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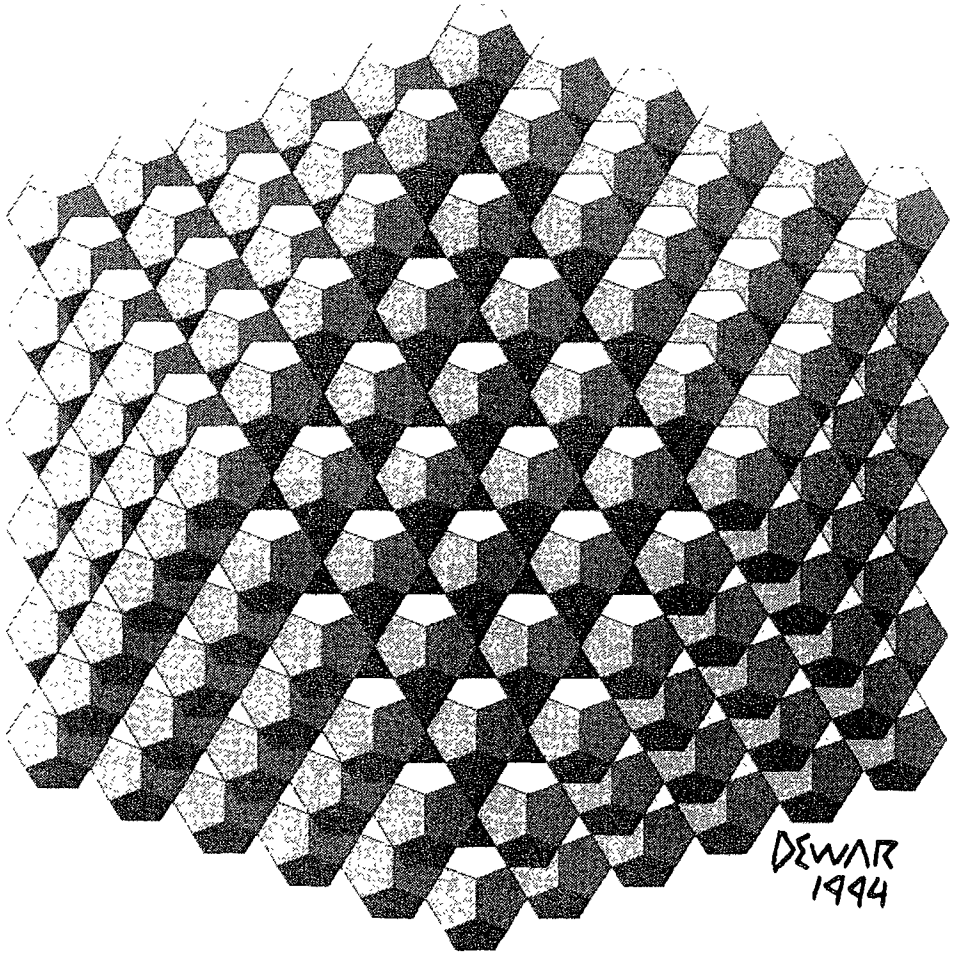

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INFORMATION SCIENCE AND SYMMETRY

On the Emergence of a New Disciplinary/Interdisciplinary Avenue of Enquire

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INTRODUCTION: SYMMETRY AND THE NATURE OF INFORMATION

The conceptual pair Symmetry-Information (see Matsuno's presentation for this Symposium) constitutes one of the most intriguing, and perhaps important, discussions in today's interdisciplinary arena.

Initially, the very nature of information has to be discussed: whether it appears as a single concept which can be elucidated accurately enough (e.g., Shannonian metrics), or it actually implies a too complex series of emergences occurring in widespread networks of interrelated "social" processes. The latter option allows to contemplate, so to speak, the possibility of a "vertical" science devoted to information (*"information science"*), giving coherence to the many treads in widely separated disciplines converging on the analysis of informational phenomena. As a matter of fact, the possibility of such a "new science" devoted to information has been recently considered by practitioners from fields as diverse as computer science, quantum physics and biophysics, biocomputing, neurosciences, and social sciences (F.I.S., 1995).

