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Exploring the Foundations of Organizational Knowledge

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Exploring the Foundations of Organizational Knowledge¹

Abstract

If knowledge management is to be more than an art, it needs to be based on a sound epistemology and understanding of organizations. We present a paradigm and an ontology of organizational knowledge based on Karl Popper's 1972 and later works on evolutionary epistemology, Maturana and Varela's concept of living things as self-producing complex systems ("autopoiesis"), and theories of hierarchically complex systems. This approach to ontology development leads us to conclude that organizations can become living systems and thus have emergent properties of a higher order than the sum of the parts. We develop this theoretical argument by providing examples of how several different types of knowledge created by people within organizations emerge and change through time. We suggest the social processes of creating these different types of knowledge give rise to meta-levels of organization that act to maintain the existence and coherence of organizations. We think that our ontology improves the basis for understanding the nature of knowledge that is important for proper organizational functioning. We draw out recommendations about the management of transformations between personal and organizational knowledge. We propose this biological understanding of knowledge in organizations because as practitioners, we think it provides a way of interpreting the dynamics of what actually happens in the realm of managing organizational knowledge. Thus, we lay a foundation for better understanding the considerable challenges associated with developing a practical approach to organizational knowledge management as a result.

Keywords: Knowledge Management, Evolutionary Epistemology, Knowledge Ontology, Organization Theory, Autopoiesis, OODA Loop

*The endless cycle of idea and action,
Endless invention, endless experiment,
Brings knowledge of motion, but not of stillness;
Knowledge of speech, but not of silence;
Knowledge of words, and ignorance of the Word.
All our knowledge brings us nearer to our ignorance,
All our ignorance brings us nearer to death,*

....

*Where is the Life we have lost in living?
Where is the wisdom we have lost in knowledge?
Where is the knowledge we have lost in information?*

[T.S. Eliot - Choruses from the Rock, Faber & Faber, London, 1934]

INTRODUCTION AND SCOPE

As recognized by Baskerville and Meyers (2002), Katerattanakul et al. (2006), Gregor 2006, and Furneaux et al. (2007) Information Systems (IS) is an applied discipline referencing theories from a variety of other disciplines. But it also aspires to serve as a reference point in relation to other disciplines concerned with understanding the roles and management of information and knowledge in organizations. Gill and Bhattecherjee (2009) suggest that IS has not yet achieved sufficient status as an "informing" discipline to give its practitioners reasonable security in the academic hierarchy. Following Kuhn (1962, 1983), we think that the IS discipline is still pre-paradigmatic, with little foundation theory of its own that draws upon explanatory theories from a variety of "reference" disciplines. An apt historical comparison for IS was the state of natural history in the 19th Century before Darwin's Origin

¹ This paper is derived from and extends ideas first presented by Richard Vines, Luke Naismith and William P. Hall in a conference paper, "Exploring the foundations of organisational knowledge: An emergent synthesis grounded in thinking related to evolutionary biology", presented in the actKM Conference, Australian National University, Canberra, 23-24 October 2007.

of Species and the early 20th Century rediscovery of Mendelian genetics that provided the foundation theories for what became today's biological sciences.

Significant indicators of IS's pre-paradigmatic status are the ambiguities, confusions and debates over such basic concepts of "information" and "knowledge" in relation to management (Hildreth and Kimble [2002](#); Stenmark [2002](#); Wilson [2002](#); Miller [2002](#); Bates [2005](#); Land [2009](#)). More specifically, a recent review focusing on knowledge management's "foundation" theories (Baskerville and Dulipovici [2006](#)), clearly illustrates the ad hoc nature and lack of coherence of the diversity of theories (many sourced from other disciplines) claiming to explain aspects of the discipline. There are so many theories that a taxonomy is needed to categorize them and a matrix (with many blank spaces) is required to indicate how they cite and reference each other. Baskerville and Dulipovici do see some signs of "cohesion" and development of "overarching theories" such as "knowledge strategy", "knowledge creation", and "knowledge transfer/reuse", but these still only explain aspects of the dynamics of organizational knowledge. A proper "foundation" theory should provide a single coherent framework for the whole discipline.

A major source of the uncertainty over what information or knowledge management entails may be because these disciplines are largely based on paradigms sourced from the social sciences (McKelvey [1997](#), [2002](#), [2002a](#); [2003](#)). What is often not considered when looking at organizations and knowledge from the purely sociological point of view is that the increasing use of various tools and production technologies to extend human physical capacities caused many changes in organizations and organizational governance, such that it is useful to consider "socio-technical" organizations comprised of people plus their machines and technologically mediated processes (Harvey [1968](#)). Over the last 30 years, in addition to the ways humans organize to produce physical products, use of tools such as personal computers and the internet that act to extend human cognition have even more radically revolutionized the way people interact in organizations (Hall [2006b](#); Yakhlef [2008](#)). People in today's socio-technical organizations are cognitively knitted together with a wide variety of technologies (e.g., Hall [2006b](#); Hall et al. [2008a](#); [2010](#); Hall and Kilpatrick [2011](#); Nousala et al. [2011](#)) that support distributed decision-making processes extending beyond the mental bounds of human bodies. The result is what Pepperell ([1995](#)), Hayles ([1999](#)) and Yakhlef ([2008](#)) consider to be a "post-human"² condition where humans as organisms and their technologies essentially become inseparable. Paradigms from the traditional social sciences do not encompass or adequately illuminate this post-human complexity (Yakhlef [2008](#)).

We suggest considering these matters from a new point of view. McKelvey ([1997](#)) calls for the development of a "quasi-natural" organization science. Gregor ([2009](#)) suggests this should be constructed building on Simon's ([1996](#)) sciences of the artificial as informed by traditions of the philosophy of science. Following Gregor our central claim is that organizations need to be understood as complex socio-technical systems exhibiting emergent properties that evolve spontaneously in unanticipated directions (Hayles [1999](#)). Going beyond Gregor, we believe a new "biological" paradigm of organization based on Karl Popper's ([1972](#)) evolutionary epistemology, Maturana and Varela's ([1980](#)) concept of autopoiesis, and the theory of hierarchically complex systems (Simon [1962](#), [1973](#), [2002](#); Pattee [1973](#), [2000](#); [2007a](#); Salthe [1985](#), [1993](#), [2004](#); Hall [2011](#)) provides the conceptual framework for understanding the roles and growth of knowledge in socio-technical organizations. These ideas at the core of our approach have long histories on the fringes of their respective disciplines. However, the synergistic synthesis we present here is new and provides a coherent foundation theory for information systems and a variety of other disciplines

² In our use of the term "post-human" we do not imply any deep philosophical implications, but only the literal fact that aspects of human cognition are extended, distributed, and may even be shared beyond the physical limits of human bodies.

concerned with the acquisition, development and management of knowledge in complex organized systems.

Evolutionary epistemology was established in the cognitive sciences by Campbell ([1960](#), [1974](#), [1991](#)) and in philosophy by Popper ([1935](#), [1963](#), [1972](#), [1994](#)).

The concept of autopoiesis (“self” + “production”) as a set of criteria for recognizing when a complex adaptive system would be considered to be living was developed in the 1970s by the neurobiologists Maturana and Varela (Varela et al. [1974](#); Maturana [1980](#), [2002](#); Maturana and Varela [1980](#); Varela [1980](#)) and is being refined and restated by Maturana’s student Hugo Urrestarazu ([2004](#), [2011](#)) and Hall ([2006a](#), [2011](#)).

The theory of hierarchically complex systems was developed progressively from several threads, respectively from viewpoints in organization theory (Simon [1962](#), [1973](#), [2002](#)), philosophy (Koestler [1967](#), [1978](#)), biophysics (Pattee [1973](#), [2000](#)), and evolutionary biology (Salthe [1985](#), [1993](#), [2004](#)).

Each of these ideas independently has had some recognition but only minor take-up in organization theory or in the information and knowledge management disciplines, e.g. Popper’s work via Firestone and McElroy ([2002](#), [2003](#), [2003a](#), [2005](#)); autopoiesis via Luhmann ([1986](#), [1990](#), [1995](#)), von Krogh and Roos ([1995](#); von Krogh [1998](#)) and Magalhães ([1998](#); Magalhães and Sanchez [2009](#)); and hierarchy theory via Simon ([1996](#)). However, despite their completely independent and very different paradigmatic lineages, these three sets of theory are mutually supportive, and as we review here, the resulting synthesis (Hall [2003](#), [2005](#), [2006a](#), [2011](#); Hall et al. [2011](#)) offers a unified theory that provides a foundational framework for understanding organizational processes and systems for building and managing information and knowledge.

