CYBERNETIC MATERIALS FOR A THEORY OF INTELLIGENT SYSTEMS

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Abstract

This article addresses how second-order cybernetics, as a schema, facilitates the theoretical enablement of intelligent systems without reducing the comprehension of intelligence, as a concept, to the passive operationality of “automated optimisation” as embodied in so-called artificial intelligence systems. There is a wide array of operations and problems which are computationally intractable in an ontology of algorithmic systems. In lieu of Stuart Kauffman’s proclamation, that the the evolution of life marks the end of a physics world view of law entailed dynamics, I present a synthetic review of various approaches in systems theory and cybernetics which address such a rupture in epistemology. I discuss approaches and implications of defining intelligence in terms of “ontological expansion” and in terms of “eigenvalue problem”. I shall analyze arguments made by Denizhan, Negarestani, Rosen, Kineman, von Foerster and others and conclude with a discussion on the generality of complexity with respect to intelligent systems.

Keywords: second-order cybernetics, systems theory, philosophy of intelligence, Rosennean complexity, theoretical biology

1 | Introduction

Questions about the metaphysical status of intelligence and a general theory of intelligence are pertinent and unavoidable today, especially with the rise of so called artificial intelligence or more accurately *automated optimisation* systems as Denizhan (2023) has titled them. Dr. Rodney Brooks, former director of MIT's Computer Science and Artificial Intelligence Laboratory, commented in an interview that “but maybe there's more to us than computation. Maybe there's something beyond computation in the sense that we don't understand and we can't describe what's going on inside living systems using computation only.”

We can see the merit in such a speculation when we consider that research groups at MIT have failed to figure out behavior of a nematode despite the fact that we know all of its neurology, AI approaches such as connectionist models “just abstract too far away from the physical properties of the nervous system” (Chomsky, 1993). What kind of information could it be that we are missing from the picture? In the following article, I present a synthesis of a number of analyses from systems theory and cybernetics which converge on a notion of circular causality in relation to living and intelligent beings which has models unsimulable by machines of static phase space i.e. Turing machines.

2 | The Nature of Computation

1.1 | In terms of Information Resolution

Let us define computation as any process which processes information. However, this regresses the question to *what is information?*. Rosen (1991) notes that anything which one can ask a question about can be considered information. There is no one authoritative definition of information across disciplines (Kauffman et. al., 2007, Kampis, 1991); and Rosen’s definition, while too broad for certain practical applications, is appropriate here due to our general theoretical focus.

The questions in Rosen's definition are not questions in a formal, purely syntactical language which encloses a given phase space $\mathbf{Q_F}$, rather such questions in natural languages enclose an *unprestatable* (Kauffman et. al., 2012) phase space $\mathbf{Q_N}$ as they are in self-referential feedback with the corresponding semantic field. Such a self-referentiality leads to unformalizable conditions of impredicativity (Rosen, 2000). In general, we can say: by construction, $\mathbf{Q_F \subset Q_N}$.

Following this, we can define information as potential of entailment from material or abstract processes, i.e., physical continuous processes or mathematical formal processes. Now, information defined as such, can be entirely novel, which means it was unentailed from the original input (uncertainty principle in quantum mechanics, for example) or it can be entirely entailed but in a new salient form (rearranging a mathematical expression in a new form, for example).

One shall note the virtual rather than the actual character of information as defined above as it is not a subsisting property or effect of a substrate but rather potential of an effect actualized by computation over that information. "Information is something that we make" (Brier, 1996). It also becomes apparent that such a notion of information does not lend itself to quantifiability as it is defined with respect to the set $\mathbf{Q_N}$ which cannot be pre-given. One cannot pre-state how much information a system contains without interacting with it and exhausting that information, and inadvertently creating new information, leading to the infamous *measurement problem*.

A natural process or a process in any natural system can therefore be accordingly defined as a process of computation in terms of information resolution (check section 3.1). A process of entailment or determination carried out by exploiting the material (actual) or abstract (virtual) constraints within a given system is henceforth called computation. From a practical standpoint, such a definition may seem overly generalized and potentially useless as it does not allow us to make useful distinctions for the term, however, I argue that this definition of *natural computation* has the advantage of broadening the horizon of comprehending all physical processes as computational processes and the universe as a pan-computer which encloses a computational phase space $\mathbf{C_N}$. This helps us contrast the processes which are feasible as material processes, but are intractable as syntactical operations.

1.2 | Deductive closure and Epistemic Omniscience in T

For the classical notion of Church-Turing computation which encloses a phase space T, the machine receives input and undergoes a sequence of state transitions and yields an output. In this form, the operations in **T** are deductive feedforward procedures which follow predefined formalizations of given algorithms called *programs*. During the computation process, an operation in **T** disregards everything besides the specified input and the corresponding piece of the program until the initial input is processed in **T** (Negarestani, 2018, p. 344). A given operation in **T** can have many substrate mechanisms which fulfill it, and a mechanistic system which can exhaust all operations in **T** is often called *Turing-complete.*

Hence, Negarestani (2018, p. 344) asks "if this is all that computation is—algorithmic deduction—then what exactly is gained by it?" He dubs it *the* riddle of *epistemic omniscience*, according to which, the total knowledge of such an agent can be said to be *deductively closed.* Clearly, if we are to make the claim that computation is necessarily algorithmic deduction in **T**, i.e. $\mathbf{T} = \mathbf{C}$, it implies there is no new information at any point in the future which is not in every point in the past and "while such a verdict is absolutely sound and valid in some classical logic heaven, it has no ground in reality*"*.

