# Exploring the Biological Foundations of Computation
## or Rediscovering Beauty, Harmony and Proportion in Science

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## ABSTRACT
**The proposed work is an integral part of the emerging discipline of natural or nature-inspired computation. This research addresses the phenomena of emergence, adaptive dynamics and evolution of self-organizing, self-maintaining, self-replicating and self-healing computational systems and communication architectures in a profoundly new way. In this context, we regard living systems manifested as morphogenetic fields in structural-functional patterns by means of autopoietic networks and *'hidden'* relational semantics and semiotics which dynamically enfold and unfold inside the constituent elements as a result of the composite interplay with each other and their environments. This approach provides a unique frame for exploring the biological foundations of computation at the frontiers of science. The attained knowledge can be used in the design of biosynthetic systems which go beyond Turing's discrete computation model and von Neumann's self-replicating automata, thus unleashing science to grow towards new horizons.**

## Keywords
Biological Mathematics and Computation, Computational Systems Biology, Naturalistic Computing, Integral Biomathics.

## 1. INTRODUCTION
Scientific progress is inconceivable without powerful computation and the Internet today. As a result, the rising complexity of ITC systems approaches those of biological organisms and ecosystems. Recent efforts in autonomic computing and communications are focused on developing systems which automatically adjust their behaviour in response to the changing conditions of their work environments. The goal of this research involving the whole range of contemporary computer science from automata theory to artificial intelligence is to manage the growing complexity of modern computing and communications architectures and enrich them with capabilities that occur in living systems such as self-configuration, self-optimization, self-repair and self-protection, etc [1, 2]. On the other hand, life and physical sciences always demand high-performance computation for their advancement.

Therefore, recent research roadmaps both in computational systems biology and autonomic systems are targeting to perpetuate and enrich the knowledge, technology and methodology transfer between analytic life sciences and synthetic engineering sciences. Yet, basically, binary computation itself has become a one-way road, a self-sustaining discipline today.

Therefore, we dare to question the firmness of the bridge between converging sciences and claim that it is impossible to make any significant progress in this multidisciplinary field of research without inaugurating a breakthrough paradigm change (back) towards truly *biologically driven mathematics and computation*.

## 2. MOTIVATION
Our major argument is that living systems have fundamentally different notions for self-organization from those conceived in engineering sciences today. Whereas artefacts are designed and programmed to serve human needs as tools and mechanisms, organisms are just beings with the only purpose to maintain, survive and reproduce in a changing environment. The former are closed deterministic systems conform to the laws of physics; the latter are open non-deterministic systems [3] that also follow the patterns of biology. Therefore, when devising the plan for future converging sciences, one should be aware of the limits of engineering and of the fact that "various relations within organisms…are outside the scope of metric mathematical biology" [4] and contemporary science. This holds also for computer science (dominated by the Turing machine model for the past 30 years) and for the emerging discipline of *nature-inspired* or *natural computation* [5], including constructivist approaches such as evolutionary, neural and neuromorphic, as well as cellular/membrane and molecular/DNA computation. They all still suffer the inertness of exclusively syntactic and "mechanistic computing models…by utilizing numerical computation algorithms based on *recursive* functions" [6[.

## 3. SCOPE
Taking into account the above arguments, the following research areas are of major interest for our research:

**1. Fields**: The most challenging part of research is concerned with the exploration of the *physical base* of biocomputation in terms of regular assemblies of structural elements and functional patterns excited by the oscillatory character of the underlying processes allowing the evolution of stable nonlinear systems through moving equilibria [7]. Essential for this research will be new findings about the fundamental nature of the physical continuum in support of unified field theories addressing the explanation of transfomations between energy and information underlaying the emergence and evolution of life and consciousness [8].

**2. Relations:** Natural computation is relative. Relational variables are created by the system itself, as it evolves. Organisms can be represented e.g. as *n*-placed predicates or *n*-ary relations, [4, 14].

There are numerous other mathematical approaches that can be used as an *abstract base* for the symbolic description of living systems such as category theory, set theory, graph theory or combinations and powers of them. The expected results from the research in this field are the definition of a formal *bio-logic* analogous to Elsasser's concept [9] and the development of a relational calculus that considers non-local causality and anticipatory control that depends on the observer [10]. However, this formalism should be also capable to integrate such phenomena as instant response to unpredicted stimuli, variableness, fuzziness, uncertainty and superposition.

**3. Networks:** According to autopoietic theory [11], a living system as a clearly distinguishable *network* of processes for production of elements constituting and re-activating the network that produces these elements. Thus, biocomputation – being organized as a network (i.e. implying communication) – might be a by-product of ongoing structural coupling (a posteriori) between collections of autopoietic elements, but it cannot be defined as a purposeful task for the solution of a specific problem or class of problems in the way expected from artificial computational systems today. Its fundamental *intent* is not decision making, but adaptation, life maintenance, survival and replication. Any formal description of such a living network is impossible with current mathematics [12]. The research in this field is expected to deliver new insights in autopoiesis, as well as a new consistent definition of autopoiesis, a new formalism, or both.

**4. Semantics & semiotics:** Computation occurring in nature always involves semantics and semiotics. Hence, it cannot be formalized in the conventional way using purely syntactic Hilbert logic. An expected result of this research is the design of a meta-language construction model describing self-creating dynamic attributed ontologies in terms of *multi-layered patterns* (living system codes) and capable to express such phenomena as both natural and artificial neuronal activity. The patterns themselves and the ways of their spatio-temporal formation, use and recognition as signals followed by transformation into signs (semiosis) should be explained with higher layers of order in the domains of semiotics, physiosemiotics and biosemiotics [13].

## 4. OBJECTIVES

There is undoubtedly a relation between social networks and (tele)communication infrastructures. However, if the goal of future science is to develop and maintain a kind of isomorphism between these domains, it will need a new kind of computation model which is capable of expressing the special *logic* of living systems [14]. This is also true for simulating physics [15].

Therefore, we focus on understanding the premises for and the fundamental characteristics of organisation in biology. Our goal is the development and implementation of an *integral model for biocomputation* within an adequate engineering frame of relevance, rather than development of imitations and replicas via arbitrary selection and emulation of a set of limited 'organic' features. This is opposite to the purely synthetic and constructivist approaches to human and machine intelligence [16-17].

Hence, the major objective of this proposal is to define a research program for investigating the biological imperatives of computation in a refocused, but synergetic, Pythagorean way that recovers the purposeful interdependence between the scientific disciplines as seen by the vision of *integral biomathics* [18].

## 5. REFERENCES


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