At the war's end, von Braun persuaded his Peenemünde group to surrender to the US Army. Only in America, he told his colleagues, could they pursue their dream of space travel. Such adaptability allowed von Braun to also change his rocket and space-station designs for almost anyone who asked—*Collier's* magazine, Disney, or the US government—take up new hobbies and change domiciles and his church affiliation as he pleased. That adaptability also kept him, his team, and their dreams alive. By 1960 he was in charge of NASA's Marshall Space Flight Center, the administration's largest facility, with nearly 7000 civil-service and contract employees. The center produced the Saturn rocket series, which in its 12 years had no catastrophic failures in flight and boosted every Apollo capsule and the *Skylab* space station.

Neufeld adeptly incorporates engineering detail, describes at greater length than other biographers his protagonist's complex relationship with the media, and adds to the understanding of cutthroat, interservice rivalries of the armed forces in the US and in Germany. I would request, though, that the book have charts showing the evolution of German and US hardware, the branches of the military or divisions of NASA and the programs they worked on and when, and the rockets that flew and flopped.

The number and quality of sources well support Neufeld's assertions about von Braun's actions, motivations, and character, and set the standard for historians of the Nazi period. Thorough evaluation of von Braun as a complex, Faustian figure has been heretofore stymied by sanitized memoirs and biographies written by von Braun himself, friendly journalists, and coworkers. Some authors seem to believe that finding a few documents through the Freedom of Information Act constitutes responsible research that provides a solid basis for making moral accusations. It does not. What does is scholarship through the long haul: patiently seeking out obscure primary sources, sifting through gossip and legend, consulting original-language documents, deciphering technology and tedious detail, and challenging loyal family and friends for full disclosure. The result of such research is present in *Von Braun*. Neufeld's biography is a must-read for scholars, students, and anyone interested in aerospace history, Nazi Germany, and the mind, morals, and motivations of the scientist and engineer.

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Fundamental Forces of Nature

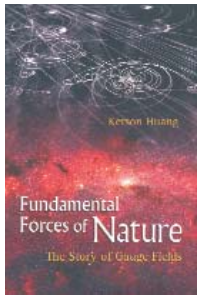
The Story of Gauge Fields

Kerson Huang
World Scientific, Hackensack, NJ, 2007. $54.00, $30.00 paper (270 pp.). ISBN 978-981-270-644-7, ISBN 978-981-270-645-4 paper

Sometimes physicists, in the twilight of their careers, undertake a coherent account of what they have learned about nature at its most fundamental level. The occasional one will even publish the result of the exercise. An example of such a summation is the late Sam Treiman's *The Odd Quantum* (Princeton University Press, 1999); Kerson Huang's *Fundamental Forces of Nature: The Story of Gauge Fields* is another. Treiman found his most profound insight in the concept of quantum field theory; Huang zeroes in more narrowly on gauge fields. Both books should be read in the way one listens to the reminiscences of one's grandparents: patiently, indulgently, and respectfully. The value of Treiman's and Huang's books lies not in their details but in their perspective and wisdom.

Huang is a professor emeritus of physics at MIT and has taught theoretical physics there for half a century. His contributions have been chiefly in the areas of many-body theory and high-energy physics. He has written several graduate-level textbooks, and I have personally enjoyed teaching from his classic *Statistical Mechanics* (Wiley, 1965). *Fundamental Forces of Nature* is his first venture into what he calls "semipopular exposition." But more about that later.

In the preface, Huang describes his aim: "The story of gauge fields is the story of our quest for the fundamental law of the physical world." His work is not a textbook, a history book, or a technical monograph; it is a narrative, with lots of equations and figures, about the evolution of a central component of modern physics. Huang's use of the word "law" in the singular suggests that he hopes to understand the world once and for all, to find a world-formula, as it were. A couple of paragraphs later, also in the preface, he writes, "Theoretical physics has given us a *true* understanding of the physical world" (his italics). In support of this bold assertion he cites the one-part-in-a-trillion accuracy of quantum electrodynamics. I hear an echo of Albert Michelson's premature claim in 1894 that the most important fundamental principles of physics have all been discovered.



