BOOK REVIEWS

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Quantum Aspects of Life. D. Abbott, P. C. W. Davies, and A. K. Pati, editors. 468 pp. Imperial College Press, London, 2008. Price: $61.00 (paper) ISBN 978-1-84816-267-9. (Vlatko Vedral, Reviewer.)

Quantum physics is usually thought of as a theory describing very small systems, such as atoms, subatomic particles, and modest collections of quanta in general. However, quantum physics also applies to large objects, and it gives the most accurate description of various solids, liquids, and gases as well as massive objects such as neutron stars and perhaps even the universe as a whole. Recently an exciting field has started to emerge, which asks whether quantum effects might also be relevant in the functioning of living systems. After all, given that we have so much evidence for it in the physics of inanimate matter, why shouldn't nature also be able to utilize quantum physics to improve information processing of biological systems?

The standard response to this is to say that biological systems, contrary to atoms and molecules, are warm and wet. Because of these two conditions, living systems experience a great deal of environmental noise. Can any genuine quantum effects survive such harsh conditions? *Quantum Aspects of Life* is a compilation of research articles discussing precisely this very issue. The book has five major parts (Emergence and Complexity, Quantum Mechanics in Biology, the Biological Evidence, Artificial Quantum Life, and the Debate) and a foreword by Sir Roger Penrose, who himself has argued for quite some time in favor of the proposal that quantum physics might play a crucial role in the brain.

Some articles are more speculative. For example, the article by Al-Khalili and McFadden explores the role of quantum mechanics in speeding up the evolution of the first replicators. Other authors are firmly grounded in experimental reality, such as Olaya-Castro *et al.*, who apply traditional solid state methods to model quantum energy transfer in photosynthesis, an area where there is already some preliminary experimental evidence for quantum coherence. Speculative or not, all articles are written well, argued coherently, and generally fun to read. Many contain surprising ideas and conclusions. Two of my favorite surprises are Davies's argument on the size of biological motors and Demetrius's argument for quantum metabolism.

The question of the smallest size of a biological system was already asked by Schrödinger about 70 years ago in his hugely influential book *What is Life?* His answer: Individual atoms behave erratically, so we need lots of them to make a reliably functioning biological unit. Davis makes the whole argument more precise. Any biological mechanism needs a clock to tell it when to start and when to finish whatever job it is required to do. Quantum physics puts a bound on how small a clock can be and still be accurate for a given needed amount of time. Amazingly, the smallest biological engines saturate this bound exactly! Is this a mere coincidence or a very profound statement about the role of quantum physics in life?

The question of metabolism that Demetrius discusses is that of scaling of energy expenditure rate with the mass of an organism. The natural guess, already known to Galileo, is that since the energy goes through system's surface area its amount should be proportional to the mass, or volume to the power of two-thirds. However, some experimental evidence suggests that in many species, the relationship is mass to the power of three quarters. How can this be explained? Demetrius suggests that the latter exponent comes from the fact that energy generation is intimately related to the vibrational degrees of freedom, and these, if treated quantum mechanically, will have a typical blackbody type behavior in energy. And this, after some simple analysis, leads to the three quarters in the exponent. Interestingly, higher species (e.g., mammals) tend to conform to this behavior better than lower species (e.g., plants), suggesting that quantum effects kick in after a certain minimal degree of biological complexity.

Be that as it may, the icing on the cake is the transcript of the two conference debates with which the book ends. One debate is on the possibility of large scale quantum computers, and the other one is on the role of quantum mechanics in biology (i.e., is quantum mechanics fundamental or trivial in biology?). The two questions are related: If biological systems can utilize quantum effects, they are already prototypes of simple quantum computers. The two debates are an exciting read and present the spectrum of opinions existing out there in the research community. The exchange of ideas between participants is both very educational and highly entertaining (it made me laugh out loud several times). You can also see the confusion resulting from the complexity of the questions in that researchers even switch sides during the course of the debate. The history of science has, of course, taught us that disagreement and confusion are not only normal and healthy but actually necessary for the progress of science. At the Fifth Solvay Council in 1927, when quantum mechanics was on the agenda, "the confusion of ideas reached its zenith," according to Paul Langevin. So watch this space!

Quantum biology is a new field. It generates a great deal of excitement and quite a bit of controversy. Questions abound, answers are few. For all that we know, it could all turn out to be just hot air. But it could also easily evolve into the next big thing in science. The book edited by Abbott *et al.* represents all the major aspects of the field and is a perfect introduction into the plethora of relevant issues involved. I highly recommend it to all researchers in science.

Vlatko Vedral is Professor of Quantum Information Science, University of Oxford, and Professor of Physics, National University of Singapore. His research is in quantum physics, with applications to information theory and biology.

