically complex system is arbitrary. However, "the cut itself is an epistemic necessity, not an ontological condition": Without establishing such an epistemic cut, any attempt to understand and explain the physics of a self-referential system regresses to infinity.

An epistemic cut between what the subject "knows" about an object and the object itself must be applied whether we, as observers, are trying to describe phenomena external to us, or whether the subject in question is a cybernetic control system and what it observes is the physics of what its knowledge controls.

What do Meaning, Learning and Knowledge Signify in Autopoietic Systems?

In Popper's and Pattee's epistemologies the concept of knowledge only applies to living systems. In its primitive sense, "knowledge" is selectively assembled and control information contributing to survival. The "meaning" of the knowledge is the result of applying the control information. Two kinds of knowledge exist in autopoietic systems. The first is implicitly embodied in the overall cybernetic dispositions of surviving autopoietic systems: this exists in W2 and is what Popper calls subjective knowledge and what Polanyi calls personal or tacit knowledge. The second is control information that has been symbolically encoded in passively persistent structures, where that information can potentially be recalled and decoded to confer survival value at other times and other places from where the initial codification occurred (Rocha 1998; Etxeberria 2004). This exists in W3 and is what Popper calls objective knowledge (Figure 3).

Gaining Strategic Power in Competitive Environments

Sustainable autopoietic systems maintain themselves in steady states far from thermodynamic equilibrium, and must be dissipative to maintain themselves against entropic tendencies to decay and dis-integrate. Dissipation demands transport of fluxes of energy and material from sources of high potential to sinks of lower potential (e.g., Prigogine 1955; Priogine et al. 1972; Morowitz, 1968, Salthe, 1993; Chaisson 2001; Ruiz-Mirazo and Moreno 2004). Potential differences autopoietic entities can use to drive their metabolic/cybernetic processes are physically limited. An inevitable consequence is that at any particular time surviving autopoietic spearheads will compete for them, resulting in natural selection.

John Boyd (1996), a military strategist, considered roles of knowledge and time in winning dogfights between jet fighters (Cowan 2002). However. he recognised that his ideas distilled in the Observe, Orient, Decide, and Act (OODA) Loop (Figure 4) represented a generic cognitive framework applicable to organizations as well as individuals seeking strategic power.

1. **Observing** entails sensing external circumstances, especially focussing on changes resulting from own or competitors' actions. In autopoiesis, "sensing" is attending to the internal disturbances propagating from environmental or internal perturbations.
2. **Orienting** includes complex cognitive processes responding to disturbances (i.e., "data") propagating from observations to assemble a response as enabled by inherent capabilities, tacit knowledge (e.g., organizational routines) and existing knowledge of history. In terms of the epistemology developed here; the processes of measurement and selection of input, recollection, and analysis and synthesis would occur in W2. Genetic heritage encoded symbolically in genes) and memories of history represent knowledge that exists in or may be exchanged via W3. Genetic heritage is immutable within the time span of a single OODA cycle, but iterated cycles ultimately determine what orientation capabilities are available over evolutionary time. Similarly, all kinds of organizational knowledge may be linguistically encoded, stored and retrieved in the form of persistently recorded knowledge, which can be used to constrain cognitive processing in the orientation phase.
3. **Deciding** represents choosing a hypothesis or plan of action for execution.
4. **Acting** assembles and executes the decided response via applying constraints and controls either internally or to the external environment.

