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Echoes of physics' Delphic oracle

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This volume derives from a meeting held in honour of John Wheeler's 90th birthday, organised and funded by the Templeton Foundation. It represents its somewhat unruly honoree pretty well, which does not make it any easier to review or to summarise.

John, a longtime colleague of mine, holds a unique position in modern physics. He is, after Robert Oppenheimer and Edward Teller, the most famous non-Nobellist of the great generation who developed the modern quantum theory. Like the other two, and perhaps not coincidentally, he is associated in the public mind with the nuclear bomb. (In fact he deserves, as much as Teller, the sobriquet "father of the H-bomb".) And in respect among his fellow theorists, he is at least the equal of Oppenheimer and higher than Teller.

This respect is not primarily based on Wheeler's considerable personal contributions to technical theoretical physics, perhaps the greatest among many important papers being the one he wrote with Niels Bohr on the mechanism of nuclear fission. His mark has been made most notably through his influence on the discourse of physics and through the achievements of his students and junior associates: Arthur Wightman, Richard Feynman, Hugh Everett, Jacob Beckenstein, Bryce Dewitt, Wojcieck Zurek, Kip Thorne and many others, several of whom are represented among the 30 authors in this volume. There came to be a "Wheelerian" style of doing physics, which was much more eye-catching and intriguing than the humdrum nuts and bolts approach that most of us take. It is from this style and from the special interests Wheeler has emphasised that such popular-science idols as Stephen Hawking, Roger Penrose and Brian Greene have taken off, and it is this persona that the present book celebrates.

Many younger physicists, my earlier self included, have tended to discount or underrate Wheeler, partly because of this somewhat flamboyant style. One sighed with some impatience, when, for instance, he joined a session on parapsychology and ESP at the American Association for the Advancement of Science meeting one year. But his decision turned out to be perfectly rational: he felt that rather than shun it, he would contribute a voice of sanity to the event, giving a strong speech about how insubstantial the evidence for such things is. What he does well is to ask questions that at first sound naive and to which the answer seems sure not to be science - that is, not to be falsifiable - but more often than not there is real science that can be done in answer to them. What is good in the present volume is that many of the contributions deal with this reality, and some are among the best expositions of their subjects I have encountered.

Each of the essays here was intended to answer one of Wheeler's notorious questions. "How come the quantum?", for instance, receives what is to me a very satisfactory answer from Lucien Hardy, who argues cogently that given a very general set of restrictions on the nature of the theory, the quantum theory is the only way to express properly the continuous symmetries of nature. (I personally feel that discrete, "bit-based" approaches become hopelessly entangled in modern versions of Zeno's paradox.) Wheeler's long-term interest in the foundations of quantum theory and the measurement problem, expressed in his massive book *Quantum Theory and Measurement*, written with Zurek and starting from Everett's famous thesis on "many worlds", stimulates a cornucopia of enlightening expositions, by Dieter Zeh, Zurek and Dewitt. This subject is timely, and the experimental aspect receives a lot of attention.

In the end, I think Zeh expresses the last word about the meaning of the quantum theory: "In the beginning was the wave function".

Wheeler's famous Delphic pronouncement "It from bit?", and his U-shaped diagram showing the universe looking at itself, stimulated a number of the essays here, including the above-mentioned group as well as a few more that delve deeply into modern cosmology. Particularly good is Max Tegmark's essay, which leads so painlessly into the multi-universe, or "multiverse", world that I found myself nodding in agreement with propositions I had previously felt were pretty wild. In fact, Tegmark makes Everett's "many worlds" seem like the most conservative of assumptions. I do not quite go along with his tie-in between Eugene Wigner's "unreasonable efficacy of mathematics" and the idea of a multiplicity of mathematical universes, but up to that final point I was right with him. In particular, Tegmark's remarks on the (gulp!) "anthropic principle" are the closest approach to reality I have heard on the subject.

Wheeler was more than 40 when he moved into the field of relativity and gravitation, on which much of his present reputation is based. The object for which he coined the name "black hole" had only a dry, mathematical existence before he took it up; other concepts that he and his associates originated acquired catchy names such as "wormhole" and the "no-hair theorem". A number of the essays delve further into the subjects of quantum gravity and Planck-scale physics, which are now fashionable. Whether Wheeler is relevant to these developments, or whether they are relevant to reality, remains to be determined. What one can say is that Wheeler, more than anyone else, is responsible for the liveliness of this former backwater.

A final section of the book, "Emergence, life and mind", is dedicated to complexity. John once asked if he could borrow the title of my 1972 article "More is Different" for one of his pamphlets. Three excellent long essays on the philosophy of emergence, by Philip Clayton, George Ellis and Marcelo Gleiser, express the section's main message: the complexities of our world - from the simplest features of identity and physical existence to the complexities of life, conscious mentality and of society - are emergent phenomena, not to be casually subsumed under the intellectual dominance of anyone's "theory of everything".

Stuart Kauffman adds a footnote on one of the many unsolved stages of this process of emergence: the achievement of autonomy as an essential feature of most forms of life.

Any chain of 30 authors will inevitably have some weak links. Some came in surprising places: Jaroslav Pelikan, as the sole humanist in the crowd, does not make a very strong case that Wheeler is the "modern Heraclitus". I do not know what Pelikan could have done, but there must surely have been some other way of relating humanism to the intellectual cornucopia before him. Freeman Dyson chooses to re-argue aspects of the Bohr-Einstein debates about quantum uncertainty - debates that succeeding chapters reduce to irrelevance. This is a disappointment, as Dyson has in the past often argued Wheelerian questions cogently and eloquently in his own inimitable style.

Shou-Cheng Zhang, as almost the sole representative of the condensed matter community, disappoints with his attempt to reproduce various forms of quantum field theory as describing simple models drawn from condensed matter. I cannot see the philosophical relevance of such endeavours; is one not just turning upside down the ideas of lattice-gauge theory? Much more cogent in the context of this book would be the condensed matter questions involved in how the real world constructs itself - broken symmetry, the real nature of irreversibility on the micro-macroscopic edge and the construction of time, macroscopic quantum coherence and the like. (Some of this kind of material is to be found in Ray Chiao's essay.) Recent fashions for cosmology and for quantum computation manifest themselves in a bit of repetition. For instance, two contributors in separate essays show the entirely unconvincing evidence for cosmic-scale variation of the speed of light.

Taken as a whole, this is not a coffee-table book. It is neither suitable nor intended for the layman. In spite of the 20-page introduction by Paul Davies that forswears equations and, of course, Pelikan's essay, most non-physicists, and even some physicists, will find the material inaccessible. However, with few exceptions, it is prepared for the physics generalist rather than the specialist, in, say, cosmology. The illustrations are marvellous. I would describe the level as that of a good physics colloquium suitable for interested graduate students and bright undergraduates. For them, I would recommend it highly - one learns here about this extraordinary man and gets a feeling for the reach of physics and for its deepest fundamentals. The book should be in every physics library.

One final note: the meeting was sponsored by the Templeton Foundation, which is dedicated broadly to the reconciliation of the spiritual and the scientific aspects of the human mind - religion and science, if you will.

As such, I was wary of its provenance and did not attend. My suspicions, or prejudices if you like, were mistaken. The generous funding provided by the foundation has helped to produce an excellent book.

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