Thus, the purpose of this paper is to outline this biological paradigm and to develop and elucidate a theory-based ontology of organizational knowledge within this framework. We do not defend the biological paradigm itself – this is done elsewhere (Hall [2003](#), [2005](#), [2006a](#), [2006a](#), [2011](#)). At this point in its development the paradigm is still somewhat speculative, but despite this Vines has agreed to collaborate with Hall for the purposes of this paper. (The authors discuss their differences in Appendix 1.) We both think that this abductive type speculation properly allows for a useful exploration of a foundation and framework for understanding the emergence and growth of socio-technical organizations and the flows of information and knowledge associated with them. We explore relationships and differences between personal knowledge and knowledge pertaining to whole organizations and some of the ways in which knowledge serves to bind humans together to form a higher order organizational entity existing in its own right. We think some of these higher order entities exhibit many of the emergent properties that provide a basis for the claim that these organizations could be considered to living “biological” entities in their own right.

Although the present work is largely theoretical, it derives from our practical experiences as information and knowledge managers. Based on their consulting experiences, Vines and Naismith ([2002](#)) adapted the concept of the Knowledge Life Cycle (Firestone [1999b](#); McElroy [1999](#), [2002](#); Firestone and McElroy [2002](#)) and concluded that knowledge management is an essential component in maintaining organizational viability and growth. Working in parallel, Hall – who was an evolutionary biologist before moving into industry – and associates from diverse backgrounds working in engineering knowledge management environments, developed a “biological” concept of organizations (Hall [2003](#), [2003a](#), [2005](#), [2006a](#), [2011](#); Dalmaris [2006](#); Dalmaris et al. [2006](#); [2007](#); Hall et al. [2005](#), [2007](#), [2008](#), [2010](#), [2011](#); Hall and Nousala [2007](#), [2010](#); Martin et al. [2009](#); Nousala [2006](#); Nousala et al [2005](#); [2007](#), [2009](#), [2011](#); Nousala and Hall [2008](#)). This multidisciplinary framework provides a theoretical foundation for the Firestone & McElroy and Vines & Naismith (loc. cit.) concepts about “knowledge life cycles” and “business knowledge support systems”.

Unlike descriptive ontologies developed from practitioner and researcher interviews (Earl [2001](#); Holsapple and Joshi [2004](#)), the theory-derived ontology developed here derives from three premises about knowledge, life and organizations: (1) All knowledge is constructed by living entities. (2) For an autonomous organization to live, knowledge necessary for the maintenance of its life must be embodied in the dynamic processes and structures comprising the entity. (3) Entities with the necessary properties to be considered living can be distinguished at different scalar levels of organization e.g., living cells, multicellular organisms including individual humans, superorganisms (ant and bee colonies, etc.), nation-states, and for our purposes here at least some economic and social organizations (Hall [2006a](#), [2011](#)). The basis for these premises is detailed in the works by Hall and his associates cited above and are the subject of ongoing work outside the scope of the present paper.

We accept that many organized systems that involve people in their dynamic structures do not meet all of the necessary criteria to be considered living (i.e., autopoietic). Also, there is a very fuzzy borderline between complicated organized systems of people on one hand, and on the other, complex adaptive organizations that in some cases exhibit all the necessary properties to be considered “living” entities. As we will show, knowledge, both at the individual level and as embodied in the higher level organization is the glue that binds the components of complex systems into living entities. To be able to analyze various organizational forms, the formation and use of knowledge in them, and their relationships to other organizations involving humans, we need a vocabulary that includes the possibility that some organizations are living. Thus, our focus here is to develop a theoretical ontology based on the above premises for discussing cognitive processes in individual humans and processes of organizational cognition within which people interact to construct and maintain the structures and processes that give life to that organization, both with one another and with technological components forming the living organization. As we will highlight, we draw upon the theory of autopoiesis (Maturana and Varela [1980](#), Maturana [2002](#), Varela et al [1974](#)) as a necessary definition for what it means for a socio-technical organization to be considered living entity.

BIOLOGICAL BASIS FOR ORGANIZATIONAL EPISTEMOLOGY

What is knowledge?

In knowledge management there are almost as many definitions of knowledge as there are practitioners, to say nothing of arguments about the meanings of and relationships between data, information and knowledge (e.g., Stenmark [2002](#), Land [2009](#)). In the pragmatic world of organizational management, “knowledge” supporting organizational decisions needs to represent the world as it exists, not as people might want to believe it is. Critical scientific realism (Niiniluoto [2002](#)) is a philosophical stance accepting that our knowledge of the world is constructed internally but that there is also an external reality that we strive to understand by criticizing the gaps between our claims about the world and what actually happens. In this framework, knowledge is considered to be “true” if it corresponds to reality. Critical scientific realism and several other different philosophical paradigms for determining truth in the context of knowledge management are discussed by Mingers ([2008](#)). An important thread deriving from critical scientific realism not mentioned by Mingers is evolutionary epistemology, as espoused by Donald Campbell, Konrad Lorenz, and Karl Popper³. This is

³ Although Mingers cites Popper’s early work on “critical rationalism” (Popper [1935](#), [1963](#)), he makes no reference to Popper’s later thinking that Firestone and McElroy (e.g., [2002](#), [2003](#), [2003a](#), [2005](#)), Blackman et

the epistemological basis for our work here. Donald T. Campbell (1974), first coined the term “*evolutionary epistemology*” for application in the social and cognitive sciences. However, Campbell credits Popper with originating evolutionary epistemology and with expressing its fundamental perspective in *Logik der Forschung* (1935). Bartley (1976) discusses the role Konrad Lorenz had in the genesis of evolutionary epistemology. Both Campbell (1960, 1991) and Popper argued that knowledge is constructed in living things as they adapt to the world. Popper argued that no objective truth could be proved - only that certain claims could be shown to be in error through tests or criticisms of the claims as they impact reality (Popper 1935 [1959], 1963). From this, as will be detailed below, Popper argued that claims to know are cognitively constructed and could be tested only through their successes and failures in responding to external reality, i.e., as solutions to problems of life. In other words, the truth of any claim’s correspondence with an external reality can never be known with certainty. However, such constructed claims may stochastically approach a correspondence with reality through repeated criticism, testing and the elimination of errors.

Here we adopt Popper’s (1972) broad concept deriving from evolutionary epistemology that “*knowledge is solutions to problems*” – or at least claims towards solutions. More technically, we use the term “knowledge” very generically for “*control information*” (Corning 2001) a cell, organism or organization uses to cybernetically control the maintenance of its existence and responses to its environment (Hall 2006a). As we develop in later sections of the present work, This broad definition of knowledge encompasses the more specific ideas of “*data*”, “*information*”, “*knowledge*”, “*intelligence*”, and “*wisdom*” (Ackoff 1989; Hall 2003, Rowley 2007), although the more specific terms are useful in particular contexts. For Popper (1972), human knowledge grows through iterated interactions of three ontological domains or “worlds”.

Karl Popper’s three worlds and evolutionary theory of knowledge

To suit our discussions of knowledge deriving from Popper (1972, 1978, 1994) across different orders of complexity, our ontology development begins with defining three ontological domains or “worlds”.

- “*World 1*” (W1)⁴ includes everything physical without interpretation⁵.
- “*World 2*” (W2) is the world of cybernetics, cognition and “living” knowledge in the broad sense⁶. Popper includes “*subjective knowledge*” (i.e., the subject’s personal knowledge), or “*dispositional knowledge*” (i.e., the subject’s structurally determined propensity or disposition to act in a certain ways in particular circumstances) in W2, which approximates Polanyi’s (1958, 1966) personal or ‘tacit’ knowledge.

al. (2004), Blackman and Henderson (2007), Capurro (2004) and Hall (loc. cit.) have applied to knowledge management.

⁴ Our use of the abbreviated terms W1, W2, and W3 is a reminder that the concepts we use in this work are defined somewhat differently from Popper’s worlds 1, 2, and 3.

⁵ Vines notes that in his Tanner Lecture, Popper (1978) stated: “we can subdivide the physical world 1 into the world of non-living physical objects and into the *world of living things*, of *biological* objects; though the distinction is not sharp”.

⁶ Vines also notes that in the same Tanner Lecture Popper (ibid) suggested that world 2 can also be subdivided in various ways: “We can distinguish, if we wish, fully conscious experiences from dreams, or from subconscious experiences. Or we can distinguish human consciousness from animal consciousness”.

- “World 3” (W3) includes all kinds of persistently encoded⁷ knowledge (e.g., hereditary information in DNA, written documents, electronically encoded information etc. – Popper [1972](#): pp. 73-74). Codified knowledge is “objective” because its logical content can exist and persist in W3 logically encoded in the physical structure of a W1 container (e.g., as marks on paper, sequences of binary bits in a computer memory, etc.) independent from the “knowing subject”, and can be decoded in W2 with similar subjective meanings by different subjects.

It is arguable that our biological point of view shades these concepts in ways Popper did not intend (Firestone, pers. comm.). However, the distinctions between the three worlds as made here⁸ provide the basis for the coherent development of additional concepts.

