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# Book Review: A Love of Discovery: Science Education—The Second Career of Robert Karplus.

Robert Fuller
rfuller@neb.rr.com

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# BOOK REVIEWS

Daniel V. Schroeder, *Editor*
*Department of Physics, Weber State University, Ogden, Utah 84408; dschroeder@weber.edu*

**The Cosmic Landscape: String Theory and the Illusion of Intelligent Design.** Leonard Susskind. 403 pp. Little, Brown, New York, 2006. $24.95 (cloth) ISBN 0-316-15579-9; $15.99 (paper) ISBN 0-316-01333-1. (Michael Dine, Reviewer.)

For more than 20 years, string—or superstring—theory has been heralded as the path to a unified theory of all interactions, including gravity. The subject has occupied the attention of a large fraction of the theoretical high energy physics community. By its nature, it is an ambitious program, and while it has had some impressive successes, there are, as yet, many puzzles to be resolved if string theory is to be shown to be the theory of the world around us.

The two largest puzzles have been around from the beginning. First, the theory seems to describe not just universes like our own, but many, many others: universes with more than three spatial dimensions (at least as many as ten), with varying numbers of particles and fields, and with different interaction strengths. The second puzzle is related to Einstein's famed cosmological constant, $\Lambda$. From a modern perspective, this is the energy density of the ground state of the universe. Simple dimensional analysis suggests that this energy density should be quite large. In the early days of string theory, cosmological data were consistent with $\Lambda=0$, so it was believed that eventually some principle would be found that would explain why the vacuum energy must vanish. But $\Lambda$ is now known to be nonzero. It is the largest component of the energy of the universe, though it is still many, many orders of magnitude smaller than our current ideas in quantum mechanics and relativity suggest.

Recently, however, theoretical developments have suggested a possible, and simultaneous, solution to both of these problems. The number of possible states of string theory might be enormous—so many that some have, by blind luck, the features of physics we see about us. Ideas in modern inflationary cosmology indicate that in this sort of circumstance, the universe, over its history, may sample all of these different states. Steven Weinberg, the Nobel Prize winner and physicist probably most responsible for the standard model, suggested about 20 years ago that in such a circumstance, only in those regions with suitable environments does anything resembling intelligent life evolve. Most strikingly, assuming the validity of such a picture, he predicted roughly the correct value of the cosmological constant *before its observation*. These developments have created excitement, but also a certain angst. While books like Brian Greene's *Elegant Universe* have given string theory a certain mystique with the general public, at least four recent works attack string theory and string theorists, arguing that these developments are leading physicists down dangerous pathways and closing out viable alternatives. The authors all express concern that these ideas are moving theoretical physics further and further from contact with experiment.

Leonard Susskind, the Felix Bloch Professor of Physics at Stanford University, is a distinguished figure in theoretical high energy physics. Among his many accomplishments, he was a leader in the development of our current understanding of the strong interactions, quantum chromodynamics. In addition to his contributions to the development of the experimentally triumphant standard model, he has contributed some of the key ideas about possible physics beyond the standard model. Many of these are the subject of intense experimental investigation at high energy accelerators. Susskind was one of the inventors of string theory and is one of its leading practitioners and advocates. Susskind is also an award-winning author of popular science articles. In *The Cosmic Landscape: String Theory and the Illusion of Intelligent Design*, Susskind presents these recent developments as representing nothing short of a scientific revolution, a basic paradigm shift in our expectation of how the observed laws of nature emerge from some more microscopic theoretical foundation. The strength of his views is clear already in his introductory chapter, where he says that his book "is about: the scientific explanation of the apparent miracles of physics and cosmology and its philosophical implications." With this, he lays down the gauntlet, not only for his more skeptical colleagues, but for the advocates of "intelligent design" to whom he alludes in his subtitle.

To lay the groundwork, in his first chapter Susskind provides a brief and very accessible overview of particle physics. (Readers looking for a meatier introduction might read the first few chapters of Lisa Randall's *Warped Passages*.) He then quickly turns to his real subject, explaining why it is so shocking that the observed cosmological constant is so small, and what it would mean to live in a vast universe (*megaverse*) where the laws of nature would differ as one traversed cosmological distances. He presents Weinberg's argument that only in a tiny fraction of this universe would circumstances be right to find structures like galaxies, presumably necessary for the development of intelligent observers. Susskind understands quite well why this use of the anthropic principle (what Weinberg called the "weak anthropic principle") causes unhappiness for many physicists; he describes the vision of many theorists for alternative approaches, but argues, very plausibly, that this vision is unlikely to be realized.

