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# THE LIVING INTELLIGENT UNIVERSE

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# The Living and Intelligent Universe

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*"Cybernetics is the science of defensible metaphors."*

Gordon Pask (1928-1996).

*"You, with all these words...."*

Marisa Bassi Stern (my wife, when I speak too much).

**Abstract**

The objective of this paper is to use the cognitive constructivism (Cog-Con) epistemological framework for the understanding of massively complex and non-trivial systems. We analyze several forms of system complexity, several ways in which systems become non-trivial, and some interesting consequences, side effects and paradoxes generated by such non-triviality.

*Keywords:* Autopoiesis, Bayesian statistics, Causation forms, Cognitive constructivism, Emergence, Epistemology, Probabilistic reasoning, Ontology, Systems' theory.

In the article Mirror Neurons, Mirror Houses, and the Algebraic Structure of the Self, by Ben Goertzel, Onar Aam, F. Tony Smith and Kent Palmer (2008) and the companion article of Goertzel (2007), the authors give an intuitive explanation of the logic of mirror houses, that is, they study symmetry conditions for specular systems entailing the generation of kaleidoscopic images. In these articles, the authors share several (in my opinion) important insights on autopoietic systems and constructivist philosophy. Another kind of more prosaic mirror houses, used to be a popular attraction in funfairs and amusement parks. The entertainment in such mirror houses comes from misperceptions about oneself or another object or, more precisely, from the misleading ways in which a subject sees where or how himself stands in relation to other objects, or the other way around.

The main objective of this paper is to show how similar misperceptions in science can lead to ill-posed problems, paradoxical situations and even misconceived philosophical dilemmas. The epistemological framework of this discussion is that of cognitive constructivism, as presented in Stern (2007a,b, 2008 a,b). In this framework, objects in a scientific theory are tokens for eigen-solutions, and these objects are characterized by Heinz von Foerster by four essential attributes, namely of being discrete (precise, sharp or exact), stable, separable and composable. The Full Bayesian Significance Test, or FBST, is a possibilistic belief calculus based on (posterior) probabilistic measures that was conceived as a statistical significance test used to access the objectivity of such eigen-solutions, that is, to measure how well a given object manifests or conforms to von Foerster's four essential attributes. The FBST belief or credal value is $\text{ev}(H \mid X)$, the *e-value* of hypothesis $H$ given the observed data $X$, interpreted as the *epistemic value* of hypothes $H$ (given $X$), or the *evidence value* of data $X$ (supporting $H$). A formal definition of the FBST and several implementations for specific problems can be found in the author's previous publications, see for example Borges and Stern (2007), Lauretto et al. (2003, 2008), Pereira and Stern (1999), Pereira et al. (2008), Stern (2003, 2004, 2008b), and Stern and Zacks (2002).

From now on, we refer to Cognitive Constructivism and the accompanying Bayesian statistical theory and tool boxes, as laid down in the aforementioned articles, as the Cog-Con epistemological framework.

Instead of reviewing formal definitions of the essential attributes of eigen-solutions, we analyze in section 1 the Origami example, a didactic case presented by Richard Dawkins. The origami example is so simple that it may look trivial and, in some sense, so it is. In subsequent sections we analyze in which ways the eigen-solutions found in the practice of science can be characterized as non-trivial, and also highlight some (in my view) common misconceptions about the nature of these non-trivial objects, like distinct forms of illusion in a mirror-house.

In section 2 we contrast the control, precision and stability of morphogenic folding processes in autopoietic and allopoietic systems. In section 3 we pay attention to object orientation and code reuse, inter-modular adaptation and resonance, and also analyze the yoyo diagnostic problem. In section 4 we explore auto-catalytic and hypercyclic networks, as well as some related bootstrapping paradoxes; this section is heavily influenced by the work of Manfred Eigen. Section 5 focus on explanations of specific components, single links or partial chains in long cyclic networks, including the meaning of some forms of directional (like upward or downward) causation. In section 6 we study the emergence of asymptotic eigen-solutions like thermodynamic variables or market prices, and in section 7 we analyze the ontological status of such entities. In section 8 we study the role and scope limitations of conceptual distinctions used in science, and the importance of probabilistic causation as a mechanism to overcome, in a constructive way, some of the resulting dilemmas. In section 9 we present our final remarks. In this paper we have made a conscious effort to use examples that can be easily visualized in space and time scales direly accessible to our senses, or at least close to it. We have also presented our arguments using, whenever possible, very simple (high school level) mathematics. We did so in order to make the examples intuitive and easy to understand, so that we can concentrate our attention on the epistemological aspects and difficulties of the problems at hand. The internet site `www.ime.usp.br/~jstern/pub/figuras/` contains several interesting figures and images that illustrate some of the concepts discussed in this paper.

# 1 The Origami Example

The Origami example, from the following text in Blackmore (1999, p.x-xii, emphasis are ours) was given by Richards Dawkins as a way of presenting the notion of reliable replication mechanisms in the context of evolutionary systems. Dawkins' example contrasts two versions of the Chinese Whispers game using distinct copy mechanisms.

> Suppose we assemble a line of children. A picture, say, a Chinese junk, is shown to the first child, who is asked to draw it. The drawing, but not the original picture, is then shown to the second child, who is asked to make her own drawing of it. The second child's drawing is shown to the third child, who draws it again, and so the series proceeds until the twentieth child, whose drawing is revealed to everyone and compared with the first. Without even doing the experiment, we know what the result will be. The twentieth drawing will be so unlike the first as to be unrecognizable. Presumably, if we lay the drawings out in order, we shall note some resemblance between each one and its immediate predecessor and successor, but the mutation rate will be so high as to destroy all semblance after a few generations. A trend will be visible as we walk from one end of the series of drawings to the other, and the direction of the trend will be degeneration...
>
> High fidelity is not necessarily synonymous with digital. Suppose we set up our Chinese Whispers Chinese Junk game again, but this time with a crucial difference. Instead of asking the first child to copy a drawing of the junk, we teach her, by demonstration, to make an origami model of a junk. When she has mastered the skill, and made her own junk, the first child is asked to turn around to the second child and teach him how to make one. So the skill passes down the line to the twentieth child. What will be the result of this experiment? What will the twentieth child produce, and what shall we observe if we lay the twenty efforts

out in order along the ground? ...

In several of the experiments, a child somewhere along the line will forget some crucial step in the skill taught him by the previous child, and the line of phenotypes will suffer an abrupt macromutation which will presumably then be copied to the end of the line, or until another discrete mistake is made. The end result of such mutated lines will not bear any resemblance to a Chinese junk at all. But in a good number of experiments the skill will correctly pass all along the line, and the twentieth junk will be no worse and no better, on average, than the first junk. If we lay then lay the twenty junks out in order, some will be more perfect than others, but imperfections will not be copied on down the line...

Here are the first five instructions... for making a Chinese junk:

1. Take a *square* sheet of paper and fold all four corners *exactly* into the *middle*.

2. Take the reduced *square* so formed, and fold one side into the *middle*.

3. Fold the opposite side into the *middle, symmetrically*.

4. In the same way, take the *rectangle* so formed, and fold its two ends into the *middle*.

5. Take the small *square* so formed, and fold it backwards, *exactly* along the *straight line* where you last two folds met...

These instructions, though I would not wish to call them digital, are potentially of very high fidelity, just as if they were digital. This is because they all make reference to idealized tasks like 'fold the four corners exactly into the middle'... The instructions are self-normalizing. The code is error-correcting...

Dawkins recognizes that instructions for making an origami have remarkable properties, allowing the long term survival of the subjacent *meme*, i.e. specific model or single idea, expressed as an origami. Nevertheless, Dawkins is not sure how he "wishes to call" these properties (digital? high fidelity?).

What adjectives should we use to appropriately describe the desirable characteristics that Dawkins perceives in these instructions? I claim that von Foerster's four essential attributes of eigen-solutions offer an accurate description of the properties relevant to the process in study. The instructions and the corresponding (instructed) operations are precise, stable, separable and composable. A simple interpretation of the meaning of these four attributes in the origami example is as follows:

*Precise*: An instruction like "fold a paper joining two opposite corners of the square" implies that the folding must be done along a diagonal of the square. A diagonal is a specific line, a 1-dimensional object in the 2-dimensional sheet of paper. In this sense the instruction is precise or exact.

*Stable*: By interactively adjusting and correcting the position of the paper (before making a crease) it is easy to come very close to what is specified in the instruction, and even if the resulting fold is not absolutely perfect (actually, in practice it never is), it will probably still work as intended.

*Composable and Separable*: We can compose or superpose multiple creases in the same sheet of paper. Moreover, adding a new crease does not change or destroy the existing ones. Hence, we can fold them one at a time, that is, separately.

These four essential attributes are of fundamental importance in the Cog-Con understanding of scientific activity. Moreover, Dawkins' origami example illustrates these attributes with striking clarity and simplicity. In the following sections we will examine a few other examples, each one less simple, not so clear or non-trivial in a distinct and characteristic way. We will also pay attention to some possible confusions and mistakes often made when analyzing systems with similar non-trivial characteristics.