Huang's story starts with $F = ma$ and ends with the standard model of particle physics. The major intermediate steps are sketched in lapidary style—with the exception of general relativity, which motivated the original, unsuccessful gauge theory of Hermann Weyl. Maxwell's, Schrödinger's, and Dirac's equations; Pauli matrices; commutation relations; electromagnetic field tensors; $SU(3)$ generators; and Feynman's path integral are displayed in full splendor. But to try to get at the real meaning of gauge theory, Huang reaches for a visual analogy. In the past, others have invoked, with varying levels of success, imaginary stopwatches, rolling ping-pong balls, and color exchanges among quarks to explain the concept. Huang, inspired by the name of the mathematical theory of fiber bundles, pictures gauge fields as beads sliding along fibers anchored at spacetime points. Eventually each fiber picks up a ring around its foot, and finally a miniature gyroscope. The resulting picture is clumsy, but better analogies are very hard to come by.

The difficult story is further fleshed out by anecdotes and lots of images, including thumbnail photographs of most of the physicists mentioned. The pictures, together with Huang's relaxed style, lend a very appealing texture to the book, a little like a family album or a personal diary. God, Napoleon Bonaparte, and the ancient Chinese poet Qu Yuan make discreet cameo appearances. There is also a physics poem, *The Waste Lecture*, attributed to T. S. Eliot and first published in John Lowell's "Mr. Eliot's Guide to Quantum Theory," on page 46 of the April 1989 issue of PHYSICS TODAY. The unsuspecting reader might be misled into believing in its authenticity by Huang's failure to flag it for what it is: an April Fools' joke.

Who should read Huang's book? Huang contends that mathematics cannot be avoided in any discussion of physics, but that this does not mean one "has to understand the equations. One could get the flavor of what is being discussed without the equations, just as one could enjoy a foreign movie without the subtitles." I disagree. A reader with no knowledge of physics would no more understand this book than I would enjoy a movie in Chinese. However, people with some physics background, including readers of

PHYSICS TODAY, understand what the equations are supposed to achieve, even if their explicit terms become increasingly arcane as the story unfolds. To such an audience, the book delivers what it implicitly promises: an instructive and thoughtful tour of 20th-century physics, with special emphasis on the theory of the fundamental constituents of matter and the forces among them, led by a friendly guide who knows the territory and its inhabitants from personal experience.

Unfortunately, the book has many typos and other slips, such as a statement of the right-hand rule that has no mention of the thumb and has a botched drawing of the magnetic field around a current-carrying coil. Perhaps the silliest mistake is the graph of Murray Gell-Mann's famous decuplet (incorrectly called "decaplet") featuring five charge states instead of four for the delta resonance (page 159). Both Huang and his readers deserve more careful editing.

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The Atomic Bazaar

The Rise of the Nuclear Poor

William Langewiesche
Farrar, Straus and Giroux, New York, 2007. $22.00 (179 pp.). ISBN 978-0-374-10678-2

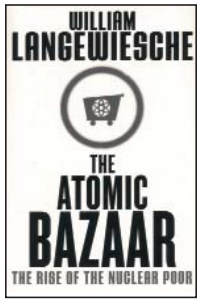
Deception

Pakistan, the United States, and the Secret Trade in Nuclear Weapons

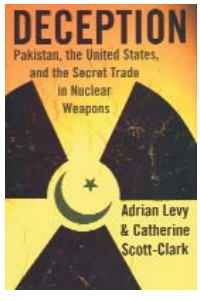
Adrian Levy and Catherine Scott-Clark
Walker, New York, 2007. $26.95 (543 pp.). ISBN 978-0-8027-1554-8

At first glance William Langewiesche's *The Atomic Bazaar: The Rise of the Nuclear Poor* and Adrian Levy and Catherine Scott-Clark's *Deception: Pakistan, the United States, and the Secret Trade in Nuclear Weapons* appear to cover the same issues: the spread in recent decades of nuclear weapons materials and technologies and Pakistan's special role in those events. Both certainly target that country as the world's greatest proliferator of nuclear weapons materials and technologies. In both cases the authors draw some fine journalistic portraits, especially of Abdul Qadeer Khan, the "father" of Pakistan's nuclear program and chief proliferator of nuclear knowledge and technology to Iran, North Korea, and Libya. Both books also provide convincing explanations of Khan's motivations and actions and of his downfall: He became a victim of his own hubris and his government's need for a scapegoat. The texts are also captivatingly written, as one would expect from first-class journalists. But here their similarities end.