*The Cosmic Landscape* will be quite an interesting book for a lay reader. Susskind teaches a little physics and exposes the reader to some of the controversies of contemporary physics; his conversational style and anecdotes about his own life and other scientists are entertaining. But I think this book will have the greatest value for someone with even a modest physics education, for whom it will provide an accessible introduction to many topics at the forefront of modern theoretical physics. The treatments of black holes and the problem of information loss, and of the quantum aspects of

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modern cosmology, benefit both from Susskind's insights and his ability to explain and simplify challenging conceptual problems. (For lay readers, the flip side of this is that some of the later chapters will be daunting; I would urge such readers to take on the first 200 pages or so and the final chapter, and attempt the rest only if they still have the energy.) I have to say, though, that the people I really hope will read this book are the "experts," including many of my own colleagues in particle physics and cosmology. This includes many in the string theory community who I believe are not confronting some of the important questions the field faces, and it includes the authors of the recent critiques, who do not seem to understand what is driving these developments. The issues, and their significance and urgency, are laid out here in a clear, honest, and thoughtful manner.

Finally, I should give away my own hand. I agree with Susskind that the facts as we currently know them seem to call out for a solution of this kind, and in my own research I have been vigorously exploring these issues for some time. I don't quite share Susskind's joy in this story, though. Perhaps, after some time, this will be remembered as one of those false steps in science or, alternatively, I will be seen like that older generation of another era who had to be dragged kicking and screaming into the quantum age. For all my fascination with these topics, the comment of Gerard 't Hooft, one of the giants of theoretical physics (quoted by Susskind), gives me pause: "I think it is far too early to make such speculations."

*Michael Dine is Professor of Physics at the University of California, Santa Cruz. His research in theoretical physics focuses on problems in physics beyond the standard model, cosmology, and string theory.*

**A Love of Discovery: Science Education—The Second Career of Robert Karplus.** Robert G. Fuller. 344 pp. Kluwer Academic/Plenum, New York, 2002. Price: $72.95 (paper) ISBN 0-306-46687-2. (Juan R. Burciaga, Reviewer.)

Robert Fuller has set out to collect in a single volume the most important works by Robert Karplus on science education. But rather than simply present the articles and writings in chronological order, the editor has grouped the papers in eight chapters, and each chapter begins with an essay written by someone who worked with Karplus. Most of these eight essays add depth and complexity to the papers and, for some, may be as valuable as the reprints.

Robert Karplus received his Ph.D. from Harvard in 1948 at the age of 21 and became a full professor at UC Berkeley just ten years later. His work as a theoretical physicist helped establish the then-new field of quantum electrodynamics, and he was frequently referred to as one of the leading theorists of his day. But in the early 1960s he turned his attention to science education—particularly to the question of how children learn to reason about science.

The 27 articles and papers reprinted in *A Love of Discovery* trace the contributions and insights of Robert Karplus from 1962 to 1981. This sweep of work describes the establishment of one of the first NSF-funded educational reform projects (the Science Curriculum Improvement Study, SCIS), the development of a model for disciplined and effective curricular change, the exploration and adoption of reasoning paradigms to explain and test how children learn science, and the growth of a community of scholars and educators bound by a common purpose and inspired by an unusually gifted physicist/educator. The book provides a glimpse of a second career that led one of the leading theorists of the 1950s to devote his time to working with children, become the president of AAPT (1977), and be awarded the Oersted medal in 1981.

Chapter 2, "A Love of Discovery," is an excellent example of the promise of this collection. The introductory essay by Rita Peterson of UC Irvine not only provides insight into the character of Robert Karplus, but also gives a genuine feeling for how an idea for curricular innovation was initiated, discussed, tested, and evaluated. The only reprint in this chapter is a review by Karplus of the SCIS, which describes the structure of the program. This is a superbly written paper that presents the reasoning behind the strategy guiding the choice of personnel, how curricular innovations were selected and tested, how a pedagogical framework was developed, and how the new lessons were disseminated. This chapter offers much to any faculty member who has decided to start working in curricular development.

At the beginning of Chap. 4, Anton Lawson, a biologist and biology educator at the University of Arizona, gives a very nice introduction to the learning cycle paradigm and how it is viewed today. But the three articles of Karplus reprinted in this chapter give much more of a hands-on approach to using the learning cycle in the classroom. This is not surprising, since one of these reprints is from the teacher's handbook developed for the SCIS materials.