He resolves this impasse via the notion of *ludics* (see section 4.3). In this article, I extend Negarestani's attempt to resolve this impasse by formulating an *in-reality ground* for a notion of computation which is not an abstract and unconstrained heaven of the Cartesian metric space (and time).

Therefore, I claim that **T** is not exhaustive in **C**. It should also be noted that when the desired output cannot be derived by construction of any finite number of finite state machines (von Foerster, 1970) i.e. if it cannot be reduced to an output of a finite algorithm, the given computational problem is said to be not *effectively calculable* (Turing, 1938). Non-trivial finite state machines which enclose **T**, known as Turing machines, are the formal basis of computational effectivity as a notion.

Irreducibility of computational complexity of **C** to **T** is similar in its nature to the fact that there are *way more* differential equations than elementary functions, therefore it should be obvious that *most* differential equations cannot be reduced to an elementary form. As entailments can be drawn about anything which one can ask a coherent question about, we have a much larger class **C** of computations than **T**, where instead the space of questions is limited to those which one can ask in the formal language of a Turing machine.

2 | What are Vital systems?

2.1 | In terms of Functional Organization

This question has already been thoroughly examined by various scholars. Rosen (1991, 2000) highlights the fact that comprehending living systems in terms of a notion of organization, as defined in thermodynamics or information theory involves only statistical considerations instead of any of the functional aspect of living systems. The vital systems (henceforth represented as **V**) when characterized in terms of *negentropy* have a persistent non-random or 'organized' systemic architecture which replicates itself across time, thereby maintaining an homologous and homeostatic structure, while contributing to the increase in entropy in the environment. However, this description fails to address what this organization entails. It is unentailed from this description, as Rosen argues.

It can be said that classical notion of Shannon information ignores *semantic* value of that information. Kauffman et. al. (2007) point out, because of this indifference towards semantics of the information, where a random soup of organic chemicals is considered to have more information in this formalism, on the other hand a structured biotic agent, a living organism with more structure and more organization, which therefore has more *functional meaning* than the soup, has less Shannon information. "This is counterintuitive to a biologist's understanding of a living organism. We therefore conclude that the use of Shannon information to describe a biotic system would not be valid. Shannon information for a biotic system is simply a category error."

Rosen (1991) describes the order in **V** in a functional sense of what it *does* rather than what it merely is. He redefines order therefore in terms of context and function of the component. If the component, which is defined as that whose removal or addition within a particular systemic context alters the system's behavior, therfore it is relevant to this context in terms of function as a differential activity, then such a component is in order, otherwise disordered.

2.2 | In terms of Compatibilization

Simondon's (2020) theory of individuation is remarkably distinct from historical approaches to concept of individual. It understands individual via a theory of individuation as a process of becoming, which casts physical individuation as distinct from vital individuation. Crucially for our goals, he distinguishes physical and vital individuation on the basis of compatibilization, i.e., the characteristic feature or function of vital systems is that "it discovers in its field of reality structural conditions that allow it to resolve its own incompatibilities". This implies that living systems are open systems which are responsive to their environment in such a way that they “compatibilize” *singularities* as problems to be resolved in service to their replicative and reproductive continuity. Therefore this definition of vital systems is strictly in functional terms, in continuity with the above arguments.

3 | What are intelligent systems?

3.1 | Anticipation as Non-ergodic Compatibilization

It has been said that “living systems are cognitive systems, and living as a process is a process of cognition. This statement is valid for all organisms, with and without a nervous system” (Maturana & Varela, 1980). It should be noted here, that merely an passive or reactive mode of information transduction as a process of problem resolution or “compatibilization” in **V** is not altogether enough for situations and scenarios which present novel problems. Since, the possibility of such scenarios can be anticipated when their historical contingency is properly considered, preparation and dealing with these scenarios requires context-based inferential reasoning abilities.

A process whose phase state cannot be determined independently of its historical contingency is called a *diachronic* process. Systems which present such problems are called ‘non-ergodic’ i.e. these systems do not span the entirety of their phase space given an indefinite amount of time, as their trajectories are contingent on their histories by recursive qualifications, that is, each historical contingency modifies the effect of previous recursions on next ones, each of which modifies the overall phase space. This implies that trajectories of such systems are in a very specific sense, non-arbitrary, and therefore, an ahistorical or *synchronic* analysis of such systems will always be grossly inadequate.

Just as the vascularization of the cardiovascular system over the evolutionary course comes forth as an entirely non-ergodic and biologically robust solution to the problems of biotic resource supply and allocation, which merely rudimentary osmotic processes would have been insufficient for, in higher order creatures; similarly, a system of active information processing (information resolution and compatibilization) which requires abstract problem solving becomes necessary for higher order problems which require spatio-temporal contextual reasoning, foresight, and metacognition.

This implies that the operations native to the space of intelligent systems, which is henceforth referred to as **I**, are far more flexible and dynamically responsive than can be afforded by an unconscious mode of arbitration with the environment. Intelligent systems can respond to problems not presented in the environment and even to entirely hypothetical and imagined problems. Where does this imagination come from? This question can be addressed by highlighting the distinction between what Simondon (2020) called ‘*order of the simultaneous*’ and ‘*order of the successive*’:

> *The pure living being indeed integrates its past experience into its present behavior, but it cannot carry out the inverse integration, because it cannot introduce reflection due to which the present behavior, already imagined in its results and analyzed in its structure, is placed on the same ontological level as the past behavior.*

Here, Simondon (2020) describes what we have characterized as passive affect-based responsiveness of the living where the past and present behaviour are on the ‘same ontological level’. It is to be noted that he denotes simple living beings that do not have a psychological dimension as *pure living beings* as opposed to psychological individuals. For such beings, he highlights a discrepancy between experience and behavior which is, which is reduced in psychological beings due to faculties of cognition and imagination; as they conserve information of past experiences which is reflected upon and fedback in the present behavior, while current behavior is simultaneously experienced as temporal self-awareness.