# 2 Autopoietic Control, Precision, Stability

The origami folding is performed and controlled by an external agent, the person folding the paper. In contrast, this section studies organic development processes that are self-organized, that is, the process is not driven by an external agent, it does not require external supervision, nor is it amenable to external corrections. Artifacts and machines manufactured like an origami are called *allopoietic*, from $\alpha\lambda\lambda o$-$\pi o \iota \eta \sigma \iota \varsigma$ - external production, while living organisms are called *autopoietic*, from $\alpha \upsilon \tau o$-$\pi o \iota \eta \sigma \iota \varsigma$ - self production.

Autopoiesis is a non-trivial process, in many interesting ways. For example the inexistence of external supervision or correction mechanism, requires an autopoietic process to be very stable. Moreover, typical biological processes occur in environments with high levels or noise and have large (extra) variability. Hence the process must be intrinsically self-correcting and redundant so that its noisy implementation does not compromise the viability of the final product.

## 2.1 Organic Morphogenesis: (Un)Folding Symmetries

In this section we make some considerations about morphogenic biological processes, namely, we study examples of tissue folding in early embryonic development. This process naturally invites strong analogies, but also sharp contrasts with the origami example. At a macroscopic (supra cellular) level, the organisms' organs and structures are built by tissue movements, as described in Forgacs and Newman (2005, p.109), and Saltzman (2004, p.38).

The main types of tissue movements in morphogenic process are:
1) Epiboly: spreading of a sheet of cells over deeper layers.
2) Emboly: inward movement of cells which is of various types as:
2a) Invagination: infolding or insinking of a layer,
2b) Involution: inturning, inside rotation or inward movement of a tissue.
3) Delamination: splitting of a tissue into 2 or more parallel layers.
4) Convergent/Divergent Extension: stretching together/apart of two distinct tissues.

The blastula is an early stage in embryonic development of most animals. It is produced by cleavage of a fertilized ovum and consists of a hollow sphere of around 128 cells surrounding a central cavity. From this point on, morphogenesis unfolds by successive tissue movements. The very first of such moves is known as gastrulation, a deep invagination, producing a tube, the archenteron or primitive digestive tract. This tube may extend all the way to the pole opposing the invagination point, producing a second opening. The opening(s) of the archenteron become mouth and anus of the developing embryo.

Gastrulation produces three distinct (germ) layers, that will further differentiate into several body tissues. Ectoderm, the exterior layer, will further differentiate into skin and nervous systems. Endoderm, the innermost layer at the archenteron, generates the digestive system. Mesoderm, between the ectoderm and endoderm, differentiates into muscles, connective tissues, skeleton, kidneys, circulatory and reproductive organs. We will use this example to highlight some important topics, some of which will be explored more thoroughly in further sections.

### Discrete vs. Exact or Precise Symmetries

Notice that origami instructions, that implicitly rely on the *symmetries* characterizing the shape of the paper, require foldings at sharp edges or cresses. Hence, a profile of the folded paper sheet may look like it breaks (is non-differentiable) at a discrete or singular point.

Organic tissue foldings have no sharp edges. Nevertheless, the (idealized) symmetries of the folded tissues, like the spherical symmetry of the blastula, or the cylindrical symmetry of the gastrula, can be described by equations just as exact or precise, see Beloussov (2008), Nagpal (2002), Odel et al. (1980), Tarasov (1986), and Weliky and Oster (1990). This is why we usually prefer the adjectives *precise* or *exact* to the adjective *discrete* used by von Foester in his original definition of the four essential properties of an eigensolution.

### Centralized vs. Decentralized Control

In morphogenesis, there is no agent acting like a central controller, dispatching messages ordering every cell what to do. Quite the opposite, the complex forms and tissue movements at a global or macroscopic (supra cellular) scale are the result of collective cellular behavior patterns based on distributed control. The control mechanisms rely on simple local interaction between neighboring cells, see Keller et al. (2003), Koehl (1990), and Newman and Comper (1990). Some aspects of this process are further analyzed in sections 3 and 6.

# 3 Object Orientation and Code Reuse

At the microscopic level, cells at the several organic tissues studied in the last section are differentiated by distinct metabolic reaction patterns. However, the genetic code of any individual cell in a organism is identical (as always in biology, there are exceptions, but they are not relevant to this analysis), and cellular differentiation at distinct tissues is the result of differentiated (genetic) expression of this sophisticated program.

As studied in Lauterro et al. (2009) and Stern (2008, ch.5), complex systems usually have a modular hierarchical structure or, in computer science parlance, an object oriented design. In allopoietic systems object orientation is achieved by explicit design, that is, has to be introduced by a knowledgeable and disciplined programmer, see Budd (1999). In autopoietic system modularity is an implicit and emergent property, as analyzed in Angeline (1996), Banzaff (1998), Iba (1992), Stern (2008b, ch.5) and Lauretto at al. (2009).

Object oriented design entails the reuse, over and over, of the same modules (genes, functions or sub-routines) as control mechanisms for different processes. The ability to easily implement this kind of feature was actively pursued in computer science and software engineering. Object orientation was also discovered, with some surprise, to be naturally occurring in developmental biology, see Carrol (2005).

However, like any abused feature, in some circumstances code reuse can also become a burden. The difficulty of locating the source of a functionality (or a bug) in an intricate inheritance hierarchy, represented by a complex dependency graph, is known in computer science as the yoyo problem. According to the glossary in Budd (1999, p.408) - *Yoyo problem:* Repeated movements up and down the class hierarchy that may be required when the execution of a particular method invocation is traced.

Systems undergoing many changes or modifications, under repeated adaptation or expansion, or on rapid evolution are specially vulnerable to yoyo effects. Unfortunately, the design of the human brain and its mental abilities are under all of the conditions above. In the next subsection we study some examples in this area related to biological neural networks and language; These examples also include some mental dissociative phenomena that can be considered as manifestations of the yoyo problem.

## 3.1 Doing, Listening and Answering

In this section we study some human capabilities related to doing (acting), listening (linguistic understanding) and answering (dialogue). The capabilities we have chosen to study are related to the phylogenetic acquisition and ontogenetic development of:

- Mechanisms for precision manipulation, production of speech and empathic feeling;

- Syntax for complex manipulation procedures, language articulation and behavioral simulation;

- Semantics for action, communication and dialogue; and the learning of

- Technological know-how, social awareness and self-awareness.

When considering an action in a modern democratic society, we usually deliberate what to do (unless there is already a tacit agreement). We then communicate with other agents involved to coordinate this action, so that we are finally able to do what has to be done. Evolution it seems, took exactly the other way around. Phylogenetically, the path taken by our species follows a stepwise development of several mechanisms (that were neither independent nor strictly sequential), including:

1- Mechanism for 3-dimensional vision and precision measurement, fine motor control of hand and mouth, and visual-motor coordination for complex procedures of *precision manipulation.*

2- Mechanisms for *imitating*, *learning* and *simulating* the former procedures or actions.

3- Mechanisms for *simulating* (possible) actions taken by other individuals, their consequences and motivations, that is, mechanisms for awareness and (behavioral) understanding of other individuals.

4- Mechanism for *communicating* (possible) actions, used as mechanisms for command, control and coordination of group actions. Using such mechanisms implies a degree of awareness of others, that is, some ability to communicate, explain, listen and learn what you do, *you* - an agent like *me.*

5- Mechanisms for *dialog* and *deliberation*, that is, mechanisms for negotiation, goal selection and non-trivial social planning. Using such mechanisms implies some *self-awareness* or *consciousness*, that is, the conceptualization of an ego, an abstract *I* - an agent like *you.*

In a living individual, all these mechanisms must be well integrated. Hence, it is natural that these mechanisms work using coherent implicit grammars, reflecting compatible subjacent rules of composition for action, language and inter-individual interaction. Indeed, resent research in neuroscience confirm the coherence of these mechanisms. Moreover, this research shows the this coherence is based not just on compatible designs of separate systems, but on intricate schemes of use and reuse of the same structures, namely, of the same firmware code or circuits implemented as biological neural networks.

*Mirror neuron* is a concept of neuroscience that highlights the reuse of the same circuits for distinct functions. A mirror neuron is part of a circuit which is activated (fires) when an individual executes an action, and also when the individual observes another individual executing the same action, as if the observer were performing the action himself. The following passages, from important contemporary neuro-scientists, give some hints on how the mechanisms mentioned in the past paragraph are structured.

The first quotes, from Hesslow (2002, p.245), states the mirror neuron *simulation hypothesis*, according to which, the same circuits used to control our actions are used to learn, simulate, and finally "understand" possible actions taken by other individuals. Hence, according to the simulation hypothesis, we are naturally endowed with the capacity of observing, listening, and "reading the mind" of (that is - understanding, by simulation, the meaning or intent of the possible actions taken by) our fellow human beings.

