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Editorial

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This special issue presents neuroscience from an interdisciplinary perspective. Each research paper in this publication contributes to a singular endeavor: the integration of cognition and computation on biological grounds. "*Pointing at Boundaries*" refers to computing with biological substrates, including alternative ways of modeling action potentials, multi-scale computation, ionic dynamic patterns, and mechanisms of information integration.

The topics raised in *Pointing at Boundaries* contribute to earlier computing research such as biological mathematics and cellular automata [1] and the bio-inspired in silico *computing* proposed by Wooley et al. [12]. Biological substrates might further inform computer research. Several aspects of biological substrates appear in this special issue: astroglial cells in brain cognitive computing, ionic interactions, cortical mini-columns, and statistical neocortical dynamics models. These biological phenomena reframe earlier computational protocols while suggesting research on biophysical grounds for consciousness research.

A biological approach to cognitive computation is based upon structures containing both a substrate (as ionic solutions) and mechanisms (as membrane ion channels) that induce the formation of patterns upon the substrate and manipulate an organism's biological substrate. The papers in this special issue contribute to a hypothesis: a biological substrate and its mechanisms act as a diaphragm to better *mark differences*, according to a topology with highly configurable neighborhoods. Research into this hypothesis might be as suggestive as the configurability of crystalline symmetry groups capturing spatial neighborhoods in the form of diffraction patterns. In this regard, this publication represents groundwork towards uncovering the theoretical and experimental basis to develop biological substrates and mechanisms as the ionic permeation of membranes. By investigating the biophysical aspects of consciousness, future biophysical computational research might investigate with a variety of physical signal types (chemical, mechanical, and electromagnetic) through the sensory pathways found in the 26 vertebrate cranial nerves or the 12 human cranial nerves [7].

Synopsis

In this issue, the opening paper by Dorian Aur contributes to the conceptualization of brain electrodynamics underlying the formation of action potentials and reveals multiple computational levels in neurons. This paper raises foundational questions and objections to existing standards in neural activity research. Aur applies to computational neuroscience Wegner's [11] interactive computation paradigm. Consequently, Aur formulates a continuous

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computational model that diverges from the dominant discrete computational models evident in von Neumann and Turing classical approach.

Erhard Bieberich in this issue places biological substrates within an in silico architecture. Bieberich's research focuses upon the physicality of consciousness seen through what he calls "bright matter," in a recurrent fractal neural network. Bieberich (this issue) presents a fractal principle to address the "*binding problem*." Accordingly, Bieberich proposes the brain integrates spatially distributed information into unitary percepts.

In addition to the two opening papers, there is a complement of research papers that further detail the topic of biophysical consciousness: (1) quantum aspects of action potential generation (Gustav Bernroider and Summhammer); (2) statistical mechanics of neocortical interactions (Lester Ingber); and (3) the putative role of astrocytes in cognitive computation in the brain (Alfredo Pereira Jr.). Each paper stands within its own research framework, but as a group the first five papers in this special issue provide an opportunity to examine biophysical consciousness across several fields of inquiry.

In Crick and Koch's [3] approach to the neurobiology of consciousness, the general structure appears as follows: (1) general neurobiological aspects; (2) blindness/brain split; (3) neural firing; (4) biological pathways of vision; and (5) Hebbian/Non-Hebbian model. A similar outline of topics appear in the papers exploring biophysical consciousness: (1) bio-ionic interactions; (2) epilepsy; (3) neural interactions; (4) dendritic or astrocyte pathways; and (5) quantum entanglement in semi-classical Hodgkin-Huxley equation and a semi-quantum classical description. Thereby, the overlapping and distinctive points raised by the authors make headway in transforming the *binding problem* discussed by Crick and Koch [3].

Bernroider and Summhammer (this issue) propose quantum entanglement of ions or atoms within a Na^+-conducting ion channel can lead to an observable effect on the shape of a classical (Hodgkin-Huxley) neuronal action potential. This paper opens a new field of research to bridge quantum effects in the brain and macroscopic neural pulse generation. Bernroider and Summhammer's analysis provides a quantum mechanical description of probabilistic gating mechanisms that controls the movement of sodium ions through the neuronal membrane.

Ingber (this issue) uses statistical modeling to investigate how electromagnetic fields generated by neuronal excitability can influence dynamic ionic patterns, as those found in calcium ion waves in astrocytes. The phenomena of neocortical interactions is considered to suggest levels of information processing in the brain that trigger the formation of conscious states and episodes. The mathematical modeling of neocortical interactions by Ingber in this issue provides detailed calculations that support the possibility of ephaptic transmission of information from neurons to astrocytes.

Finally, Pereira Jr. (this issue) discusses the possible role of astrocytes in brain information integration supporting conscious processes and sets the stage to conduct an experimental project on artificial astrocytes. He departs from glutamatergic tripartite synapse and neuro-astroglial interactions to propose a new model of conscious processing, assigning cognitive functions to the neuronal network and affective evaluation of the content of neuronal information to the astroglial network, which is part of emotional processing structures, such as the limbic system, the insular, and orbital cortex.