> *The possibility of foresight and the possibility of remembering converge because they share the same nature and have a single function: to establish the reciprocity of the order of the simultaneous and the order of the successive.*

And thus, he distinguishes the two orders of processual compatibilizing functions in **I**, discussed in terms of reflection as an information transduction across the orders of the successive and the simultaneous. One can see how such a transduction makes the phase space highly non-ergodic. Here, **I** is a characteristic sub-class of **V**, distinguished regardless of how complicated, sophisticated or effective its characteristic operation is, rather based on the kind of reflective agency the system demonstrates via the processing of the task. This distinction has been formalized in terms of Denizhan's razor (section 3.2).

> *What really distinguishes a biological system from a (merely) complex system is not a new kind of causality, nor even the presence of internal models, but the development and specialized use of models in adapting to predicted futures. (Kineman, 2011)*

An intelligent system can be considered, first and foremost an anticipatory system (Rosen, 2012). Rosen's anticipatory systems have the ability to select and be selected by their contexts, and thus increasing the set of possible behaviors in a process of non-ergodic complexification which alters both the system and its context and consequently increasing order and information.

3.2 | Ontological Expansion Function in $\mathbf{I}_D$ (Denizhan's razor)

Denizhan (2023) was concerned about the equalization of artificially *intelligent* systems and what we will call natural intelligence found in higher order animals as representatives of **I**. She considers artificial intelligence (AI) as a misleading term and instead, proposes the name *Automated Optimisation* which more accurately describes a process that does not involve reflective activity on behalf of an agent.

She defines intelligence in **I** as characteristic of an agent which can traverse between a passive or conservative mode A (the mode of *modelled regime* where all problems are in some sense trivial or reducible to an algorithm) and an active or creative mode B (the mode of unmodelled regime where problems are new and it's impossible to tell, by pre-defined criteria, what is relevant for the new required model and what is not, i.e. noise). Mode B is hard to deal with syntactical or heuristic procedures because of, among other reasons, framing problem (Fodor, 2001) which forces the requirement of context-specific models, "founded on the ground of reality which has risen in the course of biological evolution through embodied structures and processes, and keeps rising during the lifetime of the Agent towards increasingly abstract mental models" (Denizhan, 2023).

Cognitive systems enter this mode when some part of their internal meta-model (edifice of all internal models) is destabilized (when the involved models fail to serve their purpose due to accumulating change in the unmodelled parameters or the emergence of an entirely novel situation), creating the need and opportunity for a restructuring of the meta-model. This mode terminates with the discovery of a new resolution and order, leading to "*an expansion of the Modelled into previously unmodelled realms of reality.*" It should be noted here that, it is impossible to completely model all possible parameters involved in environmental processes, trivializing the creative mode, as this has been demonstrated several times (Rosen (1985, 1991), Kauffman (2012), Kampis, (1991)).

Exhibit 1. (Denizhan, 2023).

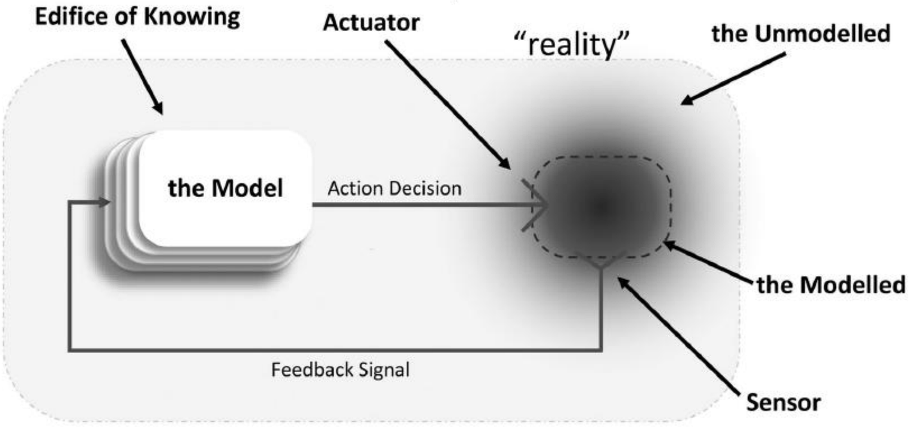


Fig. 4. The proposed representation for cognitive processes. The Model stands for one of the many context-specific models in the Edifice of Knowing, and the Modelled for its hypothetical ontic pre-image.

Mode A refers to routine and low-level cognitive processes which follow rather invariant procedures that are driven by sensory inputs, and operate within a predefined ontology which can be described with reasonable accuracy in terms of the information-processing paradigm. However, it confines the agent’s (internal and external) activities to a predefined ontology which cannot account for the creativity nor can it explain how a model has emerged in the first place whereas mode B is precisely when a context-specific model is destabilized, which if not addressed, can leave the agent debilitated in her actions in the respective context.

Therefore, this operational mode is opportunity for restructuring of the assortment of context-specific models or *edifice of knowing*. This restructuring demands ontological expansion, i.e. “an expansion of the Modelled into previously unmodelled realms of reality” (Denizhan, 2023).