> ...the simulation hypothesis states that thinking consists of simulated interaction with the environment and rests on the following three core assumptions:
> (1) simulation of actions: we can activate motor structures of the brain in a way that resembles activity during a normal action but does not cause any overt movement;
> (2) simulation of perception: imagining perceiving something is essentially the same as actually perceiving it, only the perceptual activity is generated by the brain itself rather than by external stimuli;
> (3) anticipation: there exist associative mechanisms that enable both behavioral and perceptual activity to elicit other perceptual activity in the sensory areas of the brain. Most importantly, a simulated action can elicit perceptual activity that resembles the activity that would have occurred if the action had actually been performed. (p.5).
>
> In order to understand the mental state of another when observing the other acting, the individual imagines herself himself performing the same action, a covert simulation that does not lead to an overt behavior. (p.5).

The second group of quotes, from Rizzolatti and Arbib (1998), states the mirror neuron *linguistic hypothesis*, according to which, the same structures used for action simulation, are reused to support human language.

> Our proposal is that the development of the human lateral speech circuit is a consequence of the fact that the precursor of Broca's

> area was endowed, before speech appearance, with a mechanism for recognizing actions made by others. This mechanism was the neural prerequisite for the development of inter-individual communication and finally of speech. We thus view language in a more general setting than one that sees speech as its complete basis. (Rizzo.p.190).
>
> ...a 'pre-linguistic grammar' can be assigned to the control and observation of actions. If this is so, the notion that evolution could yield a language system 'atop' of the action system becomes much more plausible. (p.191).
>
> In conclusion, the discovery of the mirror system suggests a strong link between speech and action representation. 'One sees a distinctly linguistic way of doing things down among the nuts and bolts of action and perception, for it is there, not in the remote recesses of cognitive machinery, that the specifically linguistic constituents make their first appearance'. (p.193-194).

Finally, a third group of quotes, from Ramachandran (2007), states the mirror neuron *self-awareness hypothesis*, according to which, the same structures used for action simulation are reused, once again, to support abstract concepts related to consciousness and self-awareness. According to this perspective, perhaps the most important of such concepts, that of an abstract self-identity or ego, is built using one's already developed simulation capacity for looking at oneself as if looking at another individual.

> I suggest that 'other awareness' may have evolved first and then counter-intuitively, as often happens in evolution, the same ability was exploited to model one's own mind - what one calls self awareness.
>
> How does all this lead to self awareness? I suggest that self awareness is simply using mirror neurons for 'looking at myself as if someone else is look at me' (the word 'me' encompassing some of my brain processes, as well).

> The mirror neuron mechanism - the same algorithm - that originally evolved to help you adopt another's point of view was turned inward to look at your own self. This, in essence, is the basis of things like 'introspection'.
>
> This in turn may have paved the way for more conceptual types of abstraction; such as metaphor ('get a grip on yourself').

### Yoyo Effects and the Human Mind

From our analyses in the preceding sections, one should expect, as a consequence of the heavy reuse of code under fast development and steady evolution, the sporadic occurrence of some mental yoyo problems. Such yoyo effects break the harmonious way in which the same code (or circuits) are supposed to work as an integral part of several functions used to *do*, *listen* and *answer*, that is, to control action performance, language communication, and self or other awareness. In psychology, many of such effects are known as *dissociative phenomena.* For carefully controlled studies of low level dissociative phenomena related to corporal action-perception, see Schooler (2002) and Johansson et al. (2008).

In the following paragraphs we give a glimpse on possible neuroscience perspectives of some high level dissociative phenomena. Simulation mechanisms are (re)used to simulate one's actions, and also to simulate another agent's actions. Contextualized action simulation is the basis for intent and motivation inference. From there, one can access even higher abstraction levels like tactical and strategic thinking, or even ethics and morality. But these capabilities must rely on some principle of decomposition, that is, the ability to separate, to some meaningful degree, one's own mental state of mind from the mental state of the other, he whose behavior is being simulated. This premise is clearly stated in Decety and Grèzes (2005, p.5):

> One critical aspect of the simulation theory of mind is the idea that in trying to impute mental states to others, an attributor has to set aside her own current mental states and substitute those of the target.

Unfortunately, as seen in the preceding section, the same low level circuits used for to support simulation is also used to support language. This can lead to conflicting requests to use the same resources. For example, verbalization requires introspection, a process that conflicts with the need to set aside one's own current mental states. This conflict leads to *verbal overshadowing* - The phenomenon by which verbally describing or explaining an experienced or simulated situation somehow distorts, modifies or impairs its correct identification, like recognition or recollection, or its understanding, like contextualization and meaning. Some causes and consequences of this kind of conflict are addressed by Iacoboni (2008, p.270):

> Mirror neurons are pre-motor neurons, remember, and thus are cells not really concerned with our reflective behavior. Indeed, mirroring behaviors such as the chameleon effect seem implicit, automatic, and pre-reflexive. Meanwhile, society is obviously built on explicit, deliberate, reflexive discourse. Implicit and explicit mental processes rarely interact; indeed, they can even dissociate. (p.270).

Psychoanalysis can teach us a lot about high level dissociations like emotional / rational psychological mismatches and individual / social behavioral misjudgments. For a constructivist perspective of psychotherapy see Efran et al. (1990), and further comments on section 7.

We end this section posing a trick question capable of inducing the most spectacular yoyo bouncings. This provocative question is related to the role played by division algebras; Goertzel's articles mentioned at the introduction give a good list of references. Division algebras capture the structure of eigen-solutions entailed by symmetry conditions for the recursively generated systems of specular images in a mirror house. The same division algebras are of fundamental importance in many physical theories, see Dion et al. (1995), Dixon (1994) and Lounesto (2001). Finally, division algebras capture the structure of 2-dimensional (complex numbers) and 3-dimensional (quaternion numbers) rotations and translations governing human manipulation of objects, see Hanson (2006). Hence, we can ask: Do we keep finding division algebras everywhere out there when trying to understand the physical universe because we already have the appropriate hardware to see them, or is it the other way around? We can only suspect that any trivial choice in the dilemma posed by this trick question, will only result in an inappropriate answer. We shall revisit this theme at sections 7 and 8.

## 3.2 Mnemes, Memes, Mimes, and all that.

As if the ladder of hierarchical complexity in the systems analyzed in the last sections did not climb high enough, we can make it go even further up including new steps in the socio-cultural realms standing above the level of simple or direct inter-individual interaction, like art, law, religion, science, etc. The example in section 1 is used by Richard Dawkins as a prototypical *meme* or a unit of imitation. The term *mneme*, derived from $\mu\nu\eta\mu\eta$, the muse of memory, was used by Richar Semon as a unit of retrievable memory. Yet another variant of this term, *mime*, is derived from $\mu\iota\mu\eta\sigma\iota\varsigma$ or imitation. All these terms have been used to suggest a basic model, single concept, elementary idea, memory trace or unit, or to convey related meanings, see Blackmore and Dawkins (1999), Dawkins (1976), van Driem (2007), Schacter (2001), Schacter et al. (1978), and Semon (1904, 1909, 1921, 1923).

Richard Semon's theory was able to captures many important characteristics concerning the storage or memorization, retrieval, propagation, reproduction and survival of mnemes. Semon was also able to foresee many important details and interconnections, at a time where there were no experimental techniques suitable for an empirical investigation of the relevant neural processes. Unfortunately, Semon analyses also suffer from the yoyo effect in some aspects, what is not at all surprising given the complexity of the systems he was studying and the lack of suitable experimental tools. These yoyo problems were related to some mechanisms, postulated by Semon, for mnemetic propagation across generations, or mnemetic hereditarity. Such mechanisms had a Lamackian character, since they implied the possibility of hereditary transmission of learned or acquired characteristics.

In modern Computer Science, the term *memetic algorithm* is used to describe evolutive programming based on populational evolution by code (genetic) propagation that combine a Darwinian or selection phase, and a local optimization or Lamackian learning phase, see Moscato (1989). Such algorithms were inspired by the evolution of ideas and culture in human societies, and they proved to be very efficient for solving some complex combinatorial problems, see Ong et al (2007), Smith (2007). Hence, even if we now know, based on contemporary neural science, that some of the concepts developed by Semon are not appropriate to explain some specific phenomena among those he was studying, once again he was postulating, far ahead of his time, some very interesting and useful ideas.

Nevertheless, for Semon's misfortune, he published his theory at the aftermath of the great Drawinian victory over the competing Lamarckian view in the field of biological evolution. At that time, any perceived contamination by Lamackian ideas was a kiss of death for a new theory, even if it was postulated at a clearly distinct context. As a regrettable consequence, the mneme concept was rejected and cast into oblivion for half a century, until its revival as Dawkin's meme. This drama is by no means unusual in the history of science. It seems that some ideas are postulated ahead or their time, and then have to be incubated and remain dormant for a while, until the world is ready for them. Another example of this kind, related to the concept of statistical randomization, is analyzed in great detail at Stern (2008a).

