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The Advancement of Information Science Is a New Way of Thinking Necessary?

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Abstract: *The advancement of a new scientific perspective, information science, devoted to the study of the vast field of informational phenomena in nature and society, implies putting together a number of cognizing domains which are presently scattered away in many other disciplines. Comparable to previous scientific revolutions spurred by thermodynamics and quantum mechanics, it would be time to go beyond the classical discussions on the concept of information, and associated formal theories, and advance a "new way of thinking". Cells, Brains, Societies, and Quantum information would be crucial arenas for this discussion. Rather than hierarchy, reduction, or unification, the catchword is unending recombination... A mature information science should offer a new panoramic view on the sciences themselves and contribute to achieve social adaptability & sustainability.*

Keywords: Information science, Limited pre-hension, Meaning, Categories, Cognits, Recombination.

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Arguably in this very decade, the second scientific generation that has explicitly confronted the *information problem* should hand over the "torch of inquiry" to a new generation of researchers. If the experience of a couple of similar historical cases holds (thermodynamics with the *problem of heat*; quantum mechanics with the *problem of irradiative energy*), we may expect decisive disciplinary advancements along this second transition.

Looking at those historical precedents, their scientific problems were closely related to ongoing technological developments, respectively steam and combustion engines for thermodynamics and electrical-radio-optical and metrological systems for the quantum; not very far from the technological stimulus provided by computers and Internet regarding the advancement of information science in our time (Stonier, 1990; Marijuán, 1996a; Scarrott, 1998; Wright, 2007). Needless to say, the solution to those historical conundrums implied a dramatic reformulation of the concepts and thinking avenues initially proposed –except historians of science, who reminds now about *flogiston*, *caloric*, or *aether luminiferous*? Quite strenuously, a new way of thinking was established which made possible the emergence and consolidation of a new scientific discipline...

De te fabula narratur? Should this be the case with the lingering *information problem* and the advancement of a Science of Information?

1. The way we think about Information

The towering legacy of mechanics (in its four branches: classical, statistical, fluids, and quantum), coupled with the engineering feats in communications, have conformed most of the received wisdom on information. Although that classical way of thinking may produce acceptable results in a number of applications, it ostensibly fails at the integration side, explaining how informational processes may escalate, ascend, descend, percolate, etc. so to organize collective, open entities capable of successfully adapting to their environment (Conrad, 1996). Somehow,

the received wisdom on information implies subtle but important stumbling blocks along both the integrative and analytical paths of the concept (Marijuán & Villarroel, 1998). Depending upon the approaches, it may imply: unlimited, disembodied observers; a restricted characterization of the information phenomenon in a closed "mode of existence"; unrestricted boundary conditions and laws; idealized categorization schemes; reduction; hierarchical relationships between isolated disciplines... Overall, deeply interrelated themes to discuss and revise coherently. We will address some of the issues in what follows.

From the start, a new type of abstraction, one where the limits of the individual are taken into account, seems necessary. As Whitehead (1948) put: "*Operations of thought are like cavalry charges in a battle--they are strictly limited in number, they require fresh horses, and must only be made at decisive moments*." Or more recently, as Lanham (2006) posits: "*in the information economy what we lack is the human attention needed to make sense of it. Attention is the commodity in short supply*."

What consequences would follow from such type of *limited prehension* statements? Although we still lack adequate "theories of mind" to rely upon (a very unfortunate theoretical void), approaching science itself as a composite informational construction seems feasible. It would imply addressing the "natural" division of work within scientific communities: the need of specialized disciplines and the reliance on paradigms, the historical evolution of communicational structures in science, the role of mnemonic aids and the interplay between verbal exchanges and the written world, the citation networking structures of scientific publications, the notion of "epistemic distance" between disciplines, the fracture and emergence of new fields, the systematic generational doubling of disciplines in the modern world during last centuries (e.g., close to 7.000 fields right now, around 3.000 in early 70's; presumably less than 1.000 fields one century ago)...