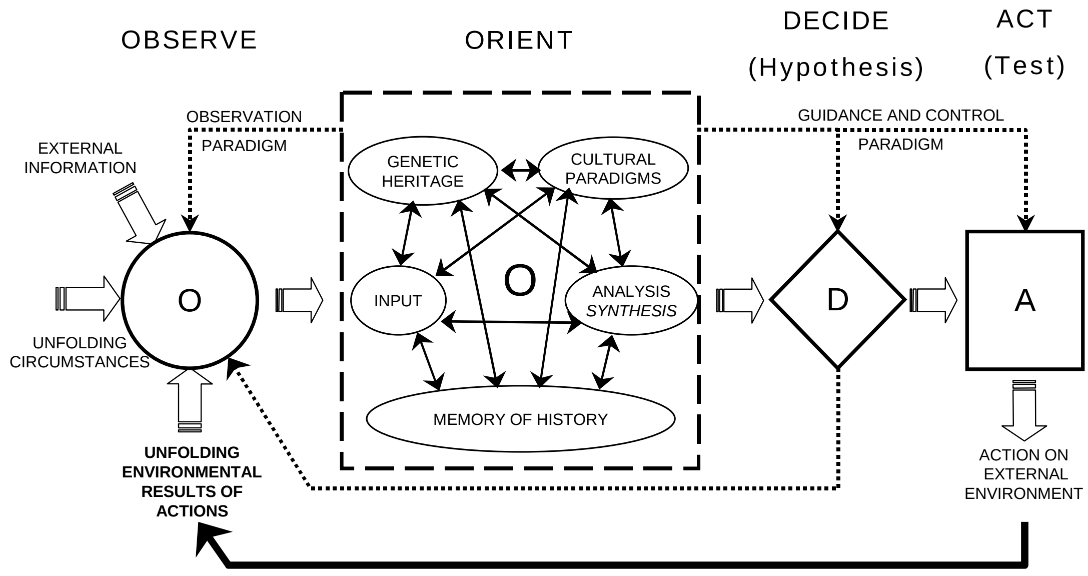

Figure 4. John Boyd's OODA Loop Concept, based on Boyd (1996 - http://www.belisarius.com/modern_business_strategy/boyd/essence/eowl_frameset.htm)

The OODA loop summarises an entity's iterated cognitive cycle of sensation, cognition, hypothesising, and testing to track and improve responses to its dynamic environment. Such cognition involves (cybernetic) guidance and control paradigms for observing, deciding and acting as well as for the orientation process itself. The actions of these paradigms can be observed so they too may be improved. Genetic heritage in an individual's orientation is just that: variation (W3 tentative solutions) is generated independently from need, and the developed logical content is tested over generations of natural selection.

To here, the discussion of knowledge and learning (i.e., the extension of knowledge through iterated processes of selection and/or criticism) has been applicable to any complex autopietic system. It now remains to determine if and when social organizations might be autopoietic, and if so, what conclusions can be drawn from that determination.

Are Organizations Autopoietic?

To an evolutionist, the thought that organizations may be living entities offers an exciting prospect to study at first hand how life emerges from non-living media. Human economic organizations are a new phenomenon in biological evolution, and probably even relatively new in human evolution. If organizations are alive, not only are they at a very early stage of evolution compared to living cells or multicellular organisms, but human observers have a unique viewpoint as active components within the process of organizational life itself that enables insights that cannot be gained from studying organisms with microscopes or dissecting tools. Not only should looking at organizations biologically give us a better understanding of organizational processes and activities, but reflecting what can be learned from organizations about how living things are formed back into biology should give us a better understanding of life in general.

Biological Framework for Analysing Human Organizations

The kinds of human organizations considered here unquestionably involve autopoiesis at some level of organization. Organizations are formed by associations of living human individuals, who in turn are formed by associations of living cells exhibiting autopoiesis. The question is whether the concept of autopoiesis can legitimately be applied to organized entities at higher orders of complexity than cells. This involves understanding different levels of hierarchical complexity and epistemological issues of discriminating complex entities and understanding their relationships to their constituent components.

The first autopoietic entities on Earth were either individual cells or the biosphere considered as a whole. However, as described by Simon (1962), Salthe (1985), Baum and Singh (1994), Chaisson (2001), Gould (2002), and others, when we look either outward or inward from our viewpoint as multicellular individuals, we can see life has evolved a very complex hierarchically nested organization. If entities can be discriminated at other levels of biological organization, how can an arbitrary entity be evaluated to determine if it exhibits the properties of autopoiesis and, consequently "life", in its own right?

Consideration has to be given to placing an epistemic cut between the domain of the observer's description, analysis and modelling of the entity, and the domain of the material phenomena to be described. Stephen Gould's (2002) thinking and insights on the action of natural selection across several levels of biological organization highlight the epistemological stance needed for testing the autopoietic nature of economic organizations.

Epistemological Framework for Analysing Human Organizations

Baum and Singh (1994), using some of the same sources Gould used (e.g., Hull 1980), suggest that organizational evolution follows from complex interactions between two categories of processes in hierarchies of entities relating to these processes: "ecological entities" corresponding to Gould's "interactors" and "genealogical entities" corresponding to Gould's "replicators".

Following Gould (2002), my **focal level** (i.e., my "epistemic focus") is the human economic organization, where the organization, such as a firm, is the **individual**. Its **parts** are (a) the people who participate in the organization, (b) its physical assets and (c) its physical heredity is comprised of knowledge about the organization embodied in its human members as objects and encoded in its routines, procedures and other documentation. Its **collectivity** is the industry to which it belongs. And, the environment of primary concern is that of its economic relationships required for its sustained existence.