A fundamental question is, *How does knowledge emerge?* We think evolutionary epistemologies have something important to say about this question. Popper argued that no objective truth could be proved - only that certain claims could be shown to be in error through tests or criticisms of the claims as they impact reality (Popper [1935](#) [1959], [1963](#)). However, a theory referring to W1 can be constructed and shared verbally by entities in W2 and (optionally) be expressed or “*codified*” in the form of persistent W3 content. Through iterated testing and intersubjective criticism to eliminate errors, what is asserted in W2 or W3 can approach correspondence with W1’s reality, as Popper ([1972](#)) explains in his “tetradic schema” or “general theory of evolution” (Figure 1).

P_n is a “*problem situation*” the living entity faces in the world, TS_m represent a range of “*tentative solutions*” or “*tentative theories*” the entity may act on or propose. TS s may even be randomly generated (cf. Campbell’s ([1960](#)) “blind variation”). EE (“error elimination”) represents a process by which TS s are tested or criticized against the world to selectively remove solutions or claims that don’t work in practice (this is the converse to Campbell’s “selective retention”. P_{n+1} represents the now changed problem situation remaining after a solution has been incorporated. As the entity iterates and re-iterates the process (the arrow indicating iteration is added by Hall), it will construct increasingly accurate representations of and responses to external reality, even where there is no possibility for knowledge to directly “reflect” external reality. Thus, the value of knowledge is determined in practice by the extent to which workable solutions to pressing problems are constructed or identified and exploited (Dalmaris et al [2006](#); Hall et al [2007](#), [2011](#)).

⁷ Popper (1978) said of world 3 objects: “Of most though not of all world 3 objects it can be said that they are *embodied*, or *physically realized*, in one, or in many, world 1 physical objects”. In our explanation of World 3 we have chosen to use the term *encoded* rather than *embodied*. We do this because for the purposes of this paper we want to emphasise the *relationship* between people and world three objects. We contend that human intelligence is used in the processes of encoding (writing and authoring) and decoding (apprehending via activities such as reading) W3 content. We contend this matter has significant implications for the design of socio-technical organisations and the relationships between people and machines / computers in such organisations. We also note that embodied knowledge is reflected in the dynamical structure of the living entity, while encoded knowledge is impressed onto the structure of carrier structures in the form of energy degenerate states that are physiologically comparatively inert (Pattee [2005](#), [2006](#), [2008](#)).

⁸ Hall observes that although Popper in his later books appeared to have a biological approach to his development of a theory of knowledge, Popper did not have a scientifically comprehensive understanding of evolution or the cognitive sciences. Bartley ([1976](#)) notes that Popper and Konrad Lorenz, the Nobel laureate ethologist, were boyhood friends and both students of the philosopher-psychologist Karl Bühler. Popper described his worlds in philosophical terms, while Hall ([2006a](#) and [2011](#)) has reformulated them in physical and biological terms. Hall’s distinctions separate the intangible cybernetic phenomena of life (W2) from the raw physical dynamics of moving particles (W1) – for which see the discussion beginning on the next page of Pattee’s concept of the epistemic cut; and the dynamic structure of life in W2 from the inert but potentially decodable imprint of knowledge in W3, that is also separated from W2 by an epistemic cut. Popper (1973) considered that articulated language as thought or speech belonged in W3. For reasons discussed in footnote 11, Hall limits W3 to persistently encoded/imprinted knowledge.

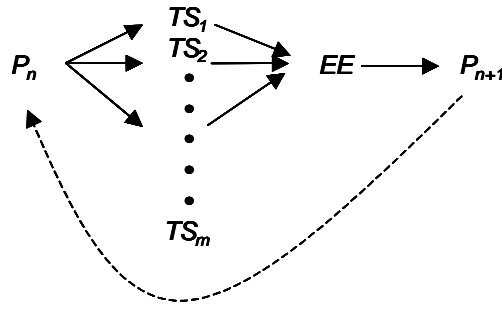


Figure 1. Popper's "general theory of evolution" (From Hall [2005](#), after Popper [1972](#): pp. 243).

Heritable knowledge may be constructed over evolutionary time via Darwinian natural selection, i.e., by random variation in heritable "solutions", the selective elimination of variants that fail to solve their problems of life, and the hereditary transmission solutions that have proved to be viable. Where solutions are represented in individual cognition, through continuously iterated cycles of problem solving (i.e., through testing tentative solutions and eliminating those that fail), the entity constructs increasingly accurate knowledge about the world it is living in. These interconnected ideas formed the basis of Popper's (1972) "general theory of evolution" and "growth of knowledge" that takes place in living entities (Figure 1).

The concept that Howard Pattee ([1995](#), [2000](#), [2001](#), [2006](#), [2007](#); [2008](#)) called the *epistemic cut*⁹ provides an account of the biophysical basis for Popper's three worlds or domains. This has also been called the "*Heisenberg cut*" (Graben & Atmanspacher [2009](#)), that relates to Wolfgang Pauli's ([1950](#), [1952](#)) principle of complementarity. The epistemic cut should not be confused with the "*epistemic gap*" separating "phenomenological knowledge" from "physical knowledge" (Alter & Walter [2006](#); Chalmers [2006](#)). Not only are the paradigms surrounding the "cut" and the "gap" quite different, but "epistemic gap" relates to forms of human consciousness, not fundamental aspects of living things. Pattee's "cut" relates to the ontological difference between uninterpreted physical reality on one side and information about that reality on the other side, i.e., the cut is between physical reality and knowledge of the physics.

Pattee argues that there is a strict ontological separation (in physical and philosophical senses) between

...knowledge of reality from reality itself, e.g., description from construction, simulation from realization, mind from brain [or cognition from physical system]. Selective evolution began with a description-construction cut.... The highly evolved cognitive epistemology of physics requires an epistemic cut between reversible dynamic laws and the irreversible process of measuring initial conditions.... [Our italics, Pattee [1995](#): p. 23].

What "epistemic cut" means depends on Pattee's definitions of information and knowledge:

Knowledge is potentially useful information *about* something. **Information** is commonly represented by *symbols*. Symbols *stand for* or are *about* what is represented. Knowledge may be about what we call reality, or it may be about other knowledge. It is the *implementation* of "standing for" and "about" - the process of executing the epistemic cut - that [we need] to explore.

⁹ To our knowledge Pattee never addressed Popper's ideas or evolutionary epistemology directly.

Heritable, communicable, or objective knowledge requires an epistemic cut to distinguish the knowledge from what the knowledge is about. By *useful* information or knowledge I mean information in the evolutionary sense of information for construction and control, measured or selected information, or information ultimately necessary for survival. [my emphasis, his italics]. ...

The requirement for heritable or objective knowledge is the [epistemic] separation of the subject from the object, the description from the construction, the knower from the known. Hereditary information originated with life with the separation of description and construction.... [Pattee's italics, our bold - Pattee [1995](#): p. 26]

Following Pattee, there is a clear separation from the dynamics of living things in W1 and the codified knowledge of life in W3, but what he does not see clearly and admits he cannot understand is how the genetic code (W3) can emerge from the world of physical dynamics (W1). What is missing from Pattee's ontology of two domains and one cut is knowledge embodied in the structural dynamics of autopoietic systems.

As discussed extensively by Hall ([2011](#)), natural selection favors the autopoietic stabilization of dissipative structures. The first kind of knowledge to emerge within an energetically dissipative system that may be evolving towards autopoiesis is structure that is organized in such a way that dynamic feedback loops work to maintain that structure (i.e., by solving "problems" caused by perturbations that might otherwise cause the system to disintegrate). Corning ([2001](#): p. 1277) called this structural "knowledge" *control information*: "the capacity (know how) to control the acquisition, disposition and utilization of matter/energy in purposive (teleonomic) processes." To us this is the system's structurally determined propensity or disposition to act in a certain way in particular circumstances, falling into W2. The epistemic gap in this definition between the physical world and knowledge of that world is clear. Hoffmeyer and Emmeche ([1991](#); Emmeche and Hoffmeyer [1991](#); Hoffmeyer [2000](#), [2002](#)), citing Pattee's epistemic cut, recognize two kinds of knowledge: "analog" embodied in dynamic structure that we consider to be "dispositional" in W2; and "digital" or symbolic knowledge that clearly fits into W3.

Thus, as argued much more extensively in Hall ([2011](#)), we think there is a clearly rational physical basis for Popper's three worlds ontology that we will show can be applied to all kinds of complex knowledge-based organized systems.

Emergence of life in complex adaptive systems

Complexity

To us both people and organizations are "*complex adaptive systems*" at different scales or levels of organization, where each of the terms in this phrase implies aspects that may be difficult for some to grasp. A "*system*" is a set of causally connected components as determined either intrinsically by their degree of connectedness or as discriminated by an external observer. Following Simon ([1962](#): p. 468), a "*complex system*" is "one made up of a large number of parts that interact in a non-simple way. In such systems, the whole is more than the sum of the parts, not in an ultimate, metaphysical sense, but in the important pragmatic sense that, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole." By contrast to complicated systems, which simply have large numbers of parts that interact in predictable ways, complexity implies the interactions of the parts include aspects of nonlinearity and/or indeterminacy that make it impossible to make long-term predictions about the behaviour of the system.