She takes a non-reductionist approach to distinguishing intelligence in **I** on basis of “the capacity of achieving ontological expansion via internal restructuring of the Edifice of Knowing”. This implies that the creative mode B necessitates an active dynamic conception of internal metamodel called the Edifice of Knowing “that evolves under the pressure of conflict resolution” and that an authentic simulation of such a creative mode would require some form of partial or complete representation of the dynamics of a destabilised Edifice of Knowing.

She notes that the “typical attempts of simulating ontological openness include random search in a huge (but still predefined) space, or random recombination of predefined building blocks into arbitrarily complex hierarchical organisations.” But since their phase space is predefined, they cannot be said to have *expanded* their ontology in a responsive and dynamic sense, and is therefore, still restricted to the conservative mode A.

Exhibit 2. (Denizhan, 2023).

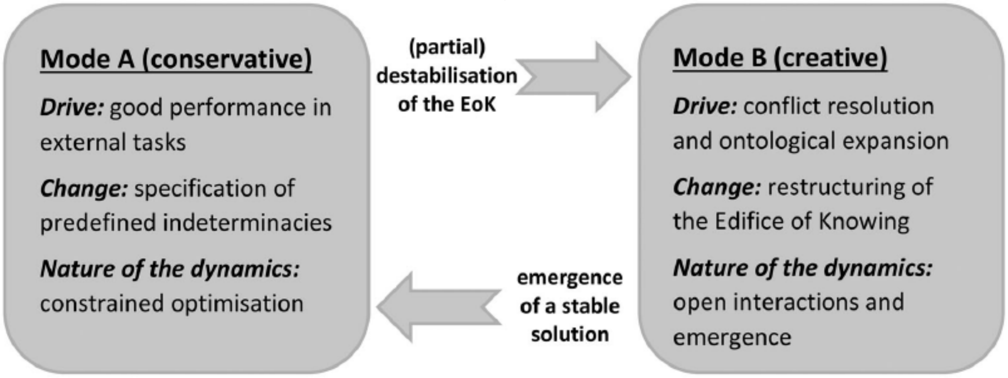


Fig. 5. Two modes of cognitive processes and transitions between them.

In light of these considerations, one can see how the aforementioned definition of **I**, henceforth represented as $\mathbf{I_D}$ has several advantages, one of them being that it excludes routine-based low-level processes that follow predefined stepwise procedures or specifically, *algorithms*. An algorithmic procedure, no matter how sophisticated, elaborate or complicated in its operation, is not qualified for $\mathbf{I_D}$ as it fundamentally operates within the confines of a given ontology predefined by all the possible permutations of the allowed operations on all the possible inputs in that domain.

Natural intelligence of animals transcends this limitation as animals can re-structure and re-organize their model to interact with a system of any given kind based on previous interactions which may violate initial model expectations. This is carried out routinely regardless of what the original model's ontology was, one can give basis to a new ontology based on one's experience. Because the definition in terms of ontological expansion includes intelligence of humans and non-human animals as well as subcategories of intelligence such an analytical or emotional intelligence, and even the ability to invent procedural algorithms, while excluding technological systems that passively rely on algorithms regardless of their performance, I wager, it deserves being called a *razor.*

4 | Impredicative or 'Closed loop' Complexity

4.1 | Holonic complexity (Kineman)

Arthur Koestler (1967, 1978) coined the term *holon* as a unit of analysis (attributed to nature), that is "*simultaneously part and whole*" (also see section 7). We shall use it to analyze the integrated causality in what we will refer to as impredicative complexity. Kineman (2011) uses the term *holon* in terms of actual (realized) and contextual (potential) *aspects of nature*.

Exhibit 3. (Kineman, 2011).

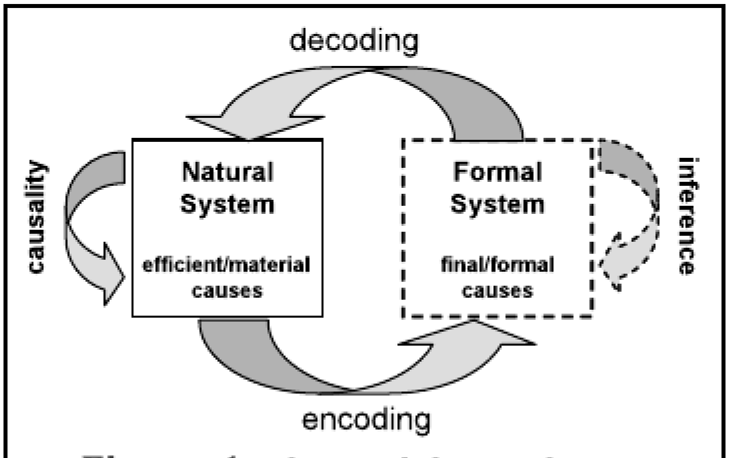


Figure 1: The Modeling Relation

Exhibit 3 shows a modeling relation as depicted by Kineman (2011), which he borrows from Rosen (1991). In this modeling relation, we see the holonic unit as the relation between the natural systems (an encompassing class of all possible systems in nature, represented as **N**) as the realized actual aspect whereas formal system represents the contextual aspect of **N**. Context, as per Kineman's usage, is the aspect of N that enables or conditions the behaviour or properties of another system, which includes the existence of that system. It can be considered as "*a domain of non-localized mirror images of realized local events"* which are deterministically or, in other words, computationally (refer to definition of computation in section 1.1) closed in **C**. Due to such a closure principle, if we consider a given system in N, as the foreground and the rest of systems in **N** as the contextual background, they form a closed loop of integrated causality.