The extension and density of communication networks within science would be essential for the "swarm intelligence" that emerges, far beyond the perception and action capabilities of the limited individual. Actually, the strict conditions put by scientific methods are also efficient protocols to grant the social decomposability of problems (Rosen, 2000). Standards, measurements, mathematical operations, formalizations, etc. become ways and means to extrovert mental operations out of the individual's nervous system and directly interconnect perceptions and actions at a social scale (Hobart & Schiffman, 1998). The success of science in this informational jumping over the individual's limitations has been rationalized as the superiority of the scientific method (leaving aside any communication, rhetoric, and thought-collective aspects) or directly attributed to "*the unreasonable effectiveness of mathematics*" (Wigner, 1960). However, in the same way that we have already developed philosophy of science, history of science, and psychology & sociology of science, we would also need a genuine informational approach to science. Otherwise global visions of the scientific enterprise will oscillate in between the mythical and the bureaucratic pragmatism of "*seeing like a state*" (Scott, 1998).

2. Varieties of biological information

The panorama of relationships between information and life has dramatically changed in last two decades. The plethora of "omic", bioinformatic and systems biology new disciplines are disclosing an extraordinary multiplicity of informational processes that go far beyond any traditional conceptualization of biological information either as code, communication, or structure. It is a world teeming up with millions of specific molecular recognition events, multiple codes, transcriptions, translations, processors, signaling systems, messengers, effectors, second messengers, regulators, interferences, complexes, connectivity networks, etc.

Essentially it is a collective problem-solving dynamics applied to self-production of the own structures --implying both synthesis and degradation-- which is performed by a "network society" of specialized enzyme and

protein agents, continuously exchanging information about their specific activities thanks to the especial solvent properties of the water matrix. In response to *communicational* signals of the environment, thousands of *constitutive* enzymes and proteins, "nanomolecular processors" endowed with a peculiar modular structure, are synthesized (and also degraded) out from the sequential *generative* information of the DNA and RNA "data bases", which are themselves incessantly subject to an evolutionary and re-combinatory game (Marijuán, 2002).

There appear multiple varieties of biomolecular information to distinguish (at least the three broad categories mentioned: *constitutive*, *generative*, and *communicational*, further subdivided into *sequential* and *diffuse* or *amorphous*; plus the endless heterarchical instances of process derived from formation of *complexes* and *modules*). In the interplay of all those varieties of information, the tides of self-production processes are orchestrated in a complex and flexible way, harmoniously engaging synthesis and degradation on an equal footing (the functional importance of both "negative phenomena", *protein & RNA degradation* and *apoptosis*, or cell death, cannot be overestimated). The whole productive-informational processes culminate in the regularity of a specific cell-cycle *open* to the environment, both in terms of energy and information.

The living enacts a new way of existence, an active "informational" one that is based on the capability to keep the own structures in a permanent state of "flow", by piling up synthesis and degradation processes in a way that reminds critically self-organized phenomena. Thus, the living cell may systematically respond to signals from the environment, and produce the "meaning" they imply, by letting the signals themselves to interfere with the ongoing molecular dynamics of the cellular self-production "flow". Therefore, *meaning* may be defined throughout molecular *mining*: as the (signal) induced changes in components and connectivity of the constitutive enzyme-protein populations and the associate metabolites and substrates. The *relevance* and *value* of the signal can subsequently be considered and gauged --cellularly, this would correspond to second messengers and the cycle "checkpoints". Completion of the cell cycle always appears as the fundamental reference. The phenomenon of *knowledge* may be appended too, once the generative codes of the successful responses have been evolutionarily selected, refined, and cohered within the life cycle (Marijuán & del Moral, 2007).