Adaptation

We also follow Simon's ([1962](#): p. 479) definition of "*adaptation*":

The distinction between the world as sensed and the world as acted upon defines the basic condition for the survival of adaptive organisms. The organism must develop correlations between goals in the sensed world and actions in the world of process. ... Given a desired state of affairs and an existing state of affairs, the task of an adaptive organism is to find the difference between these two states, and then to find the correlating process that will erase the difference.

As reviewed above, Popper's (1972) general theory of evolution explains how adaptation can evolve in non-teleonomic ways.

Defining life as autopoiesis

The concept of "*autopoiesis*" (i.e., "self + production") was developed in the 1970s as a necessary and sufficient definition for what it took for a complex adaptive molecular system to be considered a living organism (Maturana and Varela 1980, Maturana 2002). Varela et al (1974) listed six criteria that we abbreviate here (original definitions given in quotes):

1. *Bounded* ("the unity [entity] has identifiable boundaries"). In this Varela et al. were primarily concerned that the entity could be discriminated by an external observer. To us this criterion should read, "the entity has *self-identifiable* boundaries". Note: in living cells the boundary is a semi-permeable membrane, protected by a cell wall in plants.
2. *Complex* ("there are constitutive elements of the unity, that is, components").
3. *Mechanistic* ("the component properties are capable of satisfying certain relations that determine in the unity the interactions and transformations of these components"). In other words, the complex entity is dynamical, such that components show causal interactions driven by energy dissipation.
4. *Self-referential* or *self-differentiated* ("the components that constitute the boundaries of the unity constitute these boundaries through preferential neighborhood relations and interactions between themselves, as determined by their properties in the space of their interactions"). That is, the boundaries of the system are determined by the structural relationships between the entity's components.
5. *Self-producing* ("the boundaries of the unity are produced by the interactions of the components of the unity, either by transformations of previously produced components, or by transformations and/or coupling of non-component elements that enter the unity through its boundaries"). Note that there is no implication here that the entity is physically closed against exchanges of matter and energy.
6. *Autonomous* ("all the other components of the unity are also produced by interactions of its components as in [the statement above], and ... those which are not produced by the interactions of other components participate as necessary permanent constitutive components in the production of other components").

It is arguable that, as was the case for our treatment of Popper's three worlds, our paraphrase for the purposes of developing an ontology here shades Maturana and Varela's original concepts in ways they did not intend (Urrestarazu, pers. comm.)¹⁰. However, implicit in the definition of autopoiesis is the concept of "*self-sustainability*", i.e., that the autopoietic entity contains within its cybernetic structure sufficient capacity for cybernetic self-regulation

¹⁰ What we are doing here is unifying the paradigms of Popper's later epistemology and Maturana and Varela's autopoiesis, such that an understanding of evolutionary epistemology informs the understanding of autopoiesis, and vice versa. Following the insights of Kuhn (1962, 1983), some shifts in concepts and vocabulary are required to make the contents of the two paradigms commensurable. This in no way denies the importance or value of the two schools to the present project.

to be able to compensate against potentially disruptive perturbations that might otherwise cause its disintegration (Maturana and Varela [1980](#)).

Luhmann ([1986](#), [1990](#), [1995](#)), Von Krogh and Roos ([1995](#)), Magalhaes ([1998](#)) amongst others extended the concept of autopoiesis to suggest that social organisations or systems might be autopoietic entities at a higher order of complexity. Luhmann extended the idea of autopoiesis to establish a theory of social systems, where intangible human social systems were formed by recursive networks of communications. Hall and Nousala ([2010](#)) claim 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 (see below) shows that what Luhmann thought was a vicious circle is 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.

Stafford Beer ([1981](#), [1984](#)), in his "viable systems model", and in his Preface to Maturana and Varela ([1980](#)), also argued that self-directing systems with properties of life could exist at different orders of complexity. Others (Zolo [1990](#); Mingers [1992](#), [1995](#), [2002](#), [2004](#); Biggiero [2001](#); Kay [2001](#); Brocklesby [2004](#); etc.) have argued that higher order entities cannot be considered to be autopoietic from a variety of philosophical and sociological points of view too diffuse and too numerous to review here. Also, Maturana ([2002](#)) and Varela ([1980](#)) both made it clear that they only ever intended the concept of autopoiesis to be applied to macromolecular systems at the cellular level of organization.

However, the approach followed here, unifying autopoiesis and evolutionary epistemology with the theory of hierarchically complex systems, is very different from Maturana and Varela, Luhmann, and Beer's approaches to autopoiesis. We will show that autopoietic systems may also emerge at levels of hierarchical complexity above the cellular level.

Autopoiesis, life and knowledge

As described by Hall ([2005](#), [2006a](#), [2011](#); Hall et al. [2005](#)) and substantially simplified here, autopoiesis is an emergent phenomenon growing out of entropically dissipative eddies (i.e., emergent systems) transporting fluxes of energy from source to sinks. These may be shaped by natural selection that favors the survival of those systems that are so organized that the cyclical dynamics of their structure applies some degree of self-regulatory feedback to maintain the dynamics of the structure. It should be noted that such systems must reach some degree of complexity before feedback is possible, and that systems with feedback are inherently non-linear.

Where chance arrangements of the structural organization of complex systems provide tendencies for even the slightest self-regulatory capacity to maintain itself, such tendencies represent an embodiment of at least some control information (W2 knowledge) that can be amplified and extended by further natural selection favoring survival of better regulated systems. That is, randomly emerging systems lacking feedback regulation soon disintegrate in the face of perturbations. Any knowledge embodied in the structure of the system prior to its disintegration is lost in that disintegration. In Popper's terms, systems that disintegrate have been eliminated as "errors" that failed to solve "problems of life". Progress towards any of the six criteria of Varela et al. ([1974](#)) listed above will add the capacity to survive an increasing range and magnitude of perturbations (i.e., robustness) to surviving systems, and will thus be favored by natural selection.

It follows from this kind of argument that (1) to survive, autopoietic systems depend on the control information/survival knowledge embodied in the organizations of their dynamic

structures, and (2) the evolutionary consequence of natural selection working on autopoietic systems is the generation of knowledge. In other words, (1) *life cannot exist without knowledge*, and (2) *knowledge is a product of living*.

Living systems in a complex hierarchy

What does it mean that the Universe, organizations, people and cells are all “*hierarchically complex systems*”? Simon (1973, 2002) defines the key concepts (see also Simon 1996; Pattee 1973, 2000; Salthe 1985, 1993, 2004; Chaisson 2001). “*Hierarchy*”, as used here (Salthe’s “scalar” hierarchy) refers to nesting relationships where a large object, e.g., a “Chinese box”, may exist as one of a set of similar objects within a still larger object, and contains a set of smaller objects (boxes), where each of the smaller objects may itself contain a set of still smaller objects, and so on up and down along a dimensional scale. When applied to dynamic systems, a given system observed at one scalar level may be seen to be composed of a number of subsystems when examined at a smaller scale, or be seen to be one of several or many components of a supersystem that can be discriminated at a larger scale.

Although hierarchies may be arbitrarily established by an observer, there are completely natural criteria by which observers can discriminate hierarchically organized systems in the real world by their dynamic properties. If the dynamics of interactions in the system are observed at a particular level of focus for a length of time, τ , and we cannot discriminate changes that take place in less time than \mathbf{T} , there are three classes of change: (1) those at higher levels that are too slow to be seen during our observation such that they appear to us to be constant; (2) those at our level of focus that we can see happening; and (3) those at lower levels of focus that are so fast that the systems in which they occur seem to be in equilibrium or steady-state, such that they interact as “rigid” objects. Simon (1973) calls systems with these properties “nearly decomposable”. Thus, even though the several components of a complex system at a given level of complexity may each have a high frequency of internal dynamics, the internal dynamics of one component is only very loosely coupled by much slower dynamics with the fast internal dynamics of other components. Even though each component is internally complex and dynamic, the loose coupling between the internal dynamics of one component and another allows them to be clearly discriminated as discrete objects or entities. Maturana recognized near decomposability as follows (Maturana 1980: p. 30): “...the physical boundaries of a living system... are realized by [their] components through their preferential interactions within the autopoietic network, [which then] become apparent as surfaces of *thermodynamic cleavage*” [our italics], where rates of energy dissipation outside the boundary are substantially less than that within the boundary. Observers can recognize such self-defined systems at a given level of organization by selecting an appropriate “level of focus”.

It is easy for humans to recognize and see complex system entities at our own focal level or lower levels of organization in a complex systems hierarchy (e.g., where we would use a magnifying glass or microscope). On the other hand it is much more difficult for us to discriminate and focus on complex entities at larger scales and higher levels of focus than our own, e.g. ‘evolutionary entities’ that contain us such as *Homo sapiens*, or the planet Earth, or the Milky Way Galaxy, (Gould 2002; Chaisson 2001). It takes the equivalent of looking through the wrong end of a telescope and considerable mental effort and practice for us to recognize and “see” the boundaries of such higher level systems that include us in their structures. However, many human organizations are at least self-identifiably bounded by the equivalent of an individual cell’s semi-permeable boundary or a multi-cellular organism’s skin, e.g., by physical walls and boundary fences, access security policies, ID tags, property deeds and ownership records, etc. that we can also learn to see as boundaries.