BOOKS RECEIVED

The Amazing Story of Quantum Mechanics: A Math-Free Exploration of the Science that Made Our World. James Kakalios. 333 pp. Gotham Books, New York, 2010. Price: $26.00 (hardcover) ISBN 978-1-592-40479-7.

Atlas of Science: Visualizing What We Know. Katy Börner. 265 pp. The MIT Press, Cambridge, MA, 2010. Price: $29.95 (hardcover) ISBN 978-0-262-01445-8.

Complex Variables for Scientists and Engineers: An Introduction. Richard E. Norton. 464 pp. Oxford U. P., New York, 2010. Price: $52.95 (paper) ISBN 978-0-19-850983-7.

The Dark Matter Problem: A Historical Perspective. Robert H. Sanders. 213 pp. Cambridge U. P., New York, 2010. Price: $60.00 (hardcover) ISBN 978-0-521-11301-4.

Extreme Environment Astrophysics. Ulrich Kolb. 287 pp. Cambridge U. P., New York, 2010. Price: $60.00 (paper) ISBN 978-0-521-18785-5.

The 4% Universe: Dark Matter, Dark Energy and the Race to Discover the Rest of Reality. Richard Panek. 292 pp. Houghton Mifflin Harcourt, New York, 2010. Price: $26.00 (paper) ISBN 978-0-618-98244-8.

From Cosmos to Cosmos: The Science of Unpredictability. Peter Coles. 220 pp. Oxford U. P., New York, 2010. Price: $26.95 (paper) ISBN 978-0-19-958814-5.

Galaxy Formation and Evolution. Houjun Mo, Frank van den Bosch, and Simon White. 836 pp. Cambridge U. P., New York, 2010. Price: $85.00 (hardcover) ISBN 978-0-521-85793-2.

Head Shot: The Science Behind the JFK Assassination. G. Paul Chambers. 260 pp. Prometheus Books, Amherst, NY, 2010. Price: $26.00 (hardcover) ISBN 978-1-61614-209-4.

Heliophysics: Space Storms and Radiation: Causes and Effects. Carolus J. Schrijver and George L. Siscoe (editors). 456 pp. Cambridge U. P., New York, 2010. Price: $75.00 (hardcover) ISBN 978-0-521-76051-5.

Introduction to Statistical Field Theory. Edouard Brézin. 176 pp. Cambridge U. P., New York, 2010. Price: $69.00 (hardcover) ISBN 978-0-521-19303-0.

Judging Edward Teller: A Closer Look at One of the Most Influential Scientists of the Twentieth Century. Istvan Hargittai. 575 pp. Prometheus Books, Amherst, NY, 2010. Price: $32.00 (hardcover) ISBN 978-1-61614-221-6.

Laser Physics. Simon Hooker and Colin Webb. 601 pp. Oxford U. P., New York, 2010. Price: $79.95 (paper) ISBN 978-0-19-850692-8.

Neutron Physics for Nuclear Reactions: Unpublished Writings by Enrico Fermi. S. Esposito and O. Pisanti (editors). 700 pp. World Scientific, Hackensack, NJ, 2010. Price: $144.00 (hardcover) ISBN 978-981-4291-22-4.

Path Integrals in Quantum Mechanics. Jean Zinn-Justin. 333 pp. Oxford U. P., New York, 2010. Price: $54.95 (paper) ISBN 978-0-19-856675-5.

Physics Over Easy: Breakfasts with Beth and Physics (2nd Edition). Leonid V. Azároff. 300 pp. World Scientific, Hackensack, NJ, 2010. Price: $24.00 (paper) ISBN 978-981-4295-45-1.

Polymers in Solution: Their Modeling and Structure. Jacques des Cloizeaux and Gerard Jannink. 925 pp. Oxford U. P., New York, 2010. Price: $89.95 (paper) ISBN 978-0-19-958893-0.

Relativity, Gravitation, and Cosmology. Robert J. A. Lambourne. 312 pp. Cambridge U. P., New York, 2010. Price: $60.00 (paper) ISBN 978-0-521-13138-4.

Semiconducting and Metallic Polymers. Alan Heeger, Niyazi Serdar Sariciftci, and Ebinazar Namdas. 287 pp. Oxford U. P., New York, 2010. Price: $79.95 (hardcover) ISBN 978-0-19-852864-7.

Surface Diffusion: Metals, Metal Atoms, and Clusters. Grazyna Antczak and Gert Ehrlich. 778 pp. Cambridge U. P., New York, 2010. Price: $150.00 (hardcover) ISBN 978-0-521-89983-3.

Transition Metal Oxides: An Introduction to their Electronic Structure and Properties. P. A. Cox. 293 pp. Oxford U. P., New York, 2010. Price: $49.95 (paper) ISBN 978-0-19-958894-7.

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