Biologically, the proto-phenomenon of information has been remarkably enlarged. Now what it involves is far more than standard metrics on well-defined signals and structures. In a simplified way, from the part of the sender there are inner functional "needs", signal generation, and encoding; then channel transmission; plus reception, decoding, meaning, relevance, value, and cognizing response by the receiver. Thus, the phenomenon of information integrates the whole happenstances in the communication process between life cycles –in the connection between networked entities themselves in the making, "in formation". Indeed what information supports is a new mode of existence. Rather than resorting to those especial terms coined during the 70's and 80's (self-transcendence, autopoiesis, autogenesis, autocatakinesis, self-production, etc.) we may just say that the living existence is *informational.*

The similarity of biological stuff as stemming up from information, with the physical idea of "*it from bit*" (sentence coined by A. Wheeler in 1989), might be more than a superficial coincidence. Intriguingly, some of the previous discussions would dovetail with recent quantum information approaches to the generativity of the vacuum, the measurement problem, and quantum coherence (Lloyd, 2005; Seife, 2006). Perhaps it is too early to argue whether biological and quantum realms can share a common informational foundation (Conrad, 1989). However, considering information itself as "*distinction on the adjacent*" becomes a fruitful exercise in both camps. Transcending adjacency would be a permanent driver of biological and cosmological evolution.

3. Neuronal processes, cognition and categories

At the time being, theoretical schemes of human information processing and communication have not achieved yet a fair inclusion of meaning, categories and knowledge –at least, properly grounded in the neurosciences (Lanham, 2006). Again, the life cycle of the individual has to be entered as a global reference to anticipate and fabricate meanings, to configure categories, and to properly situate human knowledge.

Can one think on equivalents to the signal, the functional "void", the generative codes, the cell life-cycle, and the networking alterations in a neuronal scenario? In some sense, absences or needs ("functional voids") in the life cycle of the organism might be a *leitmotif* of any biological communication. The creation, exchange, and elimination of signals may be inseparable of sets of functional absences, which may be compressed or symbolized in a few related presences, then traded as communication items either in intercellular or social "markets" (Ulanowicz et al., 2008, have very elegantly studied the information content of absences in markets and ecological systems). Actually, isn't much of human communication directly related to absences, to publicize at large the individuals' needs or absences? (McLuhan, 1964).

In the human case (and in most advanced central nervous systems), it is the *action/perception* cycle what serves as the universal substratum for organizing behavior and subsequently tending the fabrication of meaning, categories and knowledge. Seemingly, we confront the world in accordance with such action/perception cycles or oscillations, regularly switching between dominant modes of behavior (motor centered versus sensory centered). And there is very a strong current on developing a motor-centered epistemology, which is deemed by relevant neuroscientists as the best tentative foundations for explaining our "automated cognition" (Berthoz, 2000; Arbib, 2001; Fuster, 2003; Dunbar, 2004; Buzsáki, 2006).

For a brief description of the information "engine" handling the oscillation between dominant modes in the action/perception cycle, we can follow Collins (1991), and also Marijuán & Collins (1996). The brain appears as an abstract problem-solving playground where topologically distributed variables ("tuning precision voids") occurring at the neuronal columns of cerebral maps are processed as an overall entropy that different brain substructures tend to minimize. Because of the evolutionary design of nervous systems (e.g., the vertebrate phenomenon of *decussation* of the nerve fibers) internal and external organismic "problems" locally increase that entropy value. The subsequent blind (abstract) minimization by the nervous system's topological mechanisms produces as a byproduct the adequate behavioral and learning outputs. A problem-solving behavior well adapted to the advancement of the individual's life cycle emerges from all those distributed processes and minimization operations (Marijuán, 1996b)... Therefore, in the extent to which those premises are correct, a very compact approach to knowledge automation by the central nervous system seems achievable, and further, a new "Theory of Mind" could be contemplated.