The phenomena comprising autopoiesis can emerge at different scales or levels of complexity in a hierarchically complex world. The theory of hierarchically complex living

systems derives from concepts of complexity, control and causation, scalar levels of organization, and emergence (Hall [2006a](#)). Hierarchically complex systems are those where individual parts that interact to form a system at one “*level of focus*” can be seen to be composed of several to many interacting components at a more detailed, “lower”, level of focus (Figure 2). Every complex system can be seen to have a triadic existence: as a component in a higher level “*supersystem*”, the *focal system* itself at the focal level, which in turn is comprised by lower level “*subsystems*” serving as its components (Koestler [1967, 1978](#); Salthe [1985, 1993](#)). Spontaneous dynamics in a system is entropically driven by the dissipation of free energy in a flux from a high potential source to a low potential sink (Prigogine [1955, 1981](#)). The dynamic structure of a focal system (i.e., the specific states, interactions and trajectories of the components comprising the system) at a point in time establish conditions that provide a downward control over the dynamic possibilities available to the subsystems comprising the focal system (Pattee [1973, 2000](#)). The dynamic structures providing that control can be considered to embody part of the control information governing the cybernetics of the system (Pattee [2000](#), Corning [2001](#)).

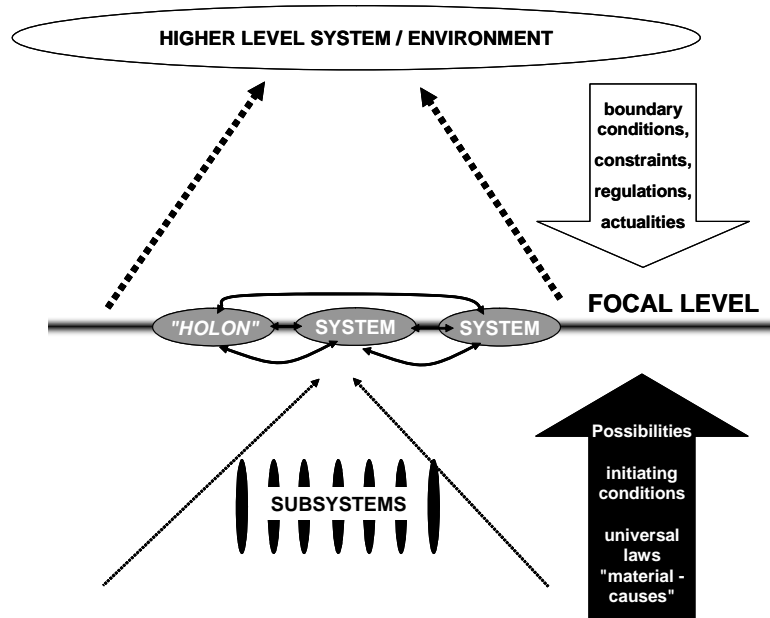


Figure 2. The systems triad in hierarchy of complex dynamic systems (Hall et al. [2005](#) after Salthe [1985](#)).

Emergence of autopoiesis at levels of complexity above the cellular

Where the potential gradient in the energy flux between the source and sink across a given focal system is particularly large (e.g., because the higher level supersystem is “inefficient”) processes may emerge to form an additional dissipative system between two existing levels of organization in the complex systems hierarchy (Salthe [2004](#); see additional references in Hall [2011](#)). Where conditions are suitable, life may emerge at any level of complexity where natural selection favors the emergence of autopoietic properties (Hall [2006a](#); Hall [2011](#)).

Maturana and Varela ([1980](#): p. 135), define an autopoietic machine as one that is

organized (defined as a unity) as a network of processes of production, transformation and destruction of components that produces the components which: (i) through their interactions and transformations regenerate and realize the network of processes (relations) that produced them; and (ii) constitute it as a concrete unity in the space in

which they exist by specifying the topological domain of its realization as such a network.

An allopoietic machine is one that has as a product of its functioning something different from itself, such as a car produced by a production line. Using these definitions, Maturana and Varela explain how an assembly of machines that are autopoietic in their own right can combine to form a higher order autopoietic entity (Maturana and Varela [1980](#): pp. 110-111):

If the autopoiesis of the component unities of a composite autopoietic system conforms to allopoietic roles that through the production of relations of constitution, specification and order define an autopoietic space, the new system becomes in its own right an autopoietic unity of second order. *This has actually happened on earth with the evolution of the multicellular pattern of organization.* When this occurs, the component (living) autopoietic systems become necessarily subordinated, in the way they realize their autopoiesis, to the maintenance of the autopoiesis of the higher order autopoietic unity which, through their coupling, they define topologically in the physical space. *If the higher order autopoietic system undergoes self-reproduction (through the self-reproduction of one of its component autopoietic unities or otherwise), an evolutionary process begins in which the evolution of the manner of realization of the component autopoietic systems is necessarily subordinated to the evolution of the manner of realization of the composite unity. Furthermore, it is to be expected that if the proper contingencies are given, higher order autopoietic unities will be formed through selection.* In fact, if coupling arises as a form of satisfying autopoiesis, a second order unity formed from previous autopoietic systems will be more stable, the more stable the coupling is [our emphasis].

In a national economy, money represents control over energy fluxes and books of account document the cash flows that economic organizations dissipate in order to maintain their survival (Hall [2005](#), [2006a](#)). Autopoietic economic organizations can emerge at a level of organization between the dissipative requirements of individual humans for food, protection from the elements, etc. and the larger national economy that inefficiently caters for the needs of particular individuals.

Hall ([2005](#): pp. 180-181) listed properties of economic organizations for each of Varela et al's ([1974](#)) six criteria for recognizing when a system should be considered to be autopoietic (see their words above, p. 9).

1. *Bounded*

Varela et al. were primarily concerned that the boundary be identifiable by an external observer. More importantly to us, to be considered autopoietic the entity itself must be able to discriminate its own components from those in the external environment. Where economic organizations are concerned, their components are often identified, physically aggregated and separated from the external environment by fences, walls, access security procedures, corporate branding and logos, 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 those fractions of their life that are important to the organization using membership and business cards, employment agreements, wages and salaries, oaths of allegiance, acceptance of creeds, wearing of uniforms, etc.

2. *Complex*

Organizational fabrics are comprised of many and varied physical, human, and economic components that in many cases are complex in their own right.

3. *Mechanistic*

For a complex organization to operate its components must be interconnected via routines and subsystems for processing energy and materials through its structural fabric to produce products and services to maintain its viability. Cash flow through organizations as registered in organizational accounts serves as a proxy for dissipative energy fluxes driving the interactions of components at lower levels of organization. If the cash balance is consistently negative, the organization eventually becomes bankrupt and disintegrates or must surrender control of its assets to other entities.

4. *Self-referential*

Most mechanistic organizations have feed-back routines, processes and procedures that observe and work internally for self-regulation. These include such things as corporate accounting systems, personnel systems, time-keeping, occupational health and safety, etc., which provide homeostatic functions to maintain the organization. An important part of these self-referential functions is to maintain the existence of the separation between that which can be and is regulated, and the external world (i.e., to maintain the boundary between self and non-self).

5. *Self-producing*

As defined by Urrestarazu ([2011](#)), 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 that are essential to maintaining organizational integrity and survival.

6. *Autonomous*

It is probably fair to say that for their own internal reasons 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, in the personal tacit knowledge of their members, and semantically encoded in organizational memory in the form of written processes and procedures. The autonomy of organizations is shown by the fact that many have life spans longer than the association of any of the human members of the organization.

Properties contributing to autopoiesis often emerge as a function of organizational growth. A company operated by a single entrepreneur or a small family company, where the entrepreneur employs a few relatives, would not be autopoietic independently from the activities of their key people. However, as organizations grow or coalesce to the point where the organization can survive the departure of key individuals, and meets all of the other criteria to be considered to be autopoietic, then there are no grounds to argue that it can not be autopoietic.

Knowledge and autopoiesis: Individual knowledge vs organizational knowledge

Following Hall ([2006a](#); [2011](#)), we have argued above that knowledge is fundamental to autopoiesis and that autopoietically produced and maintained knowledge can evolve at several different orders of biological organisation: e.g., at cellular, multicellular organismic, and (social/ economic) organisational levels. For example, in multi cellular organisms such as people, knowledge in the form of heritable DNA codes and epigenetic knowledge (e.g., based on the developmental histories of individual cells and in other heritable aspects of cell structure and function not represented in the DNA code) controls the person's growth, maturation and innate capabilities (Jablonka and Lamb [2006](#), [2007](#)). Although the person's knowledge of the world depends on inherent capabilities provided by his/her cellular organization, together with what has been learned through living, this personal knowledge is different from the genetic and epigenetic knowledge that controls the development and activities of individual cells.