# 4 Hypercyclic Bootstrapping

The Wikepedia definition (on 01-03-2009) of bootstrapping reads:

> Bootstrapping or booting refers to a group of metaphors that share a common meaning, a *self-sustaining* process that proceeds without external help. The term is often attributed to Rudolf Erich Raspe's story The Adventures of Baron Münchausen, where the main character pulls himself out of a swamp, though it's disputed whether it was done by his hair or by his bootstraps.

The attributed origin of this metaphor, the incredible (literally) adventures of Baron Münchhausen, well known as a compulsive liar, makes us suspect that there may be something wrong with some uses of this metaphor. There are however many examples where bootstrapping explanations can be rightfully applied. Let us analyze a few examples:

1- The *Tostines mystery: Does Tostines sells more because it is always fresh and crunchy, or is it always fresh and crunchy because it sells more?*

This slogan was used at a very successful marketing campaign, that catapulted the relatively unknown brand Tostines, from Nestlé, to a leading position in the Brazilian market of biscuits, crackers and cookies. The expression *Tostines mystery* became idiomatic in Brazilian Portuguese, playing a role similar to that of the expression bootstrapping in English.

2- The C computer language and UNIX operating system: Perhaps the most successful and influential computer language ever designed, C was conceived having bootstrapping in mind. The core language is powerful but spartan. Many capabilities that are an integral part of other programming languages are provided by functions in external standard libraries, including all device dependent operations like input-output, string and file manipulation, mathematical computations, etc. C was part of a larger project to write UNIX as a portable operating system. In order to have UNIX and all its goodies in a new machine (device drivers should already be there), we only have to translate the assembly code for a core C compiler, compile a full C compiler, compile the entire UNIX system, compile all the application programs we want, and voilà, we are done. Bootstrapping, as a technological approach, is of fundamental importance for the computer industry, allowing the development of always more powerful software and the rapid substitution of hardware.

3- The Virtuous cycle of open source software: An initial or starting code contribution is made available at an *open source code repository*. *Developer communities* can use the resources at the repository according to the established open source license. Developers create software or applications programs according to their respective business models, affected by the open source license agreements and the repository governance policy. The use of existing *software* motivates new applications or extensions to the existing ones, generating the development of new programs and new contributions to the open source repository. Code contributions to the repository are filtered by a *controlling committee* according to a governance model. The full development cycle works using the highlighted elements as catalysts, and is fuelled by the work of self-interested individuals acting according to their own motivations, see Heiss (2007).

4- The Bethe-Weizsäcker main catalytic cycle (CNO-I):
$^{12}_{6}C + ^{1}_{1}H \rightarrow ^{13}_{7}N + \gamma + 1.95MeV$; $^{13}_{7}N \rightarrow ^{13}_{6}C + e^{+} + \nu + 2.22MeV$;
$^{13}_{6}C + ^{1}_{1}H \rightarrow ^{14}_{7}N + \gamma + 7.54MeV$; $^{14}_{7}N + ^{1}_{1}H \rightarrow ^{15}_{8}O + \gamma + 7.35MeV$;
$^{15}_{8}O \rightarrow ^{15}_{7}N + e^{+} + \nu + 2.75MeV$; $^{15}_{7}N + ^{1}_{1}H \rightarrow ^{12}_{6}C + ^{4}_{2}He + 4.96MeV$.
This example presents the nuclear synthesis of one atom of Helium from four atoms of Hydrogen. Carbon, Nitrogen and Oxygen act as catalysts in this cyclic reaction, that also produces gamma rays, positrons and neutrinos. Note that the Carbon-12 atom used in the first reaction is regenerated at the last one. The CNO nuclear fusion cycle is the main source of energy in stars with two times or more the mass of our sun. We have included this example from nuclear physics in order to stress that catalytic cycles play an important role at phenomena occurring at spatial and temporal scales much smaller than those typical of chemistry or biology, where some of the readers may find them more familiar.

5- RNA and DNA replication? DNA and RNA dupication, translation, and copying in general, may be considered the core cycle of life, since it is the central cycle of biological reproduction. Even a simple description of this process is far too complex to be included in this paper. Moreover, RNA and DNA copy mechanisms rely on many enzymes and auxiliary structures, and those only are available because they are themselves synthesized or regenerated at the living cell at other, also very complex cyclical networks.

Examples 4 and 5 are taken from Eigen (1977). Examples 3 and 5 are, in Manfred Eigen nomenclature, hypercycles. Eigen defines an *autocatalytic cycle* as a (chemical) reaction cycle that, using additional resources available in its environment, produces an excess of one or more of its own reactants. An *hypercycle* is an autocatalitic reaction of second or higher order, that is, an autocatalitic cycle connecting autocatalytic units. In a more general context, an hypercycle indicates self-reproduction of second or higher order, that is, a second or higher order cyclic production network including lower order self-replicative units. Hence, in the prototypical hypercycle architecture, a lower order self-replicative unit plays a dual catalytic role: First, it has an auto-catalytic function in its own reproduction. Second, it acts like a catalyst promoting an intermediate step of the higher order cycle.

## 4.1 Bootstrapping Paradoxes

Let us now examine some ways in which the bootstrapping metaphor is wrongfully applied, that is, is used to generate incongruent or inconsistent arguments, supposed to accommodate contradictory situations or to explain the existence of impossible processes. We will focus on four cases of historical interest and great epistemological importance.

### Perpetuum Mobile

Perhaps the best known paradox related to the bootstrap metaphor is related to a class of examples known as Perpetuum Mobile machines. These machines are supposed to move forever without any external help, or even produce a useful energy output. Unfortunately, perpetua mobile are only wishful thinking, since the existence of such a machine would violate the first, second and third laws of thermodynamics. These are essentially "no free lunch" principles, formulated as inequalities for the flow (balance or transfer) of matter, energy and information in a general system, see Atkins (1984), Dugdale (1996) and Tarasov (1988).

Hypercyclical processes are not magical, and must rely on energy, information (order or neg-entropy) and raw materials available at its environment. In fact, the use of external sources of energy and information is so important, that is entails the definition of metabolism used in Eigen (1977):

Metabolism: (The process) can become effective only for intermediate states which are formed from energy-rich precursors and which are degraded to some energy-deficient waste. The ability of the system to utilize the free energy and the matter required for this purpose is called metabolism. The necessity of maintaining the system far enough from equilibrium by a steady compensation of entropy production has been first clearly recognized by Erwin Schrödinger (1945).

The need of metabolism may come as a disappointment to professional wishful thinkers, engineers of perpetuum mobile machines, narcissistic philosophers and other anorexic designers. Nevertheless, it is important to realize that metabolic chains are in fact an integral part of the hypercycle concept. Hypercycles are build upon the possibility that the raw material that is supposed to be freely available in the environment for one autocatalytic reaction, may very well be the product of another catalytic cycle. Moreover, the same thermodynamic laws that prevent the existence of a perpeuum mobile, are fully compatible with a truly wonderful property of hypercycles, namely, their almost miraculous efficiency, as stated in Eigen (1977):

> Under the stated conditions, the product of the plain catalytic process wilt grow linearly with time, while the autocatalytic system will show exponential growth.

### Evolutionary View

The exponential or hyperbolic (super-exponential) efficiency of auto-catalytic cycles and hypercycles has profound implications to evolutionary processes. Populations growing exponentially in environments with limited resources, or even with resources growing at linear or any polynomial rate, find themselves in the Maltusian conundrum of ever increasing scarcity of resources and individual or group competition for the same resources. In this setting, selection rules applied in a population of individuals struggling to survive and reproduce inexorably leads to an evolutive process. This qualitative argument goes back to Thomas Robert Malthus, Alfred Russel Wallace, and Charles Darwin, see Ingraham (1982) and Richards (1989).

Several alternative mathematical models for evolutive processes only confirm the soundness of the original Malthus-Wallace-Darwin argument. Eigen (1977, 1978a,b) analyses evolutionary processes based on dynamical systems models using the language of ordinary differential equations. In Stern (2008, ch.5), we take a completely different approach, analyzing evolutionary processes based on stochastic optimization algorithms using the language of inhomogeneous Markov chains. For other possible approaches see Jantsch Waddington (1976) and Jantsch (1980, 1981). It is remarkable however, that the qualitative conclusions of several distinct alternative analyses are in complete agreement.

The evolutionary view replaces a static scenario by a dynamic context. This replacement has the side effect of enhancing or amplifying most of the mirror-house illusions studied in this paper. No wonder then, that the adoption of an evolutionary view requires from the observer a solid background on well founded scientific theories together with the firm domain of a logical and coherent epistemological framework in order to keep his or her balance and maintain a straight judgment.

