

Preface

Humankind has taken tremendous strides in furthering the frontiers of science and technology. We have sent spaceprobes into unexplored regions of the cosmos, sequenced the human genome to a high degree of accuracy, devised printers that generate 3D images, proposed the existence of a single force unifying the four fundamental forces in nature and have even experimentally confirmed the veracity of the standard electroweak hypothesis through the discoveries of the W and Z bosons and then more recently, in the signatures of the Higgs particle. Yet, we have so far not made adequate progress in understanding how our mind and cognitive faculties work.

Receiving inputs from the environment, how do thoughts and feelings form? How does one quantify consciousness and how is it linked to the physical laws and the material stuff out of which we are made? A quantum mechanical description would seem a natural choice since quantum laws rule the heart of matter, at the atomic scale and within. One could therefore describe information and its transfer through a probabilistic description on a Hilbert space or on a Bloch sphere, information being gleaned through quantum measurements. Ruled by the principle of superposition of states, the quantum world however, presents difficulties in the interpretation of measurements of a property in a certain state.

In living systems, information is conveyed through the network of sensory neurons and motor neurons/central nervous system to the brain. Patterns of electrical trains and bursts encode this information, so attempts at understanding the generation of these electrical bursts and patterns by the activity of coupled neurons, represent definitive steps forward in the study of information transfer at the cellular scale. The presynaptic neuron's chemical synapse, with its distribution of excitatory or inhibitory neurotransmitters packed in vesicles, all waiting to be released at the synaptic cleft, is a highly regulated, beautifully organised dynamical

system. Why has Nature retained the electrical synapse? Is it merely for achieving faster synchrony in neuronal firing? The equations seeking to mimic the dynamic behaviour of neurons and their activity, describe the physical system at the classical level — a very nonlinear regime.

How then does one achieve the interface linking the classical information described by electrical signals with the conscious states of information of the individual, possibly describable by quantum information? When one makes a “conscious decision” about something, do the cognitive faculties then convert the probabilistic description entirely into a deterministic one? While on the one hand, challenging questions like these remain to be answered, on the other, it is known that quantum effects do manifest in living systems. An example is the detection of odors by the olfactory organ.

Physical models depend upon mathematical techniques to test their predictions. One could then ask if mathematics itself is entirely a fabrication of the human mind, or whether it exists independent of humankind. Some chapters in this volume have given very interesting and diverse views on this subject.

Nature’s diversity and intricate beauty at each scale — from dimensions beyond the Planck scale to cosmic lengths encompassing the celestial orb — only teaches us that information and its mode of transfer may be of varying kinds across different regimes. In a living being likewise, thought processes linking the cognitive faculties with the “conscious” self represent modes of information transfer not yet understood by physical laws. As Richard Feynman observed in “The Character of Physical Law”:

“Nature uses only the longest threads to weave her patterns, so that each small piece of her fabric reveals the organization of the entire tapestry”.

This volume is thus a compendium of differing views on different levels of information in living systems describable by physics and mathematics.

Several of these articles are contributions by speakers at a Workshop on “Application of Mathematics and Physics to Cognition and Consciousness” held 11–12 March, 2013 at the National Institute of Advanced Studies, Indian Institute of Science Campus, Bangalore. We hope the readers would find the material in the chapters as interesting and enjoyable as the Editors did.

Janaki Balakrishnan
B.V. Sreekantan

Bangalore, India
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