Similarly, where organizations are concerned, heritable knowledge pertinent to organizational activities is held in a variety of documents and the memories of individual humans; however, the expression of that knowledge to maintain organizational survival is cybernetically controlled by where individual people sit in the physical and network structure of the organization and other contextual factors of organizational activities. Thus, in the same way that people have knowledge beyond the knowledge possessed by the individual cells that form them, autopoietic organizations have knowledge beyond that possessed by the individual people belonging to the organization from time to time. The remainder of this paper explores the relationships and differences between individuals' personal knowledge, and knowledge embodied in and owned by autopoietic organizations.

PERSPECTIVES OF KNOWLEDGE IN LIVING ORGANIZATIONS

Following Polanyi ([1958](#), [1966](#)), "*personal knowledge*" encompasses several types of knowledge, and specifically includes what Popper described as "dispositional" or "subjective" knowledge. Personal knowledge lives *unconsciously* and *consciously* in people's minds (i.e., in W2) and is *embodied in their propensities to act* in certain ways. The un-interpreted dynamic physical-chemical structure of a person's brain exists in W1, but cybernetic control of that structure and the memory of history that together constitute the mind's knowledge, lives in W2 (Popper, [1972](#), [1994](#); Hall [2005](#), [2006a](#), [2011](#); Hall et al., [2005](#)). Aspects of this personal knowledge can then be encoded in W3, to exist in non-living (i.e., static) and objectively persistent formats.

Conscious personal knowledge emerges from individual "*sense making*" – encompassing activities in W2 that organize sensory impressions (data) of W1. Part of sense-making may involve decoding W3 content and extracting and reformulating these materials to extend living knowledge – possibly to support immediate action and/or to create new content in W3 to support W2 memory or social processes of sense making and action. We adapt Nickols ([2000](#) – Figure 3) to highlight that personal knowledge is contextualized. Knowledge initially emerges or is constructed as "*situational knowledge*" in living entities – generally in response to the situations and problems of existence (see also Figure 1). "*Tacit knowledge*" (W2) is unconscious or inherent in a person and cannot be readily articulated. Such knowledge can be considered to be "*procedural knowledge*" if it becomes embodied in unconscious personal routines. *Implicit knowledge* also resides in W2, but is consciously available to the person and can be articulated and may be codified. Personal knowledge may be shared with other people via articulation and perception. Unless it has been shared and understood, tacit or implicit knowledge important to the organization becomes "*lost knowledge*" when people holding it leave the organization. When knowledge is codified, it

becomes *explicit knowledge* (i.e., it is placed in W3, where it may be readily available to other people). Procedural knowledge enables “doing” and *declarative knowledge* is created by describing things.

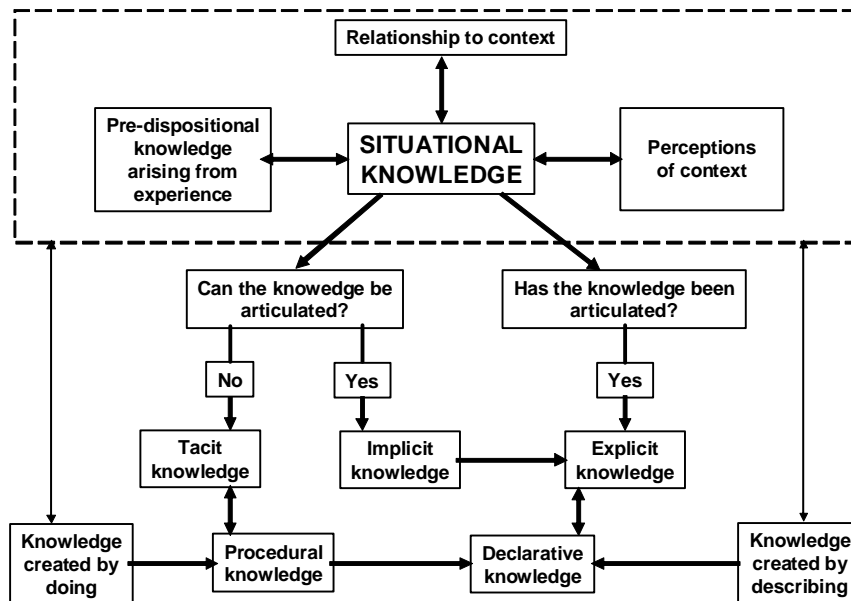


Figure 3. The contextual nature of personal knowledge (adapted from Nickols 2000)

There may be some uncertainty about when articulated or declarative knowledge becomes objective. Popper (1978, p. 159) very clearly states:

the transition from a non-linguistic thought to a linguistically formulated thought is of the greatest importance. By formulating a thought in some language, we make it a world 3 object; and thereby we make it a possible object of criticism.

To better understand varieties of knowledge at the organizational level, we here place the cut between W2 and W3 slightly differently. A strong anthropological case can be made that spoken language vanishes as it is articulated and thus its only trace is a subjective impact on minds of those who hear it (Ong 1982). Thus, speech belongs in W2, where its only persistent traces are the subjective impacts on those who heard it; while a mechanical recording or typescript of the speech able to persist independently of independently of living minds belongs to W3¹¹.

As knowledge grows within an organization, components of its content may undergo several kinds of transformation and changes of status from the personal knowledge of particular individuals to becoming part of the living organization’s solutions to problems. The following ontology encompasses these changes and transformations:

- “*Tacit organizational knowledge.*” Nelson and Winter (1982) argue that competitive differences between organizations are partially attributable to relatively stable capabilities expressed in organizational knowledge (or organizational heredity). These

¹¹ The interactions between Popper’s cut between Popper’s W2 and W3 and Ong’s considerations of language vs print deserve more attention than we can afford to give here. Very briefly, Popper (1972) argues that even the silent mental articulation of ideas about the world places them in W3, which then allows these ideas to be consciously criticized. Ong (1982) argues that pre-literate people have no capacity to criticize self-speech until they have actually seen the physical expression of words as symbols or sequences of symbols, and can then think of their expressions as external objects able to be criticized.

“genetic” capabilities include undocumented “*routinization*” of organizational activities, development of jargons that have meanings specific to the organization, the layout of plant and equipment, networks of people in the organization, and the tacit knowledge these people hold in their heads. Nelson and Winter call this “*tacit organizational knowledge*” after Polanyi (1966). This contributes to cybernetic regulatory and control mechanisms (i.e., in W2) at the organizational level that makes organizational knowledge something more than the sum of the knowledge of the organization’s individual human members. We include all kinds of organizational processes in W2, whether they are formally documented or not, because by analogy to the neurological and physiological cybernetic structures of a multicellular organism that may be described in a medical book or encoded in the genome, they contribute to organizational cybernetics. Popper’s (1972) concept of “dispositional” or “subjective” knowledge encompasses this tacit knowledge at organizational levels as well as knowledge at the personal level (Hall 2005; Hall et al. 2005).

- “*Explicit organizational knowledge*.” Explicit knowledge is “objective” in Popper’s sense, i.e., it has been persistently codified (e.g., as marks on paper, polarity changes on a magnetic surface, etc.). The logical and semantic content of the knowledge exists in W3. The physically encoded form of that content exists in W1, while its meaning is made operational as control information for individuals or machines within the organization through decoding and other dynamic processes in W2. Examples of explicit organizational knowledge include all documents, graphics, spreadsheet files, databases, software programs, emails, video clips, wikis and blogs within the organization. However, even where important organizational knowledge exists explicitly, access to that content may still rely on the personal knowledge of only one or two people (or no one). Thus, an organization might retain explicit knowledge generated by its members even after they leave, but in many cases, personal knowledge is still required to access and apply it (Cowan et al. 2000; Tsoukas 2005; Nousala et al. 2005; 2009). When personal knowledge about the existence and location of explicit knowledge leaves the organization or is not available when needed, such “*orphaned explicit knowledge*” might as well be lost.
- “*Common knowledge*”. Common knowledge is content that has been widely shared or is readily discoverable when needed using familiar retrieval methods within the organization. Personal knowledge may be shared to become common in the organization and thus, part of the organization’s tacit knowledge (Nousala 2006; Nousala et al. 2007). Apprenticeships, “grapevines”, “rumor mills” and undocumented routines – “that’s the way we do things here” – are all ways to form “*common tacit knowledge*”. Similarly, explicit knowledge that becomes widely known or easily retrievable in the organization is termed “*common explicit knowledge*”¹². Only when the knowledge is widespread or easily discovered and accessed, and thus able to survive departure of key individuals who know where it exists, does the knowledge truly become a property of the organization rather than a few individuals. Internal protocols that limit access to particular files and documents or impede tacit sharing reduce the accessibility of knowledge, and hence, the ability for it to become common. Knowledge not made common is easily lost or orphaned.
- “*Formal knowledge*” refers to “*authorized*” common knowledge. Formal knowledge is that subset of common knowledge in W2 or W3 that has been socially critiqued and approved in an organizational context. Through the process of critiquing and reaching

¹² We considered using the word “shared” in these contexts instead of “common”, but sharing refers to a process and does not indicate how wide-spread the shared content might be.

negotiated agreements, authorization is given to use knowledge in appropriate organizational contexts. Examples of formal knowledge include:

- Content of an industry training package.
- Knowledge transferred via normal apprenticeship programs.
- Learnings achieved via industry or university accredited programs.
- Instruction manuals, policies, procedures, engineering documentation, lessons-learned documents, research publications, etc. as formalized via release and publication workflows, acceptance by an organizational committee or a industry working party, etc.
- Formally established business processes and workflows.
- Documented routines and processes, including plant and equipment layout, etc., where people have authorized the implementation of chosen routines and processes.