> *Non-locality refers to contextual potentials: unrealized constraints in a contextual system that establish the potential existence (formal cause) of another system. It is very much like an ecological niche factor space in which a system can be identified, aside from its actual occurrences, by its ability to exist in various factors that are realized independently. The niche-space thus identifies potential existence in factors other than time and location (which are properties of realization) (Kineman, 2011).*

As the realized and contextual domains are interpreted as *ontological* aspects of natural systems, they cannot be considered as containing *pre-defined elements* because relational theory assumes that the only knowable elements are those "abstracted from otherwise un-described realities". Kineman (2011) further declares that "the knowable elements of a given domain that correspond to a natural system are the abstractions: structure and function. In other words, the results of a mapping are epistemological, but the domain of a mapping must be considered ontological."

The compositions of mappings or morphisms between realized states are therefore recursive holon sequences. This means that the states are mutually determined and ordered by the causal feedback loops of system and context. This is the foundation of what we shall call *holonic complexity* (exhibit 3, Kineman, 2011). As such holonic entities are entirely interactional in their nature, they cannot be said to have identity function or even an origin in a trivial sense.

Exhibit 4. (Kineman, 2011).

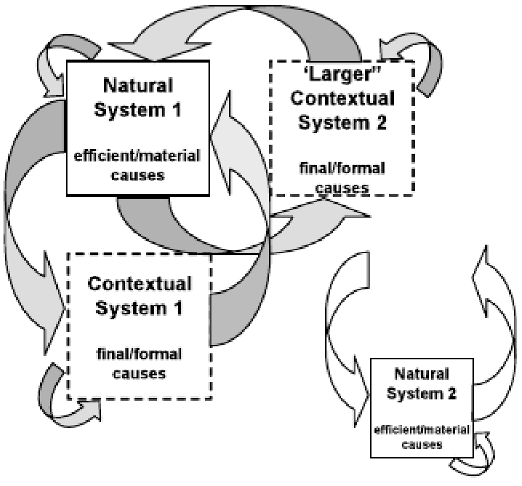


Figure 3: Equivalent Holarchy of Contextual relations.

Kauffman et. al. (2012) point out that typically when physical processes are considered in physics, we can prestate the configuration space or phase space of the process. However, for systems in **V**, the phase space itself is ever evolving due its holonic complexity, specifically in ways which cannot be prestated. Therefore, we have no settled invariant relations by which we can write down the equations of system evolution of the ever new relevant observables and parameters revealed after the fact. More specifically, "we cannot prestate the adaptive 'niche' as a boundary condition".

4.2 | Vicious circles and Meta-language semantics

Semantics is fundamental to all natural languages. When dimension of semantics is removed from a language, leaving only syntax, it is called a formal language. These formal languages are and have been for a long time beloved darlings of mathematicians and physicists as well as computer scientists because they provide an excess of rigor and context independence, which are valued in terms of objectivity. Objectivity means that a proposition's truth value can be determined without taking any consideration of the point of view of the one determining the said value (the subject), i.e. it is not subjective. When this point of view cannot be excluded from the consideration, it presents vicious circles of self-referentiality which are very tricky to deal with within the syntactical universe of formal languages.

In such a scenario, one is forced to abandon the formal language and take cues from the meta-linguistic world to corroborate the proposition. Hence, the escape from vicious circles forces taking a meta-linguistic standpoint, which we call semantics. It should be noted that strict formalization (or *semantic destratification*), which exludes semantic field from conceptual universes, are often not the demands of problems themselves that need to be solved but by extraneous standards of rigor which are standard in these departments.

Gödel's incompleteness theorem (1931) punctures a hole at the foundational assumptions of such a totalizing mathematical ambition which would have rendered semantic field epiphenomenal and all systems trivial, in von Foerster's (1970) sense. Rosen's (1991, 2000) argument for unsimulability of **V**, and **N** in general, which rests on demonstrating inherent impredicativity (self-referential vicious circles) in **V**, further reassures us that the semantic field as a meta-linguistic edifice is ineliminable. He uses the word *complex* as the designation for such unsimulable systems.

He defines systems in **V** to be closed in efficient causation (operationally closed/self-entailed/autopoietic), i.e. every efficient cause is entailed by some other efficient cause forming a closed loop of impredicative chain of entailment. He devised a class of relational models called *(M,R)-systems* which are formal systems defined to have such an impredicative loop of inferential entailment, and hence are non-simulable i.e. they are not definable by an algorithm or in equivalent terms, they cannot be effectively evaluated by a Turing machine. Kercel (2004a, 2004b) refers to such an arrangement as *endogeneity* and he demonstrates that brains are endogenous systems, in this sense.

Heinz von Foertster (1970) points out that the so called scientific method excludes formal definitions which include self-referentiality or closed logical systems that include "the referee in the reference, the descriptor in the description, and the axioms in the explanation" as they are considered logically incoherent or paradoxical inherently. "In order to refute this theorem it is tempting to invoke Gödel's Proof of the limits of the Entscheidungsproblem in systems that attempt to speak of themselves. But Lars Löfgren [1968] and Gotthard Günther [1967] have shown that self-explanation and self-reference are concepts that are untouched by Gödel's arguments."

4.3 | Dialogical Ludic Loops

Even though the phase space for an ecology of natural systems or *biosphere* maybe unprestatable, it cannot be said that biosphere is incomprehensible or meaningless in any way. Our theoretical scaffoldings in form of syntactic structures are considered useful insofar as they serve coherent descriptions of a corresponding semantic field i.e. they *mean* something. But emergence of this sense-making or semanticization is not a trivial problem. According to Negarestani (2018) semanticization is a consequence of a pragmatic interactive paradigm of games which contextualize the sense-maker within the biosphere. He deploys Girardian *ludics* as "an inferential theory of meaning, dialogical and operational semantics, an autonomy of minimal syntax, and a general notion of game devoid of any predetermined winning strategies or payoff functions".