These five opening papers outline a basic approach, namely pointing at boundaries on biological grounds. Additionally, bio-inspired computing moves toward a framework for interdisciplinary research and experimental protocols. The theories and practices maintained in the opening five papers serve as starting points for the pursuit of computing on biological grounds across a spectrum, involving the use of materials or living organisms as a computational diaphragm; industrious use of invertebrate neuroanatomy; pursuit of synthetic biology; and incubation of computational diaphragms consistent with further synthetic biological experimentation. The remaining papers in *Pointing at Boundaries* focus on explorations that emerge from interdisciplinary approaches to bio-inspired computing.

Girardin and Galizia (this issue) establish an exemplary collection of experimental techniques along several terms: (1) construction of an atlas of all glomeruli in a species; (2) development of instrumental tools (modulation of neurotransmitters and the use of optogenetics) to conduct in vivo experiments; (3) systematic study of the honeybee's neuroanatomy and neurobiology as a direct interface with the development (ontogeny) and phylogeny of a species; (4) selection of olfaction as a sensory modality suggestive for future combinatorial encoding and modulatory research; (5) an appropriate mechanism to investigate multi-scale computation through several factors: (a) the biochemical structure of a signal, (b) a topology of configurations of biochemical signals, (c) the neuroanatomy of invertebrate species, and (d) combinatorial variability of olfactory receptor's proteins [2, 10].

In juxtaposition to Girardin and Galizia's direct use of biological substrates in vivo is Vassanelli et al. (this issue) contribution to this issue. Vassanelli et al. (this issue) provide a laboratory report on the in silico integration between micro-chips and three levels of neural activity (neurons, tissue, and brain). Additionally, Vassanelli's research illustrates the techniques pioneered in Fromherz's laboratory [5]. Vassanelli et al. (this issue) proposed interface represents a current trend that enhances signal transmission from nerve cells-to-chip or from chip-to-nerve cells with an emphasis on in vivo interaction, either in terms of signal-to-noise ratio or spatiotemporal resolution. The authors examine multi-site recording that might supply biophysical consciousness researchers with diagnostic tools to consider ionic interactions. The exploration of biological substrates through invertebrate research (Girardin and Galizia, this issue) and brain-chip interface (Vassanelli et al., this issue) bring additional techniques and methods.

Durst-Andersen (this issue) supports a new linguistic theory by discussing the role of English as the "lingua franca" in the global marketplace. Durst-Andersen (this issue) proposes framing strategies in three *linguistic supertypes* and offers a foundational linguistic study that contributes to a paradigm shift in syntax theory [4]. Durst-Andersen (this issue) uses neuroscience experimentation (eye-blinking research) to discuss a global communication theory across many languages. Unlike Chomsky's universal syntax, Durst-Andersen (this issue) considers language in one's blood, with the assistance of neuroscience and communication acts that warrant further exploration of three linguistic supertypes: (1) Chinese, Russian, and Hindi speakers talk about reality assuming the situation as being common to the speaker *and* the hearer; (2) Japanese, Spanish, and Turkish speakers talk about reality from the perspective of the *speaker's experience* of the situation; (3) English, Danish, and Swedish speakers talk about reality from the perspective of the *hearer's experience*. Durst-Andersen claims that these three linguistic supertypes offer theoretical insights into communication between speakers of distinct languages.

Salomon et al. (this issue) modeling of protein folding suggests a symbolic system based upon biological grounds rather than natural language. Salomon et al. use hydrophobic/hydrophilic amino acid sequences in a 2D model to investigate the conformality of 3D protein folding. The neural network experiments and axiomatic proofs employed by Salomon et al. combine a biological symbolic system along with in silico techniques. Furthermore, Salomon et al. (this issue) sets the stage for future RNA/DNA analysis of protein folding. Both Durst-Andersen (this issue) and Salomon et al. (this issue) illustrate an interdisciplinary theme: neuroscience brings to other fields of inquiry an opportunity to conduct and redefine the underlying assumptions in a field of inquiry's research.

The research presented in this issue serves as guidelines for the future of bio-inspired computing, pointing toward a boundary that ranges between excitability of a biological substrate and *synthetic biology*. The contribution by Cardoso Guimaraes (this issue) suggests that simulation and modeling should help to design experimental procedures for synthetic biological research. His work is based on the possible role of RNA both in the origin of life and in modulation of genome expression.

The Next Step

The research presented in this issue serves as a gateway to additional research practices: (1) the experimental modulation of the biological substrate [9]; (2) symbolic cognitive development and molecular biology [8]; and (3) synthetic biology [6]. Recent breakthroughs in synthetic biology [6] at the J. Craig Venter Research Institute point toward the next step in cognition and computing.

If this special issue points toward bio-inspired computing in terms of interdisciplinary research practices, then the next step would consider bio-inspired computing in terms of experimental protocols that directly interface physical consciousness or synthetic biology research.

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