Pattee's (2001) epistemic cut needs to be placed just below the focal level, where the organization is discriminable in its own right, and the material dynamics of its high level parts. In Urrestarazu's (2004) terms, to assess whether human organizations can be considered to be autopoietic, I place human members, physical assets and the inherent dynamic properties of these parts in the "phenomenological domain". The organization itself and the dynamic interactions its parts belong in the "biological domain". The organization's symbolically encoded knowledge (not considered by Urrestarazu) and our analysis and descriptions are in the languaging domain.

Many Organizations Meet All the Criteria for Organizational Autopoiesis

By taking human economic organizations as the epistemic focus, the evidence robustly supports the claim that at least medium to large firms are autopoietic, thus possessing all of the properties of life appropriate to that focal level.

1. *The organization is discriminable from its environment.*

   Within the collectivity of an industry most organizations are readily discriminable based on their economic identifiers, e.g., corporate names and logos on transactions, records of ownership of physical assets, contractual agreements; physical aggregation of most of its activities in particular locations; etc. Most importantly, although individual people are members of an organization for only parts of days for parts of their lives, they are "tagged" in a variety of ways as members of the organization for that fraction of their life that is important to the organization using membership and business cards, employment agreements, wages and salaries, oaths of allegiance, acceptance of creeds, wearing of uniforms, etc.

Some argue that an autopoietic organization must necessarily be despotic. However, this misrepresents the exchanges bind its human parts into the organization. As autopoietically dissipative individuals in their own right below the focal level of the organization, and for their own strategic interests, people offer their capabilities for resources they require from the organizational environment in order to maintain themselves as autonomous individuals within the individual focal level. Although the boundary of an organization may seem quite diffuse from the situated point of view of a human observer belonging to several organizations simultaneously, there is rarely any ambiguity regarding the location of organizational boundaries at the focal level in the economic environment.

2. *The components of the organization are determined by the organization*.

   The identifiers described above are applied to the high level components by processes of the organization. Specifically, purchasing and receiving activities acquire and identify physical assets, legal documents identify the ownership intangible assets, humans become members of the organization through specific induction processes, the signing of employment agreements, etc.

3. *The organization is complex*.

   The fabric of an organization is comprised of many and varied physical, human, and economic components that in many cases are complex in their own rights.

4. *The organization is dynamically self-regulating*.

   Most organizations have routines, processes and procedures that are primarily regulatory. These include such things as corporate accounting systems, personnel systems, purchasing and procurement systems, sales and marketing systems, etc., which provide homeostatic functions to maintain the organization.

5. *The organization intrinsically produces its own components*.

   As defined by Urrestarazu (2004), production is a process within the system that alters a component from the organization's environment in so that it becomes a constituent part of the system. Organizational processes such as personnel recruitment, induction and training; acquisition and procurement; etc. are all well-understood production activities in this context.

6. *The organization's self-produced components are necessary and sufficient to produce the organization*.

   It is probably fair to say that most well established organizations do all of those things necessary to maintain their integrity as economically viable entities. The processes for such self-production are embodied in the organizational structure itself and semantically encoded in organizational memory in the form of written processes and procedures.

7. *The self-produced system is self-sustaining over time*.

   Many organizations have life spans longer than the association of any of the organizations' human members.

As elaborated in the next sections, organizations "learn" and adapt to changes in their physical, economic, and competitive environments both through selective processes working on organizational tacit knowledge (Nelson and Winter 1982; Baum and Singh 1994), and conscious choices made by people embedded in corporate procedures (Popper 1972; Firestone and McElroy 2003, 2003b).

Organizational Memory and Heredity

Tacit organizational knowledge is embedded in physical and cybernetic structure in routines, in connectivity provided by physical layout, organizational jargons, etc., or is embodied in and shared among people belonging to the organization from time to time (Nelson and Winter 1982). Explicit organizational knowledge is symbolically encoded for distribution and processing in a variety of physical documentation. together they form an organization's heredity or memory. Organizational learning can be said to be those cognitive processes within the organization that contribute to the growth and value of its knowledge through time. Organizational learning addresses the need for an organization to adaptively track its unpredictably changing and competitive environment.

The Cybernetics of Organizational Learning, Adaptation and Evolution

John Boyd's (1996) OODA Loop concept (Figure 4) summarises the cybernetics of learning in organizations and individuals consistent with Popper's general theory of evolution (Figure 2). Each step of the OODA loop will be considered in turn.

1. *Observing*.