### Building Blocks and Modularity

Another consequence of the analysis of evolutionary processes, using either the dynamical systems approach, see Eigen (1977, 1978a,b), or the stochastic optimization approach, see Stern (2008, ch.5), is the spontaneous emergence of modular structures and hierarchical organization of complex systems.

A classic illustration for the need of modular organization is given by the Hora and Tempus parable of Simon (1996), see also Growney (1982). This is a parable about two watch makers, named Hora and Tempus, both of whom are respected manufacturers and, under ideal conditions, produce watches of similar quality and price. Each watch requires the assemblage of $n = 1000$ elementary pieces. However, Hora uses a hierarchical modular design, while Tempus does not. Hora builds each watch with 10 large blocks, each made of 10 small modules of 10 single parts each. Hence, in order to make a watch, Hora needs to assemble $m = 111$ modules with $r = 10$ parts each, while Tempus needs to assemble only $m = 1$ module of $r = 1000$ parts. It takes either Hora or Tempus one minute to put a part in its proper place. Hence, while Tempus can assemble a watch in 1000 minutes, Hora can only do it in 1110 minutes. However both work in a noisy environment, being subject to an interruption, occurring with a probability of $p = 0.01$, while placing a part. Partially assembled modules are unstable, braking down at an interruption. Under these conditions, the expected time to assemble a watch is

$$\frac{m}{p}\left(\frac{1}{(1-p)^r} - 1\right) .$$

Substituting $p$, $m$ and $r$ for the values in the parable, one finds that Hora's manufacturing process is a few thousand times more efficient then Tempus'. After this analysis, it is not difficult to understand why Tempus struggles while Hora prospers.

Hence, closing yet another cycle, we came to the conclusion that the evolution of complex structures requires a modular design. The need for modular organization are captured by the following dicta of Herbert Simon:

> *"Hierarchy, I shall argue, is one of the central structural schemes that the architect of complexity uses."* Simon (1996, p.184).
>
> *"The time required for the evolution of a complex form from simple elements depends critically on the number and distribution of potential intermediate stable subassemblies."* Simon (1996, p.190).
>
> *"The claim is that the potential for rapid evolution exists in any complex system that consists of a set of subsystems, each operating nearly independently of the detailed process going on within the other subsystems, hence influenced mainly by the net inputs and outputs of the other subsystems. If the near-decomposability condition is met, the efficiency of one component (hence its contribution to organism fitness) does not depend on the detailed structure of other components."* Simon (1996, p.193).

### Standards and Once-Forever Choices

An important consequence of emerging modularity in evolutive processes is the recurrent commitment to once-forever choices and the spontaneous establishment of standards. This organizational side effect is responsible for mirror-house effects related to misleading questions taking to philosophical dead-ends. Why do (almost all) nations use the French *meter*, $m$, as the standard unit of length, instead of the older Portuguese *vara* ($\approx 1.1m$) or the British *yard* ($\approx 0.9m$)? Why did the automotive industry select 87 octane as "regular" gasoline and settle for 12V as the standard voltage for vehicles? Why do we have chirality symmetry breaks, that is, why do we find only one specific type among two or more possible isomeric molecular forms in organic life? What is so special about the DNA - RNA genetic code that it is shared by all life on planet earth?

In this mirror house we must accept that the deepest truth is often pretty shallow. Refusing to do so, insisting on forceps extraction of more elaborate explanations, can take us seriously astray into foggy illusions, far away far from clear reason and real understanding. Eigen (1977, p.541-542) makes the following comments:

> The Paradigm of Unity and Diversity in Evolution: Why do millions of species, plants and animals, exist, while there is only one basic molecular machinery of the cell, one universal genetic code and unique chiralities of the macromolecules?
>
> This code became finally established, not because it was the only alternative, but rather due to a peculiar 'once-forever'-selection mechanism, which could start from any random assignment. Once-forever selection is a consequence of hypercyclic organization.

# 5 Squaring the Cycle

*Ouroboros* is a Greek name, *Ουροβορς οφίς*, meaning the tail-devouring snake, see Eleazar (1760) and Franz (1981). The Ouroboros is an ancient alchemical symbol of self-reflexive or cyclic processes, of something perpetually re-creating itself. In modern cybernetics it is used as a representation of autopoiesis. The ourobouros is represented as a single, integral organism, the snake, whose head bites its own tail. This pictorial representation would not make much sense if the snake were cut into several pieces, yet, that is what may happen, if we are not careful, when we try to explain a cyclic process.

Let us illustrate this discussion with a schematic representation of the fiscal cycle of an idealized republic. This cycle is represented by a diagram similar to the one presented at section 7. This square diagram has four arrows pointing, respectively,
Down: Citizens pay taxes to fulfill their duties;
Left: Citizens elect a senate or house of representatives;
Up: The senate legislates fiscal policies; and
Right: A revenue service enforces fiscal legislation.

Focusing on each one of the arrows we can speak of, respectively,
Downward causation, whereby individuals comply with established social constraints;
Upward causation, whereby the systems constraints are established and renewed;
Leftward causation, whereby individuals (re)present new demands to the republic;
Rightward causation, whereby the status quo is maintained, stabilized and enforced.

Each one of these causal relations is indeed helpful to understand the dynamic of our idealized republic. At the other hand, the omission of any single one of these relations breaks the cycle, and such an incomplete version of the schematic diagram would no longer explain a dynamical system.

The adjectives up and down capture our feelings as an individual living under social constraints (like costumes, moral rules, laws and regulations) that may (seem to) be overwhelming, while the adjectives left and right are late echoes of the seating arrangements in the French legislative assembly of 1791, with the conservatives, protecting aristocratic privileges of the ancien régime, seating at the right and the liberals, voicing the laissez-faire-laissezpasser slogans for free market capitalism, seating at the left. How to assign intuitive and meaningful positional or directional adjectives to links in a complex network is in general not so obvious. In fact, insisting on similar labeling practices is a common source of unnecessary confusion and misunderstanding. A practice that easily generates inappropriate interpretations is *polysemy*, the reuse of the same tags in different contexts. This is due to semantic contamination or spill over, that is, unwanted or unforeseen transfers of meaning, induced by polysemic overloading.

We can ask several questions concerning the relative importance specific links in causal networks. For example: Can we or should we by any means establish precedences between the links in our diagram? Upward causes precede or have higher status then downward causes or vice versa? Rightward causes explain or have preponderance over leftward causes or vice versa? Do any of the possible answers imply a progressive or revolutionary view? Do the opposite answers imply an conservative or reactionary view? The same questions can be asked on a similar diagram for scientific production presented in section 7. Do any of the possible answers imply an empiricist or Aristotelic view? Do the opposite answers imply an idealist or Platonic view?

To some degree these can be legitimate questions and hence, to the same degree, motivate appropriate answers. Nevertheless, following the main goal of this paper, namely, the exploration of mirror-house illusions, we want to stress that extreme forms of these questions often lead to ill posed problems. Consequently, extreme answers to the same questions often give an over simplified, one sided, biased, or distorted view of reality. The dangerous consequences of falling in the temptation of eating dishes prepared with ourobourus slices are depicted, in the field of psychology, by the following quotations from Efran (1990, p.99,47):

> Using language, any cycle can be broken into causes and purposes... Note that inventing purposes - and they are invented - is usually an exercise in creating tautologies. A description is turned into a purpose that in then asked to account for the description. The example we just gave starts with the defining

characteristic of life, self-perpetuation, and states that it is the purpose for which the characteristic exists. Such circular renamings are not illegal, but they do not advance the cause (no pun intended). (p.99)

For a living system there is a unity between product and process: In other words, the major line of work for a living system is creating more of itself.

Autopoiesis in neither a promise nor a purpose - it is an organizational characteristic. This means that life lasts as long as it lasts. It doesn't come with guarantees. In contrast to what we are tempted to believe, people do not stay alive because of their strong survival instincts or because they have an important job to complete. They stay alive because their autopoietic organization happens to permit it. When the essentials of that organization are lost, a person's career comes to an end - he or she disintegrates. (p.47)

# 6 Emergence and Asymptotics

Asymptotic entities emerge in a model as a *law of large numbers*, that is, as a stable behavior of a quantity in the limit case for model parameters corresponding to a very large system or very small parts, resulting in a system with very many (asymptotically infinite) components . The familiar mathematical notation used in these cases takes the form $lim_{n\to\infty}g(n)$ or $lim_{\epsilon\to 0}f(\epsilon)$. Typically, the underlying model describes a local interaction in a small or microscopic scale, while the resulting limit correspond to a global behavior in a large or macroscopic scale.

The paradigmatic examples in this class gives the behavior of thermodynamic variables describing a system, like the volume, pressure and temperature of a gas, as asymptotic limits in statistical mechanics models for (infinitely) many interacting particles, like atoms or molecules, see Atkins (1984), Tarasov (1988). Other well known examples explain the behavior of macro-econometric relations among descriptive variables of efficient markets, like aggregated supply, demand, price and production, form micro-economic models for the interaction of individual agents, see Ingrao and Israel (1990). Even organic tissue movements in morphogenesis can be understood as the asymptotic limit of local cellular interactions at microscopic scale, as already mentioned in section 2. In this section we have chosen to examine an example that can be easily visualized in a space and time scale directly accessible to our senses, namely, some aspects of the collective behavior of flocks, schools and swarms.