In an original vision about the *category problem* advocated by neuroscientist J. Fuster (2003), and which looks compatible with the previous ideas, the *cognit* was substituting for the "concept". Any *cognit* would have "two ears" or two sides to be handled from: the motor side and the perceptual side, always one of them playing a dominant part. Applied to the language constructions, this means that any pure "noun" category would inevitably be surrounded by a shadow of multiple related actions, and any "verb" would be surrounded by a shadow of potentially subordinated objects to be applied. The very neural programs to organize motor action would take care of the loops or trajectories among the nodes and the networks of these *cognits*, organized by dominance and later on subject to grammar and logical refined constraints. In social linguistic games, the mixed, inner nature of our cognit /categories would appear in the form of metaphors, games of words, jokes, etc. Contexts delimitate very well what partial shadows are permissible and survive in order to create the ad hoc meaning.

Again, in the extent to which the *cognit* premises are correct, the construction of

categories and the explanation of linguistic meaning would appear under a new light. Probably, a reconsideration of logic is involved (Javorsky, 1995; Marijuán & Villarroel, 1998). The explicitness and sharpness of logics have dispersed all the perceptual and motor shadows and have left but the pure categorical abstractions. Even more, in the parlance of scientific disciplines, mathematical constructions have completely substituted for "action", working as a sort of "universal virtual constructor", and together with logics, they have created new forms of strictly relating abstract perception and abstract action, creating new realms to configure social meanings as disciplinary and experimental knowledge. This cognizing strategy has been extremely useful in order to explore and simulate nature, create efficient technologies, etc. But paradoxically, by killing the *cognits'* inner shadows, by restricting categorization and ignoring the observer limitations, they have really left in the shadow the individual and collective processes related to the social elaboration of "meaning" –and opened the infamous gap between natural sciences and the humanities.

4. Towards a new scientific perspective: Theoretical unification versus Ecology of domains

The possibilities of information science are historical. Perhaps comparable to the scientific revolutions spurred by thermodynamics and quantum mechanics. But the difficulties are tantamount. The advancement of a new scientific perspective, information science, devoted to the study of the vast field of informational phenomena in nature and society, implies putting together a number of cognizing domains which are presently scattered away, and well anchored, in many other disciplines: philosophy, mathematics, physics, computer science, engineering, biology, ecology, neuroscience, psychology, social science, economics, political science... Is the new agglutination viable?

Perhaps it is time to go beyond the classical discussions on the concept of information, and associated formal theories, and to seriously consider the problematic assembly of all those interdisciplinary fragments. Success in some partial theoretical unification would help, but probably it would not be enough. Advancing a "new way of thinking" seems necessary, even as a complementary strategy.

Here we argue that a new vision on information is needed. The *informational mode of existence* means an unending process of adaptation to environmental demands by means of communication and self-production activities, usually networking relationships which are continuously altered under the changes of the inner side and the signals from the outer side. Societies (e.g., structures of social bonds), Brains (neural nets), Cells (protein & gene nets), are the theatres where the changes derived from the new signals extracted from happenstances are realized as meanings. Interdisciplinary networks would join too, as they are dramatically altered in their (citation) structures when success of a new approach following alien "recombination" methods multiplies the possibilities to extract new meanings materialized in the new interconnections.

The new science should not aspire to any reductionism. Internally, it should be organized as an *ecology of domains*. Rather than systematically searching for the reduction or grand unification between theories, it should attempt the construction of "bridges" or "corridors" interconnecting the multiple domains. Externally, information science would contribute in an equal footing with other disciplines to the interdisciplinary exploration that the system of sciences performs. In this sense, an array of information based subdisciplines such as information-physics, information-chemistry, bioinformation, and socioinformation would represent a valuable complement to chemical physics, biophysics, biochemistry, psychobiology, and sociopsychology (or for that matter, neurophysics, neurochemistry, sociophysics, sociochemistry, and sociobiology), and of course, to economy and political science (Marijuán, 1996a).

Perhaps the best catchword for the knowledge game in the sciences is not hierarchy, nor reduction, nor unification –but

unending *recombination*... In the critical race against time between world problems and problem-solving capabilities, a well-developed information science could offer a new panoramic view on the recombination processes of the sciences themselves, contributing to adumbrate the plenum of social capabilities of the present scientific system.

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