Book Review

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Mind the quantum?

Physics in Mind: A Quantum View of the Brain by Werner R. Loewenstein, Basic Books, 2013. US$28.99, hbk (352 pp)
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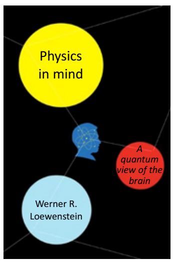

The rich multicolor sensations, thoughts, and feelings that people experience are encapsulated in the vastly complex circuitry of the brain. Brains are nothing more, and nothing less, than atoms joined together to form molecules, bounded into specialized cells, neurons, which can communicate with each other in fascinating ways [1]. Like everything else in this world, neurons and brains must obey the laws of physics. Many luminaries have pondered on the mysterious ways in which matter can give rise to the bewildering world of consciousness [2].

In his new book, *Physics in Mind*, Loewenstein takes readers on a delightful journey through one of the greatest scientific challenges of our time: the quest to understand how physics can explain brain function and consciousness. With precise, engaging, and often provocative prose, Loewenstein dares to delve into fundamental questions at the intersection of physics, biology, neuroscience, and philosophy. Without shying away from complexity, the book guides the reader across as many spatial and temporal scales as one can conceive (from galaxies all the way to the subatomic world; from the beginning of the universe to phenomena in the sub-femtosecond range). The strong formalism of information theory accompanies the reader throughout this journey, providing a rigorous and quantitative documentation of probability distributions and computational processing.

Every page explodes with enthusiasm, metaphors, and food for thought. It is not common to find science books that are accurate, without oversimplifications, and yet read like pieces of fiction that cannot be put down. Physicists with little or no experience in thinking about brains will learn about the state-of-the-art in the wonderful world of computation in neuronal circuits. Neuroscientists with little experience in physics (shame on them!) will expand their universe and be forced to rethink many of the basic notions of neuronal function. Those who are well-versed in both physics and neuroscience will benefit from a fresh perspective and a different way of telling the story.

The author manages to explain with dexterity and wit multiple concepts in physics and neuroscience, including entropy and information transmission, symmetry laws, quantum mechanics, the uncertainty principle and superposition of quantum waves, quantum computers, ion channels, neuronal circuits, sensory processing, and even neurological studies of patients with brain lesions. Along the way, the author continuously and intelligently speculates upon the evolutionary driving forces that may have led to the complexity of brain function. Unexpectedly, the word 'consciousness' mysteriously appears half-way through the book. The author eloquently advances the hypothesis that consciousness endows its bearers with enhanced capability of estimating the probabilities of future events, which could lead to a significant selective advantage.

The author argues that consciousness research will benefit from and even necessitate the interpretation of cognitive and neurophysiological phenomena at the quantum level. Although the author provides multiple intriguing arguments for the plausibility of this notion, evidence for such a grand claim is meager. And big claims require big evidence. One of the fundamental lessons of research in physics is the importance of thinking about models that are as simple as possible (but not simpler). Presumably, if Newton (and others) had worried excessively about the detailed inner structure of the apple, rather than the basic principles that made the fruit land on his head, he would have missed the elegance and simplicity that gave rise to classical mechanics and our fundamental understanding of the behavior of macroscopic objects. Thinking of elephants as point masses without friction remains an extremely useful abstraction.

Several difficulties arise when attempting to introduce quantum effects to describe cognitive phenomena [3]. The author himself notes some such difficulties when he presents arguments against Penrose's notion that quantum phenomena in proteins called microtubuli play a critical role in consciousness [4]. Other difficulties relate to the large numbers of relatively big molecules that interact to give rise to computations in the brain and the lack of concrete testable predictions from theories that posit that quantum mechanics is critical to understanding cognition. To be clear, molecules must obey quantum laws like everything else, but it is not clear that quantum phenomena can enlighten the quest to understand consciousness any more than they can help explain where and when a soccer ball will land. Although the lack of testable predictions does not necessarily preoccupy all strands of physics, before invoking quantum coherent brain materials (or ether or vital sparks), it may be a useful exercise to push forward with 'classical' neurophysiology as much as possible. Clearly, many brain phenomena, including consciousness and free will, remain elusive and hard to explain with our current understanding of neurons and how

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they interact. The field of theoretical neuroscience is young and perhaps sometimes naïve. Theory in neuroscience lacks the centuries (millennia?) of history and success behind theoretical physics. Yet, few decades have yielded suggestive and promising advances. To cite only a few examples, neuroscientists are beginning to develop quantitative and testable models that can describe the first steps in processing visual information in order to recognize objects, they have proposed plausible hypotheses about how information is encoded and stored in neuronal circuits, and they have provided quantitative descriptions of how single neurons compute and integrate thousands of inputs. The argument to continue with simple models may not be too exciting for visionaries of the caliber of Loewenstein, Penrose, and many others, but we need to learn how to walk (and fall) before we can run.

These nuances about quantum details do not in the least detract from Loewenstein's masterpiece of scientific outreach and discourse. This must-read book will promote vigorous scientific discussion in many circles. Furthermore, it will inspire new students, hopefully leading to the new generation of Turings, Schrödingers and Cricks, who will help us make sense of one of the greatest adventures of scientific exploration: the mechanistic physical basis of consciousness.

References

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