If information has to be understood as a science (or even as a group of associated sciences) rather than as a single concept corresponding to a well-defined phenomenon, then it remains open the question of which other conceptualizations have to build its inner or "vertical core" to allow the successive conceptual climbing--to put it rather roughly, "from quantum physics and computers, to cells, nervous systems and societies".

As we are going to argue, symmetry might be the conceptualization germane to information which can contribute to give a formal basis to the new disciplinary/interdisciplinary construction that looms. Starting from biological information onwards, symmetry would gain new contents and meanings while contributing to explain the dynamics of information based "societies"; perhaps paralleling the remarkable success symmetry itself had in the realm of quantum physics and subatomic particles.

BIOLOGICAL INFORMATION AND CELLULAR PROBLEM-SOLVING

The phenomenon of biological information emerges within complex "social" networks of heterogeneous elements performing particularized functions. The elements are interconnected in their functioning, precisely through the exchange of information, in order to achieve the permanence --survival-- of the social ensemble. While inanimate matter survives automatically, just following the standard physico-chemical laws, living beings need be involved in a permanent web of *extra* calculations and self-modifications (thanks to information accumulation, exchange, and processing) in order to achieve that very survival. Literally, life implies unceasing *problem-solving* activities. This is what we observe in the cell, "society of

enzymes", in the nervous system, "society of neurons" (organism, "society of cells"), and within the "society of individuals".

The cell, the "society of enzymes", is at the basis of biological problem-solving. Individually, the function of every enzyme has a non-picturable character (Conrad, 1990), implying an enormous "reservoir" of processing capabilities to be harnessed by the system. The exchange of information between the different enzymic functions occurs through the sharing and networking of substrates, products, activators, and inhibitors. This complicated network of exchanges allows the emergence of an overall functionality for the whole population of enzymes which can be extremely rich (particularly through its interconnection with the "DNA world"--the controlled expression of genes). From an abstract point of view, the whole cellular dynamics implies not only "evolution" and "self-organization", but also "self-modification" and "self-reconfiguration" (Marijuán, 1994).

A peculiar way of functioning nucleates the dynamics of the cellular system. The cell actively scans its internal and external environments looking for what we can call "absences" in the development of its overall life-functions. Any detection of an "absence" (including the non-desired "presences") provokes a series of graded responses: either a minor reorganization of the metabolic network, or a wide intervention of the signaling system (receptors, second messengers, and *converter* enzymes that act upon other enzymes, e.g., protein-kinases and phosphatases), plus the controlled expression of particular genes, and last but not least the regulated *proteolysis* of targeted enzymes and proteins.

This series of molecular mechanisms, so well known to molecular biologists, can be interpreted in a non-traditional way: as configuring a new type of quasi-universal information processing system. The overarching goal is the permanence of the entity, achieved by means of the above panoply of cellular responses in front of the infinite multiplicity of internal and external changes. It is a problem-solving dynamics basically organized around filling-in the "absences" or "functional voids" by means of the synthesis of adequate enzymes and proteins. Or more formally, it is proposed here that *the detection and solution of any "functional voids" within the life cycle of the entity is what characterizes the living cell's information processing.*

The term "functional void" represents the biochemical work to be performed by the system, after the arrival of signals or after the occurrence of external or internal events, in order to restore its life-cycle trajectory. It naturally encompasses the "meaning" of the incoming signals (Marijuán, 1995). The detailed conceptualization of the term is well in accordance with Tomkins' (1975) "metabolic code hypothesis", with Conrad's (1990) "vertical problem-solving", and with Matsuno's (1989) views on the role of "indefiniteness" in biological information. It has been postulated by Igamberdiev (1993) that symmetry and disymmetry are the most parsimonious way to understand the energetics and overall metabolism of the cell. In this sense, functional voids can be understood as instances of symmetry-breaking within an overall "circular (cycle?) symmetry". The symmetry-breakings can be efficiently counteracted, and restored the overall symmetry, thanks to the powerful (quasi-universal) information-processing and *productive* machinery of the living cell.