For ludics, we are interested in the dialogue as a dynamic process of interactive computational process in which rules (syntax) and meanings (semantics) spontaneously emerge throughout the course of the game or the dialogue. For a given dialogue, the conversation progresses via role switching between interpretation and response functions for speech acts of assertion and questioning. These players, in an imaginary dialogue exchange *utterances* as speech acts in a pragmatic context upon which themes of further utterances can develop and grow into syntactic and semantic ideas in relation to each other i.e. syntax derives *eigenfunctions* from semantics and semantics derives *eigenvalues* from syntax. A very similar approach was already hinted at, by Brier (1996), in what he termed as "languaging".

If instead of recursive non-ergodic processes, we were relying on an ergodic osmosis of information, any such structure of meaning embedded in syntax-semantic correspondances would have taken many orders of lifetimes of the universe to crystallize. Therefore, in practical terms, only such non-ergodic diachronic processes can yeild ontological expansion of a sufficiently complex system. It is the autopoietic survivalist nature of *the game* which prefigures c*ontextualization* and *topicalization* in a dialogue which selects for survival. This corresponds to Niklas Luhmann's theory of social-communicative systems where, as Brier (1996) notes "communication does not transmit meaning but rather requires it as given and as forming a shared background against which informative surprises may be articulated". It should be noted that the opponent in the dialogue can be the biosphere itself. Ludics serves as a formal description of mode B from section 3.2.

The test is the interaction between speech acts and context. The impact of the speech act on the interaction is in terms of the updating, modification, or erasing of a shared context (Negarestani, 2018, p. 372). In ludics, different interacting strategies are tested not against a preestablished model, but against one another. In the process, the rules of logic emerge from the confrontation of strategies which interact as players in a game rather than propositions. "Ludics shows that the continuity between syntax and semantics is naturally achieved through an interactive stance toward syntax in its most atomic and naked appearance: the trace of the sign's occurrence, the locus or place of its inscription" (Negarestani, 2018, p. 366).

The way Negarestani avoids the riddle of epistemic omniscience (section 1.1) is by way of embedding his computational model of ludics in an epistemically relevant environment, not just as a background of classical computation. This implies that environment dynamically and actively interacts with the system and determines its processual trajectory and therefore "it is only in the presence of an environment (another system, machine, or agent) that computation can be understood as an increase (or decrease)—rather than mere preservation—of information" (Negarestani, 2018, p. 345).

5 | Constraints and Instructional Information

The purpose of a formalization is to reduce an epistemic datum to a proposition which can be derived from a set of fixed axioms by a process of stepwise algorithmic procedure (Rosen, 1991). However, this requires specification of the phase space and boundary conditions which is not possible for general systems, including systems in **V** (Kauffman et. al., 2011). Given the fact that computation is typically directly associated with the concept of Turing computation, the aforementioned scenario seems to preclude the possibility of a discussion of life in computational terms. While it is true that Turing computation is not an adequate formalization to enclose **V** within its domain, this does not preclude a larger class of computation which does so.

Kauffman et. al. (2007) introduce the notion of *instructional information* which they identify with constraint or boundary conditions in a system. This notion of information is fundamentally functional rather than statistical:

> *The working of a cell is, in part, a complex web of constraints, or boundary conditions, which partially direct or cause the events which happen. Importantly, the propagating organization in the cell is the structural union of constraints as instructional information, the constrained release of energy as work, the use of work in the construction of copies of information, the use of work in the construction of other structures, and the construction of further constraints as instructional information. This instructional information further constrains the further release of energy in diverse specific ways, all of which propagates organization of process that completes a closure of tasks whereby the cell reproduces.*

This gives us a strong motivation towards conceptualizing a notion of computation which is not constructed out of an abstract and discrete procedural data manipulation on some material substrate but rather in the processing of instructional information as identified with functional constraints of the substrate itself. As Deutsch (2012) explains, due to the prevalent essentialist conception of computational proof of a process “if the laws of physics were such that a physical system existed whose motion could be exploited to establish the truth of a Turing-unprovable proposition, the proposition would still not count as having been genuinely proved.*”* Under this classical framing, proofs are only considered legitimate when they are carried out in an abstract space free of contingencies rather than an embedded space where the process is actually enacted.

However, the notion of instructional information provides theoretical foundation for a new conception of computational proof which involves not symbolic manipulation but a implications drawn from a physical process, i.e. *material implications* (Kampis, 1991). Rosen (1991, p. 270-275) presents an example in the form of protein folding problem, which regardless of its intractability in **T** is known to be effective via material implications. He demonstrates that protein folding problem can be understood better when viewed as an system with impredicative global relations (constraints) between its configurations. This approach is demonstrably effective but does not provide an algorithmically computable function, which Rosen argues is by necessity of the nature of the problem.

He concludes that “(1) there is no algorithm that will take us from primary structure to tertiary structure directly, and (2) there is further no algorithm that will take us from tertiary structure to functional activity, or “active sites*”*.” This is because, according to him, protein folding problem presents a case of complexity in a system, by which he means a system with no largest model (or a unifying complete model), rather, a system with multiple models which are irreducible to one another. Such a notion of complexity is called Rosennean complexity, after his name.