As for common knowledge, formal knowledge at the organizational level may be “*formal tacit knowledge*” or “*formal explicit knowledge*” depending on whether it is embodied in cybernetic structure or preserved in an objectively persistent format.

THE EMERGENCE OF ORGANISATIONAL KNOWLEDGE

Figure 3 and Figure 4 summarize our views of organizational knowledge in Popper’s three worlds. In Figure 4, the laws of physics (e.g., the dissipation of potential energy in a flow from sources to sinks) and economics (e.g., the need to maintain positive cash flows) and the contingencies of the “environmental context” of W1 make the knowing organization possible (“enable”) and “drive” (or fuel) its activities. These causative influences are represented by the inward directed arrow. The organization attempts to “anticipate and influence” the external world with tentative solutions to better protect its existence (outward directed arrow). It learns which tentative solutions work by observing, testing and making sense of its previous attempted solutions (dotted arrow). An organization may also engage in knowledge flows and exchanges with other organizations in its external environment. Within the organization’s semipermeable boundary, knowledge building for organizational learning begins with the personal knowledge built by the organization’s individual members from the sense they make of observations they make on behalf of the organization. As detailed below, the personal knowledge of individuals is made explicit and common, where it is then formalized by organizational level processes, and finally assimilated and integrated into organizational rules, routines, and processes to support organizational survival.

Organizational knowledge begins with “living knowledge”.

Organizational knowledge emerges and is constructed from the living knowledge of its individual members. As organizations adapt to their environments personal knowledge is transformed into living knowledge at the organizational level (Hall [2005](#), [2006a](#), [Hall 2011](#)). “Organizational knowledge” is dynamically involved in maintaining organizational viability. Contextual influences, such as losing a large customer or a drop in currency value may require adaptive changes in the organization’s knowledge. Organizational knowledge includes personal knowledge, organizational tacit knowledge and objectified knowledge – qualified here as explicit knowledge (EK), common knowledge (CK), and formal knowledge (FK) as defined above. We also refer to the integration of formal knowledge into the cybernetic structure of the organization (IFK), where it becomes “*integrated formal knowledge*”. The arrows linking the layers of the “onion” indicate transformations as knowledge is increasingly tested via personal and organizational processing (see Figure 5 and Figure 6). All explicit

knowledge encoded in analogue and digital objects exist inertly in W3 and can only be made “living” via dynamic activities in W2. For example, the code of a computer program exists in W3. It comes to life in W2 when embodied in a functional routine or process. Integrated Formal Knowledge (IFK) is knowledge that has become embodied in structural processes of the organization to act as W2 knowledge *at the organizational level*.

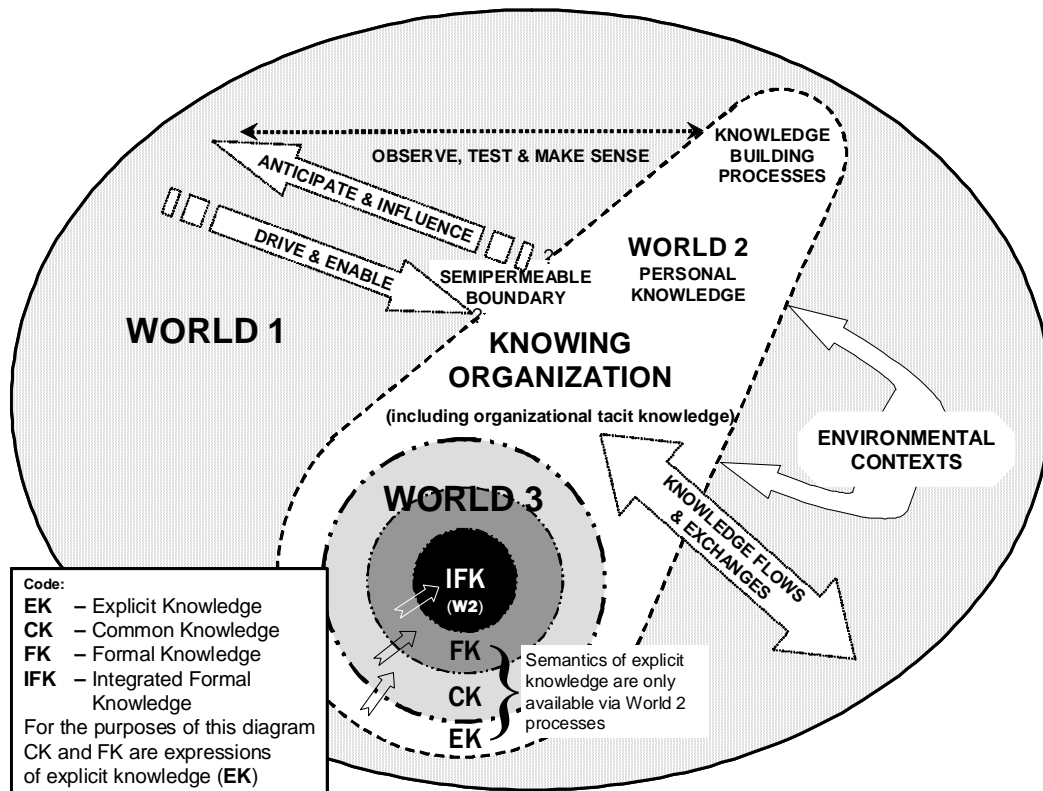


Figure 4. Karl Popper’s three worlds ontology and organisational knowledge (adapted from Hall [2003](#), [2003a](#)).

Most organizational knowledge is constructed by staff working individually or in networks and small groups (Tsoukas [1996](#); Nousala [2006](#), Nousala and Hall [2008](#); Nousala and Tersiovski [2007](#)). Knowledge intensive processes inevitably involve filtering and transformation of knowledge via individual members’ tacit and implicit world views (Kuhn [1962](#), [1983](#)). Note that the notion of tacit organizational knowledge (W2) does not conflict with these views. Knowledge can be built into (i.e., embodied in) dynamic processes and systems within the organization. Some knowledge, such as that in routinized procedures, may emerge and evolve at the level of the organization imperceptibly to individual staff (Nelson and Winter [1982](#)). However the organizational level systems and their functioning come to develop, this development takes real time and therefore, it is very important to recognize the importance of time in building organizational knowledge (Dalmaris et al. [2006](#); Hall et al. [2007](#); Philp and Martin [2009](#); Hall et al. [2011](#)). Note that the cognitive processes involved in formalizing personal knowledge into organizational knowledge and integrating it into organizational processes are akin to the conscious processes of rational criticism in the development of theory by individual people (as will be discussed in more detail below). Thus, it may be appropriate to call the processes involved in formalizing organizational knowledge part of “*organizational consciousness*”.

Organizational boundaries are semipermeable.

Organizational knowledge consists of knowledge encoded and embodied in an organization and its systems controlling the dynamics of flows across its boundary, where the boundary is understood as a semipermeable “*organizational membrane*”. Consistent with the concept of autopoiesis, the organizational membrane includes mechanisms for filtering and communicating knowledge via the controlled exchange of artifacts and people – and the knowledge they carry. Controlling trans-membrane flows of knowledge is essential to maintaining and growing organizational knowledge. Organizational boundaries consist of such physical artifacts as fences, walls, security gates, staff ID cards, computer logon IDs and passwords, etc; backed up by social factors such as individual affiliations to the organization, and communication networks within the organization. As in cellular and multi-cellular biological entities, what is allowed to pass through the entity’s external boundary is determined by its evolved genetic and epigenetic (i.e., structural) heritage (Jablonka and Lamb [2006](#), [2007](#)). If the membrane of the autopoietic organization begins to break down, either by accident or intentionally, then the life of the organization itself as a discrete autonomous entity can be threatened. For example, retaining knowledge in a company may depend on orderly movement of knowledge workers through its boundary. Personal knowledge critical for organizational survival can be lost via the uncoordinated departure of large numbers of knowledge workers or failures in induction processes (Hall et al. [2009](#)). Also, the leakage of sensitive knowledge can allow other organizations to determine points of competitive weakness. From this, organizations may lose market share and sustainable profits to suffer bankruptcy or acquisition (i.e., “*organizational death*”).

