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The Brain's Big Bang

A Universe of Consciousness: How Matter Becomes Imagination

By Gerald M. Edelman and Giulio Tononi

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Review by Richard J. Haier

Understanding the nature of consciousness is evolving from philosophical debate to scientific methodology. Cosmology has traveled this same road and is a bit further along with empirical data. The nature of the Universe and how it began is now studied with the most sophisticated and expensive tools known to human beings. Researchers are testing hypotheses about the first milliseconds of the Big Bang. Surely, steady scientific progress on a problem of this grand scope and exquisite complexity encourages similar examination of human consciousness, a problem no less grand or exquisite. Some researchers maintain that both questions may be two sides of the same coin given that we can only know the physical world through our conscious brain. It is no surprise, therefore, that the scientific study of consciousness takes as a generally agreed starting point that the brain is the place to look for answers.

Psychology as a scientific discipline also is evolving a new focus on the brain. Neuroscience approaches to learning, memory and all manner of cognition now dominate research reports. Much of this research in humans uses sophisticated and expensive brain imaging technology. This is far from the unknowable "Black Box" view maintained by Behaviorist dogma, content with a focus on reinforcement schedules of interest to pigeons. It is also far from a reliance on using reaction time to make inferences about cognitive processes irrespective of any knowledge of functional brain anatomy. Over the last ten to fifteen years, brain research in Psychology has invigorated the search for answers to long-standing problems and helped prepare the way for a renewed interest in questions about consciousness, largely forgotten or ignored since William James.

In this context, A Universe of Consciousness is one of a growing number of books taking a stab at a scientific understanding of this most mysterious core of human existence. The authors' premise can be stated simply: Put knotty philosophical issues aside and focus on the properties of brain circuitry (especially processes among specific structures rather than just the structures themselves) that must be necessary to produce the identifiable aspects of conscious experience. Although simply put, of course there is nothing simple about this, especially since the authors acknowledge that, "… we emphatically do not identify consciousness in its full range as arising solely in the brain, since we believe that higher brain functions require interactions both with the world and with other persons." (p xii).

Private, Unified and Differentiated

The two key aspects of every conscious state that must be explained by any viable theory are described in Chapter three (Every Man's Private Theater). First, there is the integrated, unitary nature of subjective conscious experience. Under normal conditions, we experience things as more than merely a sum of parts and we never experience the parts individually. Some visual illusions, like the Necker cube, are examples of forcing only one possible perceptual experience at a time. This aspect of consciousness may be most familiar as the reason why we can not do two things at once. The second key aspect of consciousness is that there are an infinite number of conscious states that can be experienced by each person and each can be differentiated rapidly from all the others. Like the aspect of unity, this property of discriminating among infinite states is often taken for granted, but try building a machine to do the same thing.

The book is organized around four questions: 1. How does consciousness arise as a result of particular neural processes and of the interactions among the brain, the body, and the world? 2. How do these neural processes account for the two key aspects of

consciousness described above? 3. How can we understand different subjective states (like "blue"), called qualia, in neural terms? 4. How can our understanding of consciousness help connect strictly scientific descriptions to the wider domain of human knowledge and experience? Are there any psychologists uninterested in at least one of these questions?

After building a case that, like the key phenomenological aspects of consciousness, each brain is highly individual (integrated) and highly variable (differentiated), a major argument evolves that consciousness arises from the interactive, reciprocal and self propagating feedback found in specific brain circuits, especially in the thalamocortical system. The argument is well constructed and includes innovative quantitative approaches to defining integration (identifying functional clusters of neurons) and differentiation (neural complexity). The going gets a bit tough here for the general reader as some concepts from neuronal modeling and network simulation experiments are not so clear. Unfortunately, the figures could be better, especially those originally in color but reproduced in shades of black. It should be noted that for helpful, high quality figures, Cosmology books in general completely dominate Consciousness books (see Hawking's The Universe in a Nutshell, 2001).