6 | Circular Causality and Anticipatory Systems

6.1 | Final Cause and Anticipation

> *It is my intent not only to liberate the “circulus vitiosus” from its bad reputation, but to raise it to the honorable position of a “circulus creativus”, a creative cycle (von Foerster, 1974).*

The name cybernetics comes from the Greek word *kybernḗtēs* for helmsperson in sense of one at the helm of steering a ship. In steering a ship, the helmsperson adjusts their steering in continual response to the effect it is observed as having, forming a feedback loop through which a steady course can be maintained in a changing environment, responding to disturbances from currents, winds and tide. This particular example of a cybernetic feedback loop is pregnant with the notion of teleology or ‘finality’. This finality as the forward orientation of operationality is fundamental to all cybernetic systems. Notably, Kauffman et. al. (2007) remarks that “our language is teleological. We believe that autonomous agents constitute the minimal physical system to which teleological language rightly applies.”

Aristotle distinguished four kinds of causes, the material cause, efficient cause, the formal cause and the final cause, the final cause being the only one which succeeds its effect and thereby, in a way, violating the temporal directionality of deterministic or ‘reactive’ causation. This finality becomes the basis for anticipatory systems in Rosen (2012) as a divergence from the Newtonian *reactive paradigm*. Heinz von Foerster (2003) points out the relevance of the notion of Aristotelian final cause to cybernetics by going so far as to say that we are all cyberneticians “whenever we justify our actions [...] with the phrase in English “in order to ...,” which in French is much more Aristotelian, “à fin de...”.”

He also points out, that for a process with closed circular causality, "the cause for an effect in the present can be found in the past if one cuts the circle at one spot, and that the cause lies in the future if one does the cutting at the diametrically opposed spot". By closing the causal chain, he not only puts effective and final causality in a *dialogue*, but also gets rid of the uncertainty of boundary conditions: as the end conditions themselves constitute the starting conditions. This is where the eigenvalue problem (section 4.3) of these eigenfunctions emerges as "only certain values of those conditions provide a solution for the processes within the circle".

We also find in Kineman (2011) a complete formalization of circular causality which integrates all four Aristotelian causes into a modelling relation which completes itself. As this setup includes final causality, which is by necessity excluded in the reactive paradigm of formalizations, it describes anticipatory systems which are in active participation and dialogical ludic game (section 4.3) with their environment.

> *Second-order closure, which is the minimum causal requirement for a complex system (that it involve two distinct holons as a duality, and thus two contexts), is hierarchical composition. [...] It ensures impredicative realizations (realizations that require more than one formalism to describe them) because it relates dual contexts that have irreducible formal causes as long as insides are distinguished from outsides. (Kineman, 2011)*

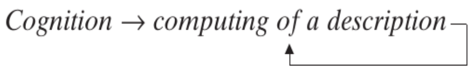
Such holons can be combined in hierarchical and sequential maps, wherefore we can have holons which enclose same contextual/natural systems or generate same functions/structures and hence overlap or even nest one another leading to hyper-complex causal topologies which Kineman uses to describe complex sequences in time, including retro-causation, where "*two systems have causal relations on different time scales.*" Such causal maps can explain anticipatory processes in the biosphere (Rosen, 2012).

6.2 | Four Postulates of Cybernetics of Epistemology

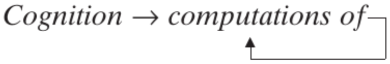
von Foerster (1974) presents following postulates of "*cybernetics of epistemology"* which shall orient our approach:

> 1. *The meaning of the signals of the sensorium are determined by the motorium; and the meaning of the signals of the motorium are determined by the sensorium.*
>
> Such a dualism which completes a holonic circuit is fundamental to an anticipatory system.
>
> 2. *The laws of physics, the so-called "laws of nature," can be described by us. The laws of brain functions—or ever more generally—the laws of biology, must be written in such a way that the writing of these laws can be deduced from them, i.e., they have to write themselves."*

This postulate fundamentally addresses the self-referential nature of biological processes, or processes of natural intelligent systems. It implies autopoietic or cascading nature of computation as "information resolution" on different orders of material apperception. For example, the first order description as a 2D retinal projection, second order post-retinal description to ganglia cells and so on to the various stages of processual stages which constitute a neurological event of visual apperception. He presents this proposition in another form, which with slight modification, can be written as



and from where it can be further simplfied as



We may refer to this as the postulate of *second-order cybernetics*. The key characteristic of such systems is that efficient cause of each recursion of the process is its preceding one while final cause is the succeeding one, and when they are chained together as such, the distinction from a non-relative perspective becomes impossible to make as it becomes a causal feedback loop. That is why, the "laws" of such systems are said to write themselves.

3. *The states of a nerve cell do not encode the nature of the cause of its activity. (Encoded is only "this much at this part of my body" but not "what?")*

This can be called the coding problem or representation problem: how can a code which is supposed to stand in for an object, be the means by which that object is known? Or how is the mapping from domain (neural activation encoding) to codomain (sensitive quality) specified? In this regard, he states "given that the qualities of sensory impression are not encoded in the receptive apparatus, it is clear that the central nervous system is organized in such a way that it computes these qualities from this meager input." He further states "only by correlating the motor activity of the organism with the resulting changes in its sense organs makes it possible for it to interpret these neural activity uniquely" (von Foerster, 1974).

Exhibit 5. (von Foerster, 1974).