THE DYNAMICS OF ORGANIZATIONAL KNOWLEDGE

We now discuss processes for constructing personal knowledge and sharing it between people to transform it into different manifestations of organizational knowledge (including transforming organizational knowledge back into personal knowledge for the benefit of the organization). The processes to absorb and integrate new knowledge transforms the content (both the meaning/connotation and message/denotation) of knowledge as it is conveyed through and between channels representing different ways of knowing. Personal knowledge can be conveyed by doing (e.g., via demonstration or sharing relevant anecdotes - Figure 4), whereas explicit knowledge is conveyed in codified form is conveyed via material and electronic communication channels such as hand-delivered documents, email, video, etc.

The dynamics of knowledge acquisition and application are cyclical, e.g., as represented at its most fundamental by Popper ([1972](#) - Figure 3), as well as other knowledge cycles including SECI (Nonaka and Takeuchi [1995](#); Nonaka et al. [2006](#)), single and double loop learning (Blackman et al., [2004](#)), the knowledge life cycle (Firestone and McElroy [2003](#)), decision-execution cycle (Firestone and McElroy [2005](#)), or Boyd’s OODA cycle of Observation, Orientation, Decision and Action (Boyd [1996](#), Osinga [2005](#) Fadok [1994](#); Spinney [1997](#); Cowan [2002](#); Hammond [2001](#); Angerman [2004](#)). Because of its similarities to Popper’s representation of the evolutionary theory of knowledge and the severe testing the concept has received in real-world conflicts (Mutch [2006](#)), we find Boyd’s “*OODA*” (Observe, Orient, Decide and Act) cycle to be more informative (Hall [2003](#), [2005](#), [2006a](#)), especially where the factor of time in a changing and competitive environment is concerned (Dalmaris et al. [2006](#); Hall et al. [2007](#), [2011](#); Martin et al. [2009](#); Philp and Martin [2009](#)). In these types of pressured environments, knowledge that supports decision and action needs to become implicit or even tacit at both individual and organizational levels to minimize processing delays between observing and acting. However, to remain effective, implicit knowledge must be continually tested and updated on the basis of observed results via

changes to observation and guidance and control paradigms (Firestone and McElroy [2003](#); Grant and Cooter [2004](#); Hall et al. [2007](#); Philp and Martin [2009](#); Martin et al [2009](#); Hall et al. [2011](#)).

To facilitate knowledge dynamics for organizational purposes, staff need skills to network effectively both inside and outside the organization. A governance and fiduciary based approach to managing knowledge (McElroy [2003](#); Firestone and McElroy [2003a](#); Firestone [2004](#)) should empower staff to develop solutions to real problems in contrast to pursuing “idealized futures”. To ensure this happens, ideally the knowledge function should be autonomous from operational management and its strategy (Firestone [2004](#); Nousala et al. [2005](#), [2009](#)).

Exchange and growth of personal knowledge in the organization.

Personal knowledge exchanges such as on-the-job training, apprenticeships, and mentoring can build common organizational knowledge where personal knowledge has been tested and validated in practice, but has not been made explicit. However, there is a risk that knowledge may also be transformed detrimentally as it is exchanged from one person to another, whether interpersonally or via W3 objects. This is because each person unavoidably constructs an understanding of the world within a personal frame of reference (Kuhn [1962](#), [1983](#)), and as these frames become socialized, there is potential for distortions based on prevailing perceptions. This problem can be exacerbated because in organizations individuals often need to have similar understandings of the knowledge in question to act predictably for organizational purposes. Prevailing views may not reflect alternatives that will deliver the greatest benefit.

It is in managing the boundaries between notions of personal and organizational knowledge where the complexities of the domain of organizational knowledge management emerges. Knowledge easily becomes contested. We discuss some of the dynamics of this challenge as follows.

Expressing personal knowledge as explicit knowledge.

Figure 5 summarizes transformation of personal knowledge into explicit knowledge. This can involve processes at both individual and social levels of organization, with an iterative interplay between observing W1; mental processes, sense-making, social languages, and narrative exchanges such as story telling and listening in W2; and the codification and decoding of knowledge between W2 and W3. Different types of knowledge artefacts are continuously produced throughout this process. The overall process is complex and contributes to organizational knowledge only if the knowledge worker is willing and able to share or make this personal knowledge explicit within an organizational context. As shown in the central core of Figure 5, personal knowledge begins with capturing data and making sense in World 2 of sense-data generated as W1 impinges on the living entity¹³. Sense making involves putting information received into contexts currently held in the mind or that may be retrieved from W3, and that may include codifying the contextualized observations back into W3. Contextualized information adds to existing knowledge when tested against W1 and the observations of tests are criticized in W2 against prior knowledge that may exist in W3. The outer blocks in Figure 5 place these personal activities in the social context of the organization. In an organizational sense, how these mediated W1↔W2↔W3 interactions are incorporated within the socio-technical organization is of fundamental importance. Vines and

¹³ Hall provides an animated presentation of our concept of this process on <http://tinyurl.com/3y6n4y> beginning with slide 11.

Firestone (2011) make what we consider to be an important claim – namely that the design of human-machine systems must incorporate the use of “human interpretative intelligence” and that a technology that fails to take this into account will be dysfunctional as compared to one that does.

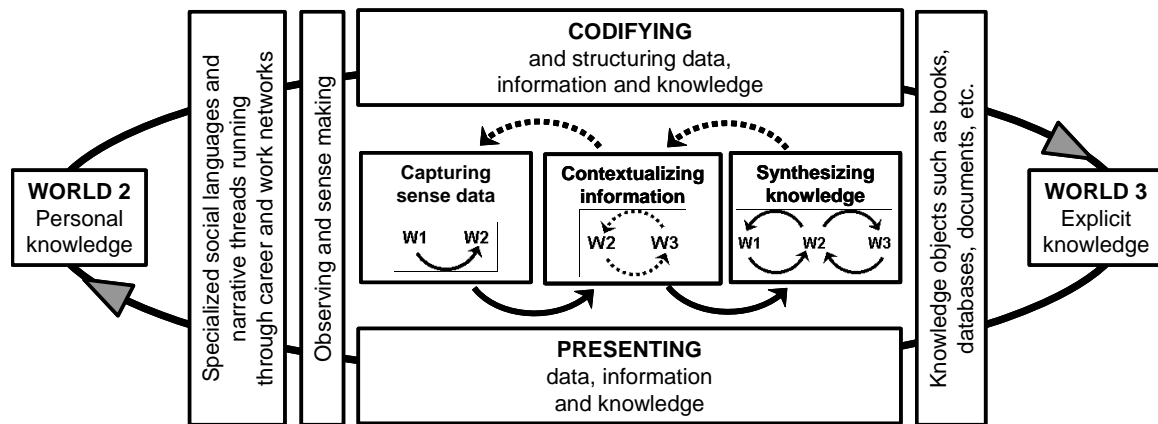


Figure 5. General process for turning personal into explicit knowledge (after Vines et al. 2007)

Personal knowledge is needed when knowledge workers collaborate across intra and inter-organizational networks. In such contexts, knowledge workers often don't know how to make explicit what they know when they solve problems. Also, solutions often emerge in a social environment, where individual personal knowledge can provide a tacit compass to guide action. Trying to use personal knowledge to create explicit knowledge so it can be applied in other contexts by other people is problematic, as emergent knowledge is not easily made explicit. In addition, for various reasons, workers may not necessarily want to make their expertise explicit in the first place (Ardichvili 2008; Bock et al. 2005). On top of this, even where people are willing to share, there are still limitations because of bounded rationality (Simon 1979; Snowden 2002; Else 2004; Nousala 2006; Nousala et al. 2005, 2009). Workers cannot share all that they know, and sharing invariably results in some loss in transfer. Workers also cannot write down everything they may share, although once codified, codified knowledge may be accessed and distributed more rapidly and widely than speech.

Turning explicit knowledge into common knowledge.

Online databases, enterprise web portals, and document management systems with electronic workflows and search mechanisms all help make explicit knowledge common (Hall et al. 2008, 2010, 2010a; Hall and Kilpatrick 2011; Hall and Nousala 2010a; Nousala et al. 2011). The challenge is to provide appropriate enterprise architectures and process workflows to make this easy and to limit the use of internal security controls that reduce the discoverability and accessibility of explicit knowledge. This is a significant topic in its own right that we do not address here but are currently working on.

Critiquing of common knowledge to create formal knowledge.

Common knowledge is converted into formal knowledge through various iterative social processes of critiquing claims against the reality and assumed logic of W1 (Figure 6). Agreements are struck about the veracity of knowledge claims and the potential application to solve specific problems (Firestone and McElroy 2003, 2003a). We contend that this continuing review of common knowledge is a type of knowledge quality-assurance process as proposed by Vines and Naismith (2002). Critiquing occurs via social processes involving