In some ways the heart of the book is Chap. 6, "Central Role of Students' Reasoning." However, even after reading the well-written introduction by Helen Adi Khoury (Northern Illinois University), college faculty unfamiliar with education papers may find the ten papers by Karplus in this section somewhat technical. But faculty beginning to work with teachers in the elementary grades will find these papers revealing.

The chapters that most resonated with me were Chap. 5, "Student Autonomy and Teacher Input," and Chap. 7, "Teaching and the Conceptual Structure of Physics." Here Karplus seems to be speaking directly to the physics community on the promise, and the challenges, of teaching physics effectively when the students are brought into focus. The four reprints by Karplus in Chap. 7 include the sparse, historical 1976 *AJP* article written with Arnold Arons on "Implications of Accumulating Data on Levels of Intellectual Development," and the elegant, comprehensive "Can Physics Develop Reasoning?" written with Robert Fuller and Anton Lawson for *Physics Today* (1977).

The reprints in Chap. 5 are his 1981 Oersted address, "Autonomy and Input," and "Discovery or Invention," a 1962 article from *The Science Teacher* written with J. M. Atkin. These two articles contain a strong appeal for a hands-on/minds-on learning environment that sounds very contemporary.

A caveat is needed here. Robert Karplus was heavily influenced by the work of Jean Piaget. ("Piaget in a Nutshell, Workshop on Physics Teaching and the Development of Reasoning," which is based on an AAPT workshop, is reprinted in Chap. 8.) But today the ideas of Piaget are no longer considered comprehensive. And though we can still view

these models as a good first-order understanding of developmental reasoning, faculty wanting to work seriously in educational development will need to go beyond these paradigms.

After eight lively chapters containing reprints, the last three chapters that simply chronicle the first career of Robert Karplus as a theoretical physicist and his migration to his work in curricular innovation and pedagogical development seem oddly flat. But that is perhaps not a serious flaw since the focus of the book is the achievements of Karplus and his co-workers in the field of science education.

Robert Fuller has done a fine job of collecting and preserving the important papers of Robert Karplus in the field of science education. But, more importantly, he has presented them in a way that shows how the love of discovery, the pleasure of figuring things out, and the expectation of rigorous testing and proof that drove so many of us to physics are also found in educational research and curricular development.

*Juan R. Burciaga is a Visiting Assistant Professor at Whitman College. He has worked on the Committee for Physics in Undergraduate Education (either as a committee member or as a Friend of the Committee) for the last 10 years and he has been involved with teacher training for over 15 years. In addition, Dr. Burciaga is an Education Officer for the National Society of Hispanic Physicists and was recently appointed Book Editor for the AAPT.*

## BOOKS RECEIVED

**21st Century Astronomy** (second edition). Jeff Hester *et al.* 725 pp. Norton, New York, 2007. Price: $72.00 (paper) ISBN 978-0-393-92443-5.

**Brainteaser Physics: Challenging Physics Puzzlers.** Göran Grimvall. 162 pp. Johns Hopkins U. P., Baltimore, 2007. Price: $65.00 (cloth) ISBN 978-0-8018-8511-2; $23.00 (paper) ISBN 978-0-8018-8512-9.

**Conceptions of Cosmos: From Myths to the Accelerating Universe: A History of Cosmology.** Helge S. Kragh. 276 pp. Oxford U. P., New York, 2007. Price: $70.00 ISBN 978-0-19-920916-3.

**Controlled Fusion and Plasma Physics.** K. Miyamoto. 393 pp. Taylor & Francis, New York, 2007. Price: $79.95 ISBN 978-1-58488-709-6.

**Electronics: Circuits, Amplifiers and Gates** (second edition). D. V. Bugg. 352 pp. Taylor & Francis, New York, 2006. Price: $69.95 (paper) ISBN 978-0-7503-1037-6.

**Fundamentals of Fibre Reinforced Composite Materials.** A. R. Bunsell and J. Renard. 398 pp. Institute of Physics Publishing, Philadelphia, 2005. Price: $59.95 (paper) ISBN 978-0-7503-0689-8.

**Fundamentals of Quantum Mechanics.** Şakir Erkoç. 433 pp. Taylor & Francis, New York, 2007. Price: $89.95 ISBN 1-58488-732-X.

**Geometric Algebra and Applications to Physics.** Venzo de Sabbata and Bidyut Kumar Datta. 168 pp. Taylor & Francis, New York, 2007. Price: $89.95 ISBN 978-1-58488-772-0.