ORGANISMIC PROBLEM SOLVING--THE "SOCIETY OF NEURONS"

The evolutionary process has pushed the cellular processing power towards higher and higher performances: quasi-universality in the global metabolism, in the signaling system, in the "DNA world", and in the proteolytic system. This enormous improvement in all subsystems --and above all, the evolutionary sophistication of signaling systems-- supports the genuine emergence of inter-cellular information as a tool for collective problem-solving among colonies of cells

The new insights recently gained in the molecular analysis of multicellular signaling systems are particularly appealing for symmetry studies (Egan & Weinberg, 1993). The set of receptors and channels (in the thousands), converter enzymes (in the hundreds), and second messengers (less than ten) might constitute a massive playground for symmetries and symmetry-breakings. They actually represent the materialization of order into the massive parallel flow of processes within the multicellular organism. Following the symmetry conceptualizations, the apparent bewildering variety of signaling pathways could receive an elegant coherence and unity (and at the same time, alternatives to the von Neuman machine might be suggested from a molecular-biological standpoint).

The multiplicity of systems within the multicellular organism (digestive, circulatory, respiratory, muscle-skeletal, hormonal, neuro-endocrine, immune system, nervous system...) can be understood as evolutionary inventions for the distribution of global problems of the organism --functional voids at the organismic level-- among specialized populations of cells. Every cell receives the signal that conveys its own local functional void; then, it is obvious that the cell needs the appropriate apparatus (signaling system) to decode and build the "meaning", and be able to internally solve it. It is a process which occurs in both directions: local needs (functional voids) of cells are integrated into global organic signals, and global organic needs are decomposed into microscopic signals generating functional voids in local cells. In general, the information processing devices that we observe at different levels of socio-biological systems, can be interpreted as machineries to detect, measure, amplify, solve, exchange, export, etc., the occurring functional voids, the problems --needs-- of the individuals in the development of their life cycles (Marijuán, 1995).

The "society of neurons" is the specialized system which leads the whole organism in its interaction with the external environment. Depolarizations and production of spikes in neurons are genuine instances of functional voids generation and solution (the production of spikes, with the associated cytoplasmic and nuclear events, restores the symmetry-breaking of depolarization). The overall "social" outcome of neurons is the production of observable behavior and learning. At this macroscopic scale, "Duality Theory", as developed by K.P. Collins (1991), see also Collins and Marijuán (1996), is founded upon the use of symmetry and antisymmetry within the topologically distributed mappings of vertebrate nervous systems. It integrates neurophysiological and neurocomputational phenomena (e.g., "decusation", "tuning precision voids") with cognitive and emotional processes (e.g., "memory-addressing", "prejudice towards the familiar"), providing a sensible explanation about the emergence of biologically adaptive behavior.

PROBLEM-SOLVING IN THE "SOCIETY OF INDIVIDUALS"

Information and symmetry are useful guiding principles for social research too. There is little doubt that human societies are organized around the life-cycle of individuals, the satisfaction of their vital "needs". It is a fact that underlies the social invention of multiple specialized systems (e.g., economic, legal, political, cultural systems; technologies, arts, communications, etc.). These systems, again, can be understood as tools to allow the distribution of global problems among specialized populations of problem-solver agents, and vice versa.

Such problem-solving interactions are extremely rich both in information and symmetries. In the economic arena, very basic tools such as "money" and the system of "prices" imply a continuous use of symmetries and symmetry-breakings by the participants (not unlike the use of ATP and second messengers by the cell; somehow, the measurement of economic "absences" within markets parallels the molecular measurements by signaling systems). In democratic societies, there is a legal and political struggle to guarantee "equal opportunities"--if conflicts and excesses of "social entropy" are to be avoided. It is to say, the legal system and the political system have to restore basic symmetries in the relationship between individuals lost during the economic process. A complicated system of balances between both symmetry and disymmetry seems the only way for societies to maximize the problem solving dynamics of its members (well-being, "happiness"). As a matter of fact, symmetry is a necessary component of any durable relationships.

As was suggested in the Madrid'94 conference (F.I.S., 1995), the "society of enzymes", the "society of neurons", and the "society of individuals", at last may well be using similar information-symmetry based strategies.

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