Two key components of the authors' argument are the Dynamic Core Hypothesis and the concept of reentry. Reentry refers to the properties of a large number of groups of neurons and how they interact rapidly and reciprocally (especially in the thalamocortical system). The Dynamic Core Hypothesis gets to the heart of the matter and addresses how a special subset of neuronal groups contributes directly to consciousness. Specifically, the consciousness core requires those functional neuronal clusters that maintain strong mutual interactions over hundreds of milliseconds, and that can be differentiated with high complexity values. Given that quantitative measures for both identifying functional clusters and for estimating complexity are detailed, this hypothesis and its implications become testable.

Further, the authors boldly propose a framework for understanding how unconscious processes interact with conscious processes. Much, if not most, brainwork is unconscious. The brain monitors many systems, filters much incoming information, and generally inhibits more than it excites. None of this constant activity typically is conscious. If the neurocircuitry involved in these routine tasks does not meet the criteria of the Dynamic Core Hypothesis, the activity will not be conscious. Moreover, from an evolutionary perspective, consciousness allows better use and integration of unconscious routines so there is a survival advantage to having more consciousness. These highlights are merely some bare bones to illustrate a well crafted, comprehensive work that is enjoyable to read because the historically complex issues are shown to be well within the scope of modern science.

Data Will Tell the Story

Is the evidence to support the specifics of the Dynamic Core Hypothesis compelling? The whole neurobiological conceptualization has elegance and the arguments are captivating and original. No reader will be disappointed at book's end because enough data are presented for a thoughtful consideration. Also, no reader will be completely convinced that the problem of how the brain produces consciousness is solved. More experiments are necessary but experiments can be targeted to specific hypotheses. Here is the great accomplishment of this and similar recent books---testable

hypotheses about the neurobiology of consciousness. Time and innovative experimentation will tell whether this universe of consciousness is the right one.

For the interested reader, it should be mentioned that a number of notable scientists have proposed other testable theories about the neurobiology of consciousness. Frances Crick (1994), Bernard Baars (1997), John Taylor (1999), and Antonio Damasio (1999), to name a few, have written similarly about consciousness and important experimental results that have generated data for theory building and hypothesis testing. All are excellent books; none is yet the final word but what a course it would make if all were on the reading list.

Do the different theories have anything in common? One striking similarity is that nearly all the researchers working in this area find something of interest about the thalamus, a complex structure acting as a kind of relay station deep in the middle of the brain. For Edelman and Tononi, the thalamocortical system is key. Our own experiments have manipulated conscious states in humans with anesthetic drugs during functional brain imaging with PET and similar studies with fMRI are in progress. The results show a key role for the thalamus (Alkire et al., 1996, 2000). The thalamocortical system is well within the spatial resolution of imaging technology so it lends itself to empirical study. We should expect increased scrutiny of this system in the near future.

For all these research efforts, one may ask, what is the most compelling possible experiment to demonstrate the specific neurobiological aspects of consciousness? In other words, how will we know when we have the right answer? No one experiment is likely to be definitive but the use of functional brain imaging, as conscious states are manipulated experimentally, certainly appears to have the potential for generating solid data for testing alternative hypotheses. Once the salient circuits and brain properties are identified, however, psychologists may provide a unique perspective for the next generation of consciousness experiments. This is the perspective of individual differences. Do the measurable neurobiological properties of consciousness differ from one person to the next? Are there individual differences in consciousness? We have proposed that individual differences among people in the neurobiological basis of consciousness may be related to individual differences in intelligence (Haier, in press). The arguments about consciousness advanced by Edelman and Tononi concerning functional neural clusters and neural complexity may be applied to the problem of understanding the neurobiological basis of intelligence. A host of conceivable experiments to link consciousness and intelligence come to mind.

A Universe of Consciousness shows where Psychology can go in the 21st century, especially in conjunction with other disciplines. Fundamental questions asked by the first psychologists about human experience and the nature of thought may well be answered relatively soon and demonstrate another triumph for the scientific method. It may yet prove to be the case that, yes, the brain can answer any question the brain can formulate. Of course, the closer the answer to any one question, the more new questions arise and the universe, physical and conscious, is infinite.

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