   As an autopoietic observer (von Glaserfeld, 2001; Krippendorf 1993; Riegler 2001), the focal organization's cognitive processing relating to the external environment is limited to dealing with internal disturbances caused by perturbations or semantically encoded information. Encoded observations may be formed through semantic processing, received from other autopoietic entities at the focal level, or from hierarchically higher (e.g., governments) or lower focal levels (e.g., individual people). However received, informal or formal organizational cognitive processes within the organizational structure further classify, store, retrieve, transmit and transform observations.

2. *Orienting*.

   Orientation (Figure 4) encompasses the bulk of the organization's cognitive processing. If not ignored, observations may trigger more complex processing as determined by memory of history, heredity and "cultural paradigms" - which in the case of an organization may be tacit organizational routines (Nelson and Winter 1982) and/or lower-level paradigms held by human parts of the organization. Analysis (Boyd's "destruction", Popper's "criticism") of the currently held world model eliminates false and inconsistent observations and hypotheses. Synthesis (Boyd's "creation", Popper's tentative "theories" or "solutions") semantically links existing knowledge and observations into an updated world view comprised of

   - new information,
   - filtered and re-linked memories of prior experience (which may be explicit, implicit or even tacit),
   - organizational heritage (as defined above),
   - cultural traditions (i.e., paradigms) or tacit organizational knowledge, and
   - possibilities for action.

3. *Deciding*.

   Decision selects amongst possible solutions generated by the orientation, actions to try. Choice is governed and informed by

   - the new possibilities for action, and
   - tested knowledge based on prior experience gained from previous OODA cycles

4. *Acting*.

   Action involves putting the decision to test by applying it to the world. The loop begins to repeat as the entity observes the results of its action

Through iteration, observation and orientational comparison of results of observed actions with memories of earlier iterations, the modelling and understanding of external reality approaches the "truth" of that external reality. From an organizational point of view, this may be said to be "conscious" organizational learning to improve organizational adaptation.

Natural selection at the focal level of organizations is a function of the capabilities of the one organization by comparison to competing organizations in the economic environment. An organization whose OODA cycle is faster and more effective than its competitors will be able to observe and change the environment to its strategic benefit before competitors can fully orient to and act on changes (Boyd 1996). Consequently, competitors may make more mistakes and be less efficient in their economic activities than the faster and more effective organization. On average, organizations with faster and more accurate cognitive processing will grow to replicate ("plurify" is Gould's 2002 term) and diversify the knowledge that has enabled their comparatively greater effectiveness. Less effective organizations will shrink through loss of strategic control over necessary resources, and if they lack the knowledge to move into areas where they are competitively successful, bankruptcy and dis-integration are inevitable - selectively removing their inadequate knowledge from the population. This is "learning" through natural selection.

Conclusion and Many Questions for Further Research

Thus, organizational memory is organizational heredity. Organizational heredity is comprised of the genetic capabilities of its constituent human parts plus persistent forms of knowledge such as articles of incorporation, systems used to tag individuals as members of the organization, corporate manuals, routines, procedures, and other persistent forms of knowledge governing interactions of individuals in the organization serving to maintain organizational integrity in a dynamic economic environment. Orientation includes the key activities for learning new knowledge for adaptation. Organizational learning produces adaptation in both evolutionary and developmental senses. And the learning organization at the focal level of human economic organizations is considered to be a viable autopoietic and evolutionary (i.e., biological) entity.

I have sketched an epistemology and model of organizational biology that provides a scientific framework for constructing, testing, and falsifying claims about how organizations actually work. Many current studies and practices in knowledge management, are based on only limited views of what constitutes knowledge in the organization and have not been conducted within any visible framework for understanding the organization's survival imperatives, or how the knowledge and processes being studied relate to the organization's overall strategic aims. To date, much of the published work in knowledge management has been descriptive and classificatory, corresponding to the kind of "natural history" work biologists did prior to Charles Darwin's (1859) Origin of Species. I believe that the framework presented here will lead towards the development of a sounder theoretical basis for studying knowledge and learning in organizations.

An interesting area for further research will be to determine the autopoietic status of other kinds of social organizations, such as extended families, work groups and departments within organizations, street gangs, sporting clubs and associations, government institutions and states and nations. Are there lower or higher levels in the social and/or economic hierarchies that can be validly treated as autopoietic?

Still more interesting will be to explore the boundaries of the autopoietically learning organization. Most enterprises are founded by individual entrepreneurs, or as entrepreneurial partnerships or family concerns. They initially represent the economic activities of a single person, or small group and are managed as autocracies. However, if the business grows, at some point it begins to take on a life of its own. What happens in such transitions to cause the emergence of life? Answers here will provide some interesting feedback into studies on the origins of biological life, the possibilities for artificial life and forms of life not based on macromolecules with carbon background.

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