**God: The Failed Hypothesis: How Science Shows That God Does Not Exist.** Victor J. Stegner. 294 pp. Prometheus Books, Amherst, NY, 2007. Price: $28.00 ISBN 978-1-59102-481-1.

**Graduate Mathematical Physics: With Mathematica Supplements.** James J. Kelly. 466 pp. (plus CD-ROM). Wiley, Hoboken, NJ, 2007. Price: $75.00 (paper) ISBN 978-3-527-40637-1.

**Gravitation and Cogravitation: Developing Newton's Theory of Gravitation to its Physical and Mathematical Conclusion.** Oleg D. Jefimenko. 367 pp. Electret Scientific Company, Star City, WV, 2006. Price: $32.00 (cloth) ISBN 0-917406-00-1; $22.00 (paper) ISBN 0-917406-15-X.

**Horizons: Exploring the Universe** (tenth edition). Michael Seeds. 516 pp. Thomson, Belmont, CA, 2006. Price: $107.95 (paper) ISBN 978-0-495-11358-4.

**An Imaginary Tale: The Story of i** (paperback edition). Paul J. Nahin. 269 pp. Princeton U. P., Princeton, NJ, 2007. Price: $16.95 (paper) ISBN 978-0-691-12798-9.

**Into the Cool: Energy Flow, Thermodynamics, and Life** (paperback edition). Eric D. Schneider and Dorion Sagan. 362 pp. U. of Chicago Press, Chicago, 2006. Price: $22.50 (paper) ISBN 978-0-226-73937-3.

**Introduction to Quantum Mechanics: A Time-Dependent Perspective.** David J. Tannor. 662 pp. University Science Books, Sausalito, CA, 2007. Price: $84.50 ISBN 978-1-891389-23-8.

**An Introduction to the Passage of Energetic Particles through Matter.** N. J. Carron. 362 pp. (plus CD-ROM). Taylor & Francis, New York, 2007. Price: $209.95 ISBN 978-0-7503-0935-6.

**Mathematics for Physics.** Michael M. Woolfson and Malcolm S. Woolfson. 783 pp. Oxford U. P., New York, 2007. Price: $54.95 (paper) ISBN 978-0-19-928929-5.

**Modeling Fluctuations in Scattered Waves.** E. Jakeman and K. D. Ridley. 313 pp. Taylor & Francis, New York, 2006. Price: $119.95 ISBN 978-0-7503-1005-5.

**Molecular Aggregation: Structure Analysis and Molecular Simulation of Crystals and Liquids.** Angelo Gavezzotti. 425 pp. Oxford U. P., New York, 2007. Price: $130.00 ISBN 978-0-19-857080-6.

**The New Cosmic Onion: Quarks and the Nature of the Universe.** Frank Close. 219 pp. Taylor & Francis, New York, 2007. Price: $39.95 (paper) ISBN 978-1-58488-798-0.

**Numerical Methods in Astrophysics: An Introduction.** Peter Bodenheimer *et al.* 329 pp. (plus CD-ROM). Taylor & Francis, New York, 2007. Price: $79.95 ISBN 0-7503-0883-4.

**Physics of Space Plasma Activity.** Karl Schindler. 508 pp. Cambridge U. P., New York, 2006. Price: $80.00 ISBN 978-0-521-85897-7.

**Physics of Strongly Coupled Plasma.** Vladimir Fortov, Igor Lakubov, and Alexey Khrapak. 520 pp. Oxford U. P., New York, 2006. Price: $130.00 ISBN 978-0-19-929980-5.

**Protecting Information: From Classical Error Correction to Quantum Cryptography.** Susan Loepp and William K. Wootters. 287 pp. Cambridge U. P., New York, 2006. Price: $80.00 (cloth) ISBN 978-0-521-82740-9; $29.99 (paper) ISBN 978-0-521-53476-5.

**The Standard Model: A Primer.** Cliff Burgess and Guy Moore. 542 pp. Cambridge U. P., New York, 2007. Price: $75.00 ISBN 978-0-521-86036-9.

**Statistical Mechanics: From First Principles to Macroscopic Phenomena.** J. Woods Halley. 283 pp. Cambridge U. P., New York, 2007. Price: $65.00 ISBN 978-0-521-82575-7.

**Supersymmetry: Theory, Experiment, and Cosmology.** Pierre Binétruy. 520 pp. Oxford U. P., New York, 2006. Price: $100.00 ISBN 978-0-19-850954-7.

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