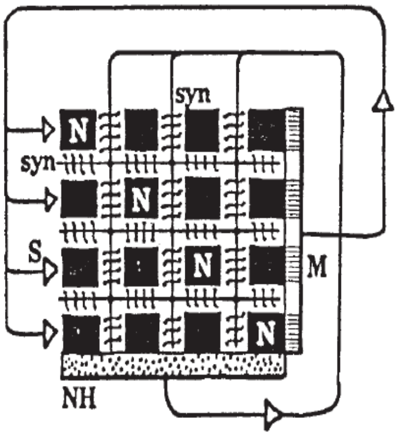


FIGURE 9. Flow of signals in the nervous system from the sensory surface (left boundary S) via bundles of nerves (black squares N) and synaptic gaps (syn) to the motor surface (right boundary M), which, in turn changes the stimulus distribution along the sensory surface; and, on the other hand, the signal flow from the neurohypophysis (lower boundary NH), whose activity modulates the composition of the steroids in the synapses and, hence, the operational modalities everywhere within the various bundles of neurons.

In the exhibit 5, he demonstrates how "the organization of the nervous system is schematically reproduced." The black squares represent neuron bundles, which effectuate on the next bundle via synaptic connections. The flow of signals runs from left to right, from the sensitive surface towards the motor surface, and then fedback into a circular loop via the ambient environment. One can see how this diagram is a visualization of postule 1.

Exhibit 6. (von Foerster, 1974).

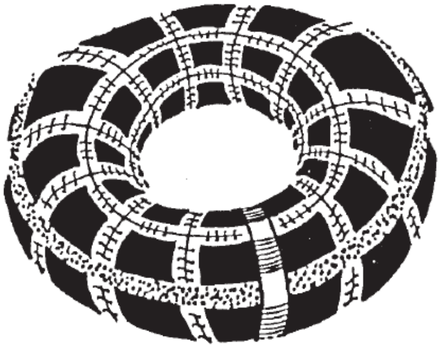


FIGURE 10. Double closure of the nervous and hormonal causal chain. Horizontal dotted line (equator) neurohypophysis. Vertically broken seam (meridian) motor-sensory "synaptic gap".

In exhibit 6, we see a representation of "the double closure of the stream of signals. The seam up front corresponds to the motor sensory synaptic gap, the horizontal seam, to the neurohypophysis." This represents a solution to the problem of infinte regress of higher and higher order observers which validate observations or computations made on the lower order by closing the loop. Here we can conclude this section with von Foerster's formulation of the eigenvalue problem as the postulate of the epistemic homeostasis:

> 4. *The nervous system as a whole is organized in such a way (organizes itself in such a way) that it computes a stable reality.*

7 | Kantian Wholes and Internal Reflection

One final aspect of systems in **V** which bears explication is the aspect which Kauffman et. al. (2012) referred to as being *Kantian wholes*:

> *Kant pointed out that in an "organized being" the parts exist for and by means of the whole, the whole exists for and by means of the parts. The parts perform tasks, typically subsets of their causal consequences, that can be defined only because they are part of a Kantian whole.*

A benefit of this notion of Kantian whole is that it can be used to make a distinction between function and side effect for a given system (Kauffman et. al., 2012) as not all effects produced by the Kantian whole contribute to the process of compatibilization and autopoietic reproduction. In a Kantian whole, it is the intertwined resonance of bottom-up and top-down causation that enables the unbroken wholeness and gives basis to the "internally generated final cause" which "imparts an identity on a process" (Kercel, 2004a). Simondon (2020) referred to this ability to give an internally generated final cause to a process as *reflection* in psychological beings.

This ability to reflect causes “the process to determine its own goals by acting in a manner that preserves the integrity of the loop” (Kercel, 2004a). Therefore, we can say that, the closed-loop autopoietic processes produce Kantian wholes “that can be perturbed by, but remains distinct from, its ambience. The closed-loop hierarchical causal entailment structure holds the process distinct and intact” (Kercel, 2004a).

8 | Conclusion

Let us reconsider Denizhan’s razor which proclaims intelligence to be only possible in the interactive space of ontological expansion (section 3.2). As a formulation of intelligence, I believe, this can be said to be considered resonant to the eigenfunction problem of syntax and semantics (section 4.3) in their dialogical interdependency where one derives from the other and contextualizes the other, or in other words, where one acts as the boundary condition for the other.

In contrast, there is an idea, formalized as Church-Turing thesis, that only those propositions which can be proven or problems which can be resolved using a symbolic language of a synactical pre-defined grammar and hence, pre-defined phase space, can be considered to have been computationally effective. This runs up against the fact that there are feasible physical processes which are not computationally tractable when represented in a syntactic language with a pre-stated phase space of an procedural mechanism, i.e. they cannot be programmed in a computer algorithm.

Rosen (1991) bolsters this critique by examplifying protein folding problem as a complex system with no largest (unifying) model. In this sense, complex systems are general, while Turing computable systems are highly non-generic (Rosen, 2000).

We understand that intelligent processes defined in terms of ontological expansion, cannot be reduced to an automated mechanism of a passive/reactive paradigm of causality, which ignores contextual final causes. We can therefore say that, in accounting for contextual frames, natural intelligence boasts of an ability to anticipate events in its environment as well as its own actions, as demonstrated by Rosen (2012). So, with these considerations, von Foerster’s postulates ground such complex systems which deduce their own actions or, in Rosen’s terms, entail their own efficient causes.

Negarestani’s ludic loops contextualize how systems, by way of feedback loops and internal interactions give shape to stable behaviors and behavioral grammars, which are encoded as semantics and syntax relations. The eigenvalue/eigenfunction problem is the fundamental problem of determinism in recursive functions which can produce such stable behaviors. In order for the system to not be considered a passive reactant, it would require an internal locus of determination of final causes, which further requires an investment of a process in its own perpetuation, i.e. auto-entailment or auto-poiesis (Maturana & Varela, 1980).

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