Large flocks of birds or schools of fish exhibit coordinated flight or swimming patterns and manifest collective reaction movements that give the impression that the collective entity has "a mind of its own". There are many explanations for why these animals swarm together. For example, they may do so in order to achieve:
- Better aerodynamic or hydrodynamic performance by flying or swimming in tight formation,
- More efficient detection of needed resources or dangerous treats by the pooling of many sensors;
- Increased reproductive and evolutive success by social selection rules; etc.
In this section, however, we will focus on another advantage:
- Reducing the risk of predation by evasive maneuvers.

The first point in the analysis of this example is to explain why it is a *valid example* of emergence, that is, let us describe a possible local interaction model from which the global behavior emerges when the flock has a large number of individuals. We use the model programmed by Craig Reynolds (1987).

> In 1986 I made a computer model of coordinated animal motion such as bird flocks and fish schools. It was based on three dimensional computational geometry of the sort normally used in computer animation or computer aided design. I called the generic simulated flocking creatures *boids*. The basic flocking model consists of three simple steering behaviors which describe how an individual boid maneuvers based on the positions and

velocities its nearby flockmates:

*Separation:* steer to avoid crowding local flockmates

*Alignment:* steer towards the average heading of local flockmates

*Cohesion:* steer to move toward the average position of local flockmates

Each boid has direct access to the whole scene's geometric description, but flocking requires that it reacts only to flockmates within a certain small neighborhood around itself.

The second point in the analysis of this example, is to explain why being part of a flock can reduce the risk of predation: Many predators, like a falcon hunting a sparrow, need to single out and focus on a chosen individual in order to strike accurately. However, the rapid change of relative positions of individuals in the flock makes it difficult to isolate a single individual as the designated target and follow the same target inside the moving flock. Computer simulation models show that this confusion effect greatly reduces the killing (success) rate in this kind of hunt.

The third point in our analysis is to contrast the hunting of single individuals, as analyzed in the previous paragraph, with other forms of predation based on the capture of the entire flock, or a large chunk of it. The focus of such alternative hunting techniques is, in the relative topology of the flock, not on local but on global variables describing the collective entity. For example, as explained in Diachok (2006) and Leighton et al. (2004, 2007), humpback whales collaborate using sophisticated strategies for hunting herring, including specific tactics for:

*Detection:* Whales use active sonar detection techniques, using specific frequencies that resonates with and are attenuated by the swim bladders of the herring. In this way, the whales can detect schools over long distances, and also measure its pertinent characteristics.

*Steering:* Some whales broadcast loud sounds below the herring school, driving them to the surface. Other whales blow a bubble-net around the school, spiraling in as the school rises. The herring is afraid of the loud sounds at the bottom, and also afraid of swimming through the bubble-net, and is thus forced into a dense pack at a compact killing zone near the surface.

*Capture:* Finally, the whales take turns at the killing zone, raising to the surface with their mounts wide open, catching hundreds of fish at a time or, so to speak, "biting of" large chunks of the school.

Finally, let us propose two short statements that can be distilled from our examples. They are going to carry us to the next section.

- Flocking makes it difficult for a predator to track the trajectory of a *single individual*, consequently, for a hunter that focus on local variables it is *hard to know* what exactly is going on.

- At the other hand, the same collective behaviors create the opportunity for *global strategies* that track and manipulate the entire flock. These hunting technique may be very efficient, in which case, we can say that the hunters *know very well* what they are doing.

# 7 Constructive Ontologies

From the several examples mentioned in sections 2, 4 and 6, we can suspect that the emergence of properties, behaviors, organizational forms and other entities are the rule rather than the exception for many non-trivial systems. Hence it is natural to ask about the ontological status of such entities. Ontology is a term used in philosophy referring to a systematic account of *existence* or *reality*. In this section we analyze the ontological status of emergent entities according to the Cog-Con epistemological framework. The following paragraphs give a brief summary of this perspective, as well as some specific epistemological terms as they are used in the Cog-Con framework.

The interpretation of scientific knowledge as an eigensolution of a research process is part of a Cog-Con approach to epistemology. Figure 1 presents an idealized structure and dynamics of knowledge production. This diagram represents, on the Experiment side (left column) the laboratory or field operations of an empirical science, where experiments are designed

| Experiment | | | | Theory |
|---|---|---|---|---|
| Operation-alization | $\Leftarrow$ | Experiment design | $\Leftarrow$ | Hypotheses formulation |
| $\Downarrow$ | | | | $\Uparrow$ |
| Effects observation | | True/False eigen-solution | | Creative interpretation |
| $\Downarrow$ | | | | $\Uparrow$ |
| Data acquisition | $\Rightarrow$ | Mnemetic explanation | $\Rightarrow$ | Statistical analysis |
| Sample space | | | | Parameter space |

Figure 1: Scientific production diagram.

and built, observable effects are generated and measured, and the experimental data bank is assembled. On the Theory side (right column), the diagram represents the theoretical work of statistical analysis, interpretation and (hopefully) understanding according to accepted patterns. If necessary, new hypotheses (including whole new theories) are formulated, motivating the design of new experiments. Theory and experiment constitute a double feed-back cycle making it clear that the design of experiments is guided by the existing theory and its interpretation, which, in turn, must be constantly checked, adapted or modified in order to cope with the observed experiments. The whole system constitutes an autopoietic unit.

The Cog-Con framework also includes the following definition of reality and some related terms:

> *1. Known (knowable) Object:* An actual (potential) eigen-solution of a given system's interaction with its environment. In the sequel, we may use a somewhat more friendly terminology by simply using the term Object.
> *2. Objective (how, less, more):* Degree of conformance of an object to the essential attributes of an eigen-solution (to be precise,

stable, separable and composable).

*3. Reality:* A (maximal) set of objects, as recognized by a given system, when interacting with single objects or with compositions of objects in that set.

The Cog-Con framework assumes that an object is always observed by an observer, like a living organism or a more abstract system, interacting with its environment. Therefore, this framework maintains that the manifestation of the corresponding eigen-solution is driven by, and that the properties of the object are specified by both sides, the system and its environment. More succinctly, Cog-Con sustains:

*4. Idealism:* The belief that a system's knowledge of an object is always dependent on the systems' autopoietic relations.

*5. Realism:* The belief that a system's knowledge of an object is always dependent on the environment's constraints.

Hence, the Cog-Con perspective requires a fine equilibrium, called *Realistic or Objective Idealism. Solipsism or Skepticism* are symptoms of epistemological analyses that loose the proper balance by putting too much weight on the idealist side, conversely, *Dogmatic Realism* is a symptom of epistemological analyses that loose the proper balance by putting too much weight on the realist side. Dogmatic realism has been, from the Cog-Con perspective, a very common (but mistaken) position in modern epistemology. Hence, it is useful to have specific expression, namely, *something in itself* to be used as a marker or label for this kind of ill posed dogmatic statements. Often, the description of the method used to access something in itself looks like:

- Something that an observer would observe if the (same) observer did not exist, or

- Something that an observer could observe if he made no observations, or

- Something that an observer should observe in the environment without interacting with it (or disturbing it in any way), and many other equally nonsensical variations.

From the preceding considerations, it should be clear that, from the Cog-Con perspective, the ontological status of emergent entities can be perfectly fine, as long as these objects correspond to precise, stable, separable and composable eigen-solutions. However there is a long list of historical objections and complains concerning such entities. The following quotations from El-Hani (2009, p.xxx) elaborate this point.

> Emergent properties are not metaphysically real independently of our practices of inquiry but gain their ontological status from the practice-laden ontological commitments we make.
>
> [concerning] the issue of the ontological epistemological status of emergents ... we simply need to be careful in our recognition of emergent phenomena and continually ask the question of whether the pattern we see is more in our eye than the pattern we are claiming to see.
>
> Related to the supposed provisionality of emergents is the issue of their ontological status: Are emergent phenomena part of the real, authentic "furniture of the world", or are they merely a function of our epistemological, cognitive apparatus with its ever-ready mechanism of projecting patterns on to the world?

From the summary of the Cog-Con epistemological framework presented above we conclude that, from this perspective, we have to agree with the first observations, and consider the last question as an ill posed problem.

