

The Universe in a Nutshell

Stephen Hawking
Bantam Books, New York, 2001.
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Thirteen years ago, Stephen Hawking turned the publishing world on its head with *A Brief History of Time*. Written in part to help pay for his round-the-clock nursing care, the book sold more than 10 million copies and has been translated into 35 languages. Despite its phenomenal success, *A Brief History of Time* is an uncompromising book, filled with difficult concepts, uninterrupted by diagrams or pictures, and probably bought by more aunts and uncles (and unread by more nephews and nieces) than any other book in history. Hawking himself has acknowledged that many people probably did not finish or understand it.

Beyond his reputation as a theoretical physicist, Hawking has a second component to his success. *A Brief History of Time* marked his elevation into the public consciousness as an icon of science. Heir to Newton and Einstein, and afflicted by a degenerative disease, Hawking represents the struggle of a brilliant mind trapped in a wasting body. His personal tragedy sharpens the metaphor of science in which humans transcend their ephemeral status by trying to comprehend a vast and ancient universe.

The Universe in a Nutshell is Hawking's latest vehicle for making the complexities of gravity theory accessible to a wide audience. As with the earlier book, *Nutshell* is very ambitious, seeking to acquaint the reader with modern (and highly mathematical) theories on the fundamental nature of matter. Along the way, Hawking includes asides on concepts ranging from holography to nuclear binding energy to the Casimir effect. The ambition of the ideas is balanced by his genuine modesty; he refers to his own "small contributions" to our ideas of time and space. The book is laced with his puckish humor, demonstrated, for example, in his regret that the Lucasian chair of mathematics is not motorized. Hawking is an accomplished and artful popularizer of science. He never writes down to his audience, and he is infectious in his enthusiasm. Thinking deeply about spacetime is fun!

Nutshell begins with a concise summary of relativity (Hawking gets more than 100 letters a year telling

him that Einstein was wrong). The second chapter introduces the concept of spacetime and gives a brief history of the search for a fundamental theory of matter, culminating in a description of the speculative M-theory. The notion that particles can be described by branes, and that our flat spacetime may embed extra dimensions, is a major theme of the book. Subsequent chapters branch off from this core material, dealing with the nature of black holes, inflationary cosmology, and even the future evolution of life on Earth.

How well does *Nutshell* succeed in conveying these complex ideas to a general audience? For the most part, Hawking's exposition is masterful. The description of the properties of black holes is wonderfully clear. He even does a good job of conveying imaginary time, although he misses the chance to use antimatter as an example of a real physical entity that is conveyed by a formalism that uses imaginary numbers. There are a few weak areas, most notably the incorporation of the Doppler effect in the cosmology chapter; the recession of galaxies would more accurately be described as due to the expanding spacetime manifold. However, Hawking aims high and he successfully puts flesh on abstract ideas. The art-generation program worked magnificently, and the well-designed illustrations are an important strength of *Nutshell*. Most readers will stay the course.

Hawking admits that many of the ideas in the book are highly speculative. In fact, he revels in his role as a provocateur, recollecting with relish the time when he and Kip Thorne pursued the "politically incorrect" idea of time travel. On the subject of M-theory, Hawking acknowledges that extra dimensions are not required to explain any observation. Like other theorists, he is guided by the elegance of the mathematics and by "dualities" indicating that we may already have the fragments of a final theory that will unify gravity and quantum physics.

Hawking's book is exciting and provocative, and it poses a fundamental question: Is nature baroque or parsimonious? In the democracy of branes, all dimensions are created equal. From the quantum state of the Big Bang, a cornucopia of universes might emerge. Hawking wields the anthropic principle like Occam's razor to slice through these possibilities. He imagines that life can exist only in a universe with three spatial dimensions, and that an inflated and nearly smooth universe is needed for ob-

servers to evolve. In his words, "the anthropic principle picks out brane models from the vast zoo of universes allowed by M-theory." In epistemological circles, the anthropic principle is suspect due to its lack of predictive power and its tendency toward tautology. In the freewheeling world of Stephen Hawking, it is just one more device to tease and engage the reader.

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Megawatts and Megatons: A Turning Point in the Nuclear Age?

Richard L. Garwin
and Georges Charpak
Alfred A. Knopf, New York, 2001.
\$30.00 (412 pp.).
ISBN 0-375-40394-9

If you wanted to offer a class on nuclear weapons and nuclear reactors, why not get a brilliant American theorist, who designed nuclear weapons, and a Nobel-prize-winning French experimentalist to present the material. That is Richard L. Garwin and Georges Charpak's *Megawatts and Megatons*.

Garwin, the American, and Charpak, the Frenchman, provide an excellent primer on nuclear fission and the advantages and disadvantages of nuclear power. Radioactivity is described from the Curies to Fermi. All current types of reactors are covered, including light water, heavy water, high-temperature gas, and breeders. The authors are not enamored of the breeder. Charpak provides insights into the French breeder program and the authors note that, if effort is devoted to developing extraction of uranium from seawater, the breeder's main advantage (to compensate for a shortage in uranium) may not be economic for centuries.

Both the once-through (direct disposal of spent nuclear fuel) and the closed fuel cycle (involving reprocessing) are described, along with the front-end enrichment process. The authors discuss the US and French nuclear programs, often seen as the world's most successful. They describe the accidents at Three Mile Island, Chernobyl, and Tokaimura, and the unresolved problem of permanent disposal of high level nuclear waste, which they see as a major obstacle to continuation of nuclear power.