The Atomic Bazaar is transparently an amalgam of updated, disparate articles on nuclear proliferation that Langewiesche wrote for *The Atlantic Monthly*, and it exhibits both the advantages and pitfalls of such work. The book is without references or a bibliography; we have to take Langewiesche's word for much of what he recounts. Levy and Scott-Clark's *Deception* is a much longer, academically oriented work that is extensively footnoted and exhaustively researched.



Langewiesche, currently the international correspondent for *Vanity Fair*, starts with the bombing of Hiroshima. He then systematically explains two different paths to nuclear weapons proliferation, both allegedly facilitated by the global atomic bazaar that he intimates is out of control. The first route is that terrorists seize or buy fissionable material and fashion it into a crude nuclear device. The second is that a nonnuclear weapons state produces its own weapons-grade uranium or plutonium to create a militarily useful arsenal as Pakistan has.



Levy and Scott-Clark have a more searing focus on Pakistan as both an acquirer of nuclear weapons and as a proliferator of nuclear weapons technology to other states and potentially to Islamic terrorists. Their principal concern, as their title suggests, is the part that deception has played in the Pakistani saga. They find it everywhere: in Khan's betrayal of his Dutch hosts in purloining their enrichment technology while he was conducting research in the Netherlands; in the successive Pakistani governments' lies to the international community about their nuclear aspirations and activities; and in several US administrations' alleged suppression of warnings from their own officials about Pakistan's nuclear transgressions because the administrations viewed as paramount Islamabad's value as a beachhead for fighting the Soviets, the Taliban, and Al Qaeda in Afghanistan.

For all the joys of Langewiesche's essays, his book is meandering and ultimately unpersuasive. The biggest surprise is that despite the anticipated revelations about how easy it might be for terrorists to acquire a nuclear weapon, he is forced (and one gets the feeling, reluctantly so) to reach a contrary conclusion. The highlight of Langewiesche's work is his pursuit of how weapons-grade, highly enriched uranium might be pilfered from a Russian bunker and spirited out through apparently lawless central Asia or the Caucasus. His investigation, a combination of interviews with experts and locals and pure speculation, convinces him that local communities and power brokers are likely to make the mission problematic, if not impossible. He concludes that "in the final analysis, if a would-be nuclear terrorist calculated the odds, he would have to admit that they are stacked against him" (page 69). That hardly sounds like an atomic bazaar.

Most important, the premise of the book that the poor will inevitably inherit the bomb is questionable, even based on Langewiesche's own evidence. Although he disparages Pakistan as a poor "rump" state, it is by no means the poorest of countries. Since the 1960s it has always been high on the list of likely proliferator nations, in part because of its scientific capabilities and strategic situation, which draws in resources—notably the massive US assistance that is so well documented by Levy and Scott-Clark. Moreover, despite Langewiesche's dismissal of the significance of the states that have rejected the nuclear weapons option, they now number in the dozens, including South Africa, Ukraine, Kazakhstan, and Belarus, which have actually disarmed themselves, and Argentina, Brazil, Libya, and even Sweden, which have ended their programs at various stages. The truth is that after the cold war, the vast majority of states, whether rich or poor, thankfully see no utility in nuclear weapons, and they are too preoccupied with economic advancement or the threat of climate change to care.

Levy and Scott-Clark's *Deception* is more consistent and thorough; it offers a painstaking description of Pakistan's nuclear journey and the tortured part that the US has played in various ways in facilitating, obscuring, ignoring, and obstructing that journey—sometimes all at once. However, the book wanders off the track toward the end, covering at