Another set of historical issues concerning the ontological status or emergents relates to our ways of understanding them. For some authors, "real" emergent entities must be genuinely "new", in the sense of being unanalyzable or unexplainable. For such authors, understanding is a mortal sin that threatens the very existence on an entity, that is, understanding undermines their ontological status. Hence, according to these authors, the most real of entities should always be somewhat mysterious. Vieira and El-Hani (2009, p.105), analyze this position:

> A systemic property P of a system S will be irreducible if

> it does not follow, even in principle, from the behavior of the system's parts that S has property P.
>
> If a phenomenon is emergent by reasons of being unanalyzable, it will be an unexplainable, brute fact, or, to use Alexander's (1920/1979) words, something to be accepted with natural piety. We will not be able to predict or explain it, even if we know its basal conditions.
>
> In our view, if the understanding of the irreducibility of emergent properties is limited to this rather strong sense, we may lose from sight the usefulness of the concept... Indeed, claims about emergence turn out to be so strong, if interpreted exclusively in accordance with this mode of irreducibility, that they are likely to be false, at least in the domain of natural science (with are our primary interest in this paper).

We fully agree with Vieira and El-Hani in rejecting unanalyzability or unexplainability as conditions for the "real existence" of emergent entities. As expected, the Cog-Con framework does not punish understanding, far from it. In Stern (2008b, Ch.4) we give the Cog-Con perspective for the meaning of objects in a given reality as their interrelation in a network of causal nexus, explaining *why* the corresponding eigen-solutions are manifested in the way they are. Such explanations include, specially in modern science, the symbolic derivation of scientific hypotheses from general scientific laws, the formulation of new laws in an existing theory, and even the conception of new theories, as well as their general understanding based on accepted metaphysical principles. In the Cog-Con perspective, the understanding of an entity can only strengthen its ontological status, embedding it even deeper in the system's life, enabling it with even wider connections in the web of concepts, revealing more of its links to the great chain of being!

# 8 Distinctions and Probability

In the last section we have analyzed the ontological status of emergent properties. In a similar way, this section is dedicated to the study of the ontological status of probability, and the role played by explanations given by probabilistic mechanisms and stochastic causal relations. We begin our discussion examining the concept of mixed strategies in game theory, due to von Neumann and Morgenstern.

Let us consider the *matching pennies* game, played by Odd and Even. Each of the players has to show, simultaneously, a bit (0 or 1). If both bits agree (i.e., 00 or 11), Odd wins. If both bits disagree (i.e., 01 or 10), Even wins. Both players only have two pure or deterministic strategies available from which to choose: $s_0$ - show a 0, or $s_1$ - show a 1.

A *solution, equilibrium* or *saddlepoint* of a game is a set of strategies that leaves each player at a local optimum, that is, a point at which each player, having full knowledge of all the other players' strategies at that equilibrium point, has nothing to gain by unilaterally changing his own strategy. It is easy to see that, considering only the two deterministic strategies, the game of matching pennies has no equilibrium point. If Odd knows the strategy chosen by Even, he can just take the same strategy and win the game. In the same way, Even can take the opposite choice of Odd's, and win the game.

Let us now expand the set of strategies available to each player considering *mixed* or *randomized* strategies, where each player picks among the pure strategies according to a set of probabilities he specifies. We assume that a proper randomization device, like a dice, a roulette or a computer with a random number generator program, is available. In the example at hand, Even and Odd can each specify a probability, respectively, $pe$ and $po$, for showing a 1, and $qe = 1 - pe$ and $qo = 1 - po$, for showing a 0. It is easy to check that $pe = po = 1/2$ is a solution to this game.

Oskar Morgenstern (2008, p.270) makes the following comments about the philosophical significance of mixed strategies:

> It is necessary to examine the significance of the use of mixed

> strategies since they involve probabilities in situations in which 'rational' behavior is looked for. It seems difficult, at first, to accept the idea that 'rationality' - which appears to demand a clear, definite plan, a deterministic resolution - should be achieved by the use of probabilistic devices. Yet precisely such is the case.
>
> In games of chance the task is to determine and then to evaluate probabilities inherent in the game; in games of strategy we introduce probability in order to obtain the optimal choice of strategy. This is philosophically of some interest.

The role played by mixed strategies can be explained, at least in part, by convex geometry. A *convex combination* of two points, $p_0$ and $p_1$, is a point lying on the line segment joining them, that is, a point of the form $p(\lambda) = (1-\lambda)p_0 + \lambda p_1$, $0 \leq \lambda \leq 1$. A *convex set* is a set that contains all convex combinations of its points. The *extreme points* of a convex set are those that can not be expressed as (non-trivial) convex combinations of ther points in the set. A function $f(x)$ is convex if its epigraph, $\text{epi}(f)$ - the set of all point above the graph of $f(x)$, is convex. A *convex optimization problem* consists of minimizing a convex function over a convex region. The properties of convex geometry warrant that a convex optimization problem has an optimal solution, i.e. a minimum, $f(x^*)$. Moreover, this minimum argument, $x^*$, is easy to compute using a procedure like the *steepest descent algorithm*, that can be informally stated as follows: Place a particle at some point over the graph of $f(x)$, an let it "roll down the hill" to the bottom of the valley, until it finds its lowest point at $x^*$, see Luenberger (1984) and Minoux (1986).

In the matching pennies game, let us consider a convex combination of the two pure strategies, that is, a strategy of the form $s(\lambda) = (1-\lambda)s_0 + \lambda s_1$, $0 \leq \lambda \leq 1$. The pure strategies form a discrete set. Hence, such a continuous combinations of pure strategies is not even well defined, except for the trivial extreme cases, $\lambda = 0$ or $\lambda = 1$. The introduction of randomization gives a coherent definition for convex combinations of existing strategies and, in so doing, it expands the set of available (mixed) strategies to a convex set where pure strategies become extreme points. In this setting, a game equilibrium point can be characterized as the solution of a convex optimization problem. Therefore, such an equilibrium point exist and is easy to compute. This is one way to have a geometric understanding of von Neumann and Morgenstein theorems, as well as to subsequent extensions in game theory due to John F. Nash, see Mesterton-Gibbons (1992) and Thomas (1986).

The matching pennies example poses a $\delta\iota\lambda\eta\mu\mu\alpha$, dilemma - a problem offering two possibilities, none of which is acceptable. The conceptual dichotomy created by constraining the players to only two deterministic strategies creates an ambush. Caught in this ambush, both players would be trapped, forever changing their minds between extreme options. Randomization expands the universe of available possibilities and, in so doing, allows the players to escape the perpetual flip-flopping at this discrete logic decision trap. In section 8.2, we want to extrapolate this example and generalize these conclusions. However, before proceeding in this direction, we shall analyze in the next section some objections to the concepts of probability, statistics and randomization posed by George Spencer-Brown, a philosopher of great influence in the field of radical constructivism.

## 8.1 Spencer-Brown, Probability and Statistics

Spencer-Brown (1953, 1957) analyzed some apparent paradoxes involving the concept of randomness, and concluded the language of probability and statistics to be inappropriate for the practice of scientific inference. In subsequent work, Spencer Brown (1969) reformulates classical logic using only the nand (not-and) operator, that he represents à la mode of Charles Saunders Peirce or John Venn, using a graphical boundary or distinction mark, see Edwards (2004), Kauffmann (2001, 2003), Meguire (2003), Peirce (1880), Sheffer (1913). Making distinctions is, according to Spencer-Brown, the basic (if not the only) operation of human knowledge, and this idea has influenced or been directly explored by several authors in the radical constructivism movement. Some typical arguments used by Spencer-Brown in his rejection of probability and statistics are given in the next quotations from Spencer-Brown (1957, p.66,105,113):

> We have found so far that the concept of probability used in statistical science is meaningless in its own terms; but we have found also that, however meaningful it might have been, its meaningfulness would nevertheless have remained fruitless because of the impossibility of gaining information from experimental results, however significant This final paradox, in some ways the most beautiful, I shall call the Experimental Paradox (p.66).
>
> The essence of randomness has been taken to be absence of pattern. But has not hitherto been faced is that the absence of one pattern logically demands the presence of another. It is a mathematical contradiction to say that a series has no pattern; the most we can say is that it has no pattern that anyone is likely to look for. The concept of randomness bears meaning only in relation to the observer: If two observers habitually look for different kinds of pattern they are bound to disagree upon the series which they call random. (p.105).

In Stern (2008b, Ap.G.1), I carefully explain why I disagree with Spencer-Brown's analysis of probability and statistics. In some of my arguments I dissent from Spencer-Brown's interpretation of measures of order-disorder in sequential signals. These arguments are based on information theory and the notion of entropy. Atkins (1984), Attneave (1959), Dugdale (1996), Krippendorff (1986) and Tarasov (1988) review some of the basic concepts in this area using only elementary mathematics. For more advanced works see Kapur (1989), Rissanen (1989) and Wallace (2005). Several authors concur, at least in part, with my opinion about Sencer-Brown's analysis of probability and statistics, see Flew (1959), Falk and Konold (1997), Good (1958) and Mundle (1959).