The authors address energy issues: global warming and the potential ben-

efit of nuclear power; the relative radioactivity risks of coal and nuclear (coal is about equal to nuclear over 10 000 years and higher for the first 500 years); cogeneration of electricity and energy efficiency (they are in favor); forecasts for 2050 and beyond (they advise “a certain humility”); and the California electricity crisis of 2000–2001. They are critical of error and exaggeration by both proponents and opponents of nuclear power. While the authors seem to favor nuclear power (in my opinion), their emphasis on objective analysis provides the necessary data for readers to make their own calculations about the relative risks of nuclear and coal power plants.

Both authors are familiar with nuclear weapons, and Garwin has worked on and advised on them since the Manhattan Project. The authors present the basics of a nuclear weapon and stress the critical importance of the choice of the fissionable material. They discuss the need to restrict access to plutonium that is separated during reprocessing of spent reactor fuel, since such plutonium can be used to make an adequate nuclear weapon. The authors cover an increasingly important issue: how to dispose of the large amounts of weapons-grade plutonium becoming available from the START treaties’ reduction in nuclear weapons.

Readers interested in understanding the current debates about mixed oxide (MOX) fuel and the Rubbia energy amplifier will find those topics well covered. Since the current US administration has decided to continue supporting programs to safeguard and dispose of Russian weapons material, *Megawatts and Megatons* provides the necessary background to understand the issues involved. (Many in the government could use this book.)

Other topics covered include the subtleties of nuclear strategy; the nuclear arms race (“mutual assured destruction,” “sufficiency”), arms control debates, the Strategic Defense Initiative (also known as Star Wars); the Comprehensive Nuclear Test Ban Treaty, and the authors’ recommendations on significant reductions in nuclear arms.

Both Garwin and Charpak have been advisers at the highest levels of their governments and bring to this book the insights gained from decades of such service. They support the use of experts as advisers—if independent (both financially and ideologically) and competent—but for providing advice, not making decisions.

The authors’ goal is to develop the level of understanding required to

make reasoned judgments about nuclear power and nuclear weapons. While some books listed by the authors as further reading have more details on some of the subjects covered here, I know of no one book that provides the breadth and depth that this one does on both nuclear power and nuclear weapons. *Megawatts and Megatons* is a valuable text for anyone interested in becoming informed on two crucial technology areas.

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Things a Computer Scientist Rarely Talks About

Donald E. Knuth
CSLI Publications, Stanford,
Calif., 2001. \$35.00 (257 pp.).
ISBN 1-57586-327-8

Many physicists know Donald Knuth as the creator of TeX, which has revolutionized the way we communicate scientific results. Some will know that he is a distinguished computer scientist, one of the giants of the field. But few will know that he is also a devout Lutheran, who has thought deeply about how his academic discipline informs his religious beliefs.

Very few highly regarded scientists are religious, in the sense of believing in a personal God, even though surveys show that close to 90% of the US population believes in God. In a random sample of scientists, roughly 40% say they believe, a percentage that has remained unchanged for over 80 years. But only 7% of members of the National Academy of Sciences profess such a belief. (See E.J. Larson and L. Witham, *Nature* **394**, 313 [1998]). While a number of conclusions might be drawn from these figures, the relevant one in this case is that Knuth is not typical of scientists as eminent as he is.

In 1999, Knuth gave a series of six lectures at MIT as part of the “God and Computers” project. *Things a Computer Scientist Rarely Talks About* is a written version of those lectures and includes the questions and answers that followed each lecture. Knuth’s tone throughout is modest. He does not claim to have “. . . solutions to problems that have challenged and baffled the best human minds for thousands of years.” Rather, he describes various projects and analyses he has carried out to expand his religious understanding, projects only a computer scientist would

undertake. For example, to deepen his understanding of the Bible, Knuth employed statistical sampling. Rather than start at Genesis and see how far he could get, he analyzed in depth chapter 3, verse 16 of each book of the Bible. This allowed him to get a pretty good idea of the Bible’s scope without a lifetime of study. From Knuth’s book, you can learn how to make your own translation of the Bible even if you don’t know any Hebrew or Greek. You probably won’t have the clout to commission world-famous calligraphers to prepare beautiful renditions of each of your verse translations, as he did, but you can read about that project here too. (Aesthetics has played an important role in Knuth’s work, especially his work on typesetting. Unfortunately, however, the small black-and-white images of the calligraphy in this book are rather disappointing.)

The most engaging parts of the book are the fascinating tidbits you encounter along the way. Here are some examples:

▷ The reason Knuth is listed in the *Guinness Book of World Records*.

▷ Why Knuth thinks users of the Emacs editor have more free will than users of Microsoft Word.

▷ The proposal to Knuth by computer scientist Edsger Dijkstra that the SLAC accelerator should run for only an hour at a time; it should then be shut down so one could think about the results for a year before restarting the machine.

▷ The appropriate scorn Knuth heaps on people who claim to have found hidden messages in the numerology of biblical texts. He points out that applying similar techniques to the license agreement for the Microsoft Access Developers Tool Kit has yielded equally dramatic prophecies.

▷ Knuth’s years of frustration at reading popular accounts of quantum mechanics, after which all became clear when he read P. A. M. Dirac and discovered that, “Apparently, when physicists talk to physicists, they talk about linear transformations of generalized Hilbert spaces over the complex numbers.”

Knuth has an interesting take on the question of whether God is finite or infinite. Knuth is perfectly happy with a finite God. Being finite isn’t much of a limitation, given an appreciation of the immense size of finite numbers, such as Super K, that Knuth discusses.

Despite many enjoyable passages, the book ultimately disappoints. While I can imagine that the lectures might have been wonderful to listen