I also disapprove some of Spencer Brown's proposed methodologies for the detection (or distinction) of patterns in empirical observations. My objections have a lot in common with the standard caveats against *post hoc* "fishing expeditions" for interesting outcomes, or simple *ex post facto* sub-group analyses in experimental data banks. This kind of retroactive or retrospective data analyses are considered a questionable statistical practice, and pointed as the culprit of many misconceived studies, misleading arguments and mistaken conclusions. The literature of statistical methodology for clinical trials has been particularly active in warning against this kind of practice, see Tribble (2008) and Wang (2007) for two interesting papers addressing this specific issue and published in high impact medicine journals less than a year before I began writing this paper. When consulting for pharmaceutical companies or advising in the design of statistical experiments, I often find it useful to quote Conan Doyle's Sherlock Holmes, in The Adventure of Wisteria Lodge:

> Still, it is an error to argue in front of your data. You find yourself insensibly twisting them around to fit your theories.

Finally, I am suspicious or skeptical of some of the intended applications of Spencer-Brown's research program, including studies on extrasensory perception for coded message communication, exercises on object manipulation using paranormal powers, etc. Unable to reconcile his psychic research program with statistical science, Spencer-Brown had no regrets in disqualifying the later, as he clearly stated at the prestigious scientific journal *Nature*, Spence-Brown (1953b, p.594-595):

> [On telepathy:] Taking the psychical research data (that is, the residuum when fraud and incompetence are excluded), I tried to show that these now threw more doubt upon existing presuppositions in the theory of probability than in the theory of communication.
>
> [On psychokinesis:] If such an 'agency' could thus 'upset' a process of randomizing, then all our conclusions drawn through the statistical tests of significance would be equally affected, including the the conclusions about the 'psychokinesis' experiments themselves. (How are the 'target numbers' for the die throws to be randomly chosen? By more die throws?) To speak of an 'agency' which can 'upset' any process of randomization in an uncontrollable manner is logically equivalent to speaking of an inadequacy in the theoretical model for empirical randomness, like the lu-

miniferous ether of an earlier controversy, becomes, with the obsolescence of the calculus in which it occurs, a superfluous term.

Sencer-Brown's (1953, 1957) conclusions, including his analysis of probability, were considered to be controversial (if not unreasonable or extravagant) even by his own colleagues at the Society of Psychical Research, see Scott (1958), and Soal (1953). It seems that current research in this area, even if not free or afraid of criticism, has abandoned the path of naïve confrontation of statistical science, see Atmanspacher (2005) and Ehm (2005). For additional comments, see Henning (2006), Kaptchuk and Kerr (2004), Stern (2008a), Utts (1991), and Wassermann (1955).

Curiously, Charles Saunders Peirce and his student Joseph Jastrow, who introduced the idea or randomization in statistical trials, struggled with some of the very same dilemmas faced by Spencer-Brown, namely, the eventual detection of distinct patterns or seemingly ordered (sub)strings in a long random sequence. Peirce and Jastrow did not have at their disposal the heavy mathematical artillery I cited in the previous paragraphs. Nevertheless, like experienced explorers that when traveling in the desert are not lured by the mirage of a beatiful but illusory oasis, these intrepid pioneers were able to avoid the conceptual pitfalls that so much confused Spencer-Brown. For more details see Dehue (1997), Hacking (1988), Peirce and Jastrow (1885) and Stern (2008a).

As stated in the introduction, the Cog-Con framework is supported by the FBST, a formalism based on a non-decision theoretic form of Bayesian statistics. The FBST was conceived as a tool for validating objective knowledge and, in this role, it can be easily integrated to the Cog-Con epistemological framework in the practice of scientific research. Contrasting our distinct views of cognitive constructivism, it is not at all surprising that I have come to conclusions concerning the use of probability and statistics, and also to the relation of probability and logic, that are fundamentally different from those of Spencer-Brown.

## 8.2 Overcoming Dilemmas and Conceptual Dichotomies

A stated by William James, our ways of understanding require us to split the reality with conceptual distinctions. The non-trivial consequences of the resulting dichotomies are captured, almost poetically, by the following passage from *A Pluralistic Universe*, in James (1909, Lecture VI):

> The essence of life is its continuously changing character; but our concepts are all discontinuous and fixed, and the only mode of making them coincide with life is by arbitrarily supposing positions of arrest therein. With such arrests our concepts may be made congruent. But these concepts are not parts of reality, not real positions taken by it, but suppositions rather, notes taken by ourselves, and you can no more dip up the substance of reality with them than you can dip up water with a net, however finely meshed.
>
> When we conceptualize, we cut out and fix, and exclude everything but what we have fixed. A concept means a that-and-no-other. Conceptually, time excludes space; motion and rest exclude each other; approach excludes contact; presence excludes absence; unity excludes plurality; independence excludes relativity; 'mine' excludes 'yours'; this connection excludes that connection - and so on indefinitely; whereas in the real concrete sensible flux of life experiences compenetrate each other so that it is not easy to know just what is excluded and what not...
>
> The conception of the first half of the interval between Achilles and the tortoise excludes that of the last half, and the mathematical necessity of traversing it separately before the last half is traversed stands permanently in the way of the last half ever being traversed. Meanwhile the living Achilles... asks no leave of logic.

Sure enough, our way of understanding requires us to make conceptual distinctions, those distinctions that are the most adequate (or adequate enough) for a given domain of reality. But the concepts that are appropriate to analyze reality at a given level, scale or granularity, may not be adequate at the next level, lower or higher, larger or smaller, coarser or finer. How then can we avoid being trapped by such distinctions? How can we overcome the distinctions made at one level in order to be able to reach the next, and still maintain a coherent or congruent view of the universe?

The Cog-Con endeavor requires languages and mechanisms to overcome the limitations of conceptual distinctions and, at the same time, enable us to build, in a coherent way, new concepts that can be used at the next or new domains. Of course, as in all scientific research, the goal of the new conceptual constructs is to entail theories and hypotheses providing objective knowledge (in its proper domain), and the success of the new theories must be judged pragmatically according to this goal. I claim that statistical models and their corresponding probabilistic mechanisms, have been, in the history of modern science, among the most successful tools for accomplishing the task at hand. For example, in Stern (2008, ch.5) we have shown in some detail how probabilistic reasoning can be used:

- In quantum mechanics, using the language of Fourier series and transforms, to overcome the dilemmas posed by a physical theory using concepts and laws coming from two distinct and seemingly incompatible categories: The mechanics of discrete particles and wave propagation in continuous media or fields.

- In stochastic optimization, using the language of inhomogeneous Markov chains, to overcome the dilemmas generated by dynamic populations of individuals with the need of reliable reproduction, hierarchical organization, and stable building blocks versus the need of creative evolution with innovative change or mutation.

In empirical science, from a pragmatical perspective, probability reasoning seems to be an efficient tool for overcoming artificial dichotomies, allowing us to bridge the gaps created by our own conceptual distinctions. Such probabilistic models have been able to generate new eigen-solutions with very good characteristics, that is, eigen-solutions that are very objective (precise, stable, separable and composable). These new objects can then be used as stepping stones or building blocks for the construction of new, higher order theories. As a consequence, coherently with the Cog-Con epistemological framework in this context, we assign a high ontological status to probabilistic concepts and causation mechanisms, that is, in this context, we use a notion of probability that has a distinctively objective character.

# 9 Final Remarks and Future Research

The objective of this paper was to use the Cog-Con framework for the understanding of massively complex and non-trivial systems. We have analyzed several forms of system complexity, several ways in which systems become non-trivial, and some interesting consequences, side effects and paradoxes generated by such non-triviality. How can we call the massive non-triviality found in nature? I call it *The Living and Intelligent Universe.* I could also call it *Deus sive natura* or, according to Einstein,

> *Spinoza's God, a God who reveals himself in the orderly harmony of what exists...*

In future research we would like to extend the use of the same Cog-Con framework to the analysis of the ethical conduct of agents that are conscious and (to some degree) self-aware. The definition of ethics given by Russell (1999, p.67), reads:

> *The problem of Ethics is to produce a harmony and self-consistency in conduct, but mere self-consistency within the limits of the individual might be attained in many ways. There must therefore, to make the solution definite, be a universal harmony; my conduct must bring satisfaction not merely to myself, but to all whom it affects, so far as that is possible.*

Hence, in this setting, such a research program should be concerned with the understanding and evaluation of choices and decisions made by agents, acting in a system to which they belong. Such an analysis should provide criteria for addressing the coherence and consistency of the behavior of such agents, including the direct, indirect and reflexive consequences of their actions. Moreover, since we consider conscious agents, their values, beliefs and ideas should also be included in the proposed models. The importance of pursuing this line of research, and also the inherent difficulties of this task, are summarized by Eigen (1992, p.126):

> But long and difficult will be our ascent from the lowest landing up to the topmost level of life, the level of self-awareness: our continued ascent from man to humanity.

Goertzel (2008) points to generalizations of standard probabilistic and logical formalisms, and urges us to explore further connections between them, see for example Caticha (2008), Costa (1986, 1993), Jaynes (1990), and Youssef (1994, 1995). I am fully convinced that this path, of cross fertilization between probability and logic, is another important field for future research.

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