he blames the crash of a Sukhoi Superjet 100 during a 2012 demonstration flight on systemic failures rather than pilot error, subsequently shown to be the cause.

Both Graham and Smil analyse human resources and education as sources of growth. Smil reveals that the traditional distinction between blue- and white-collar jobs is diminishing in the United States, pushing up the level of qualifications needed. And he shows that although US universities attract the best talent globally, the country's overall education system is failing to train enough qualified individuals. Some universities have thus been forced to give remedial courses in subjects such as mathematics to first-year students.

"No nation can survive solely on digital industry."

In Russia, Graham suggests, attempts to regenerate the research sector by attracting high-level scientists, upgrading equipment and making greater use of talented students are providing the basis for innovation. The first signs of high-tech entrepreneurship are appearing. A 2010 government directive supporting university innovation has spawned multiple success stories, such as spin-off companies and growth in private-venture investment. Yet new initiatives, Graham argues, do not overcome the barriers between science and innovation still inherent in Russian society. He points to the number of Russian scientists who remain psychologically trapped in the Soviet tradition of keeping research separate from both enterprise and universities. Nevertheless, the next generation is becoming aware that application and commercialization can complement fundamental scientific research and education.

Meanwhile, in the United States, willingness to take risks and convert inventions into commercial propositions is falling off with the rising standard of living, although it was once the norm, Smil shows. Population mobility also enabled US innovation, he argues. Graham reveals this as another dissimilarity to the situation in Russia, where even highly educated citizens tend to "stay near where they were born". But this is slowly changing: 37% of Moscow-based university students now hail from elsewhere in Russia or abroad.

Approaches to growth, whether US or Russian, can backfire. Smil points to the drive of US businesses to maximize profits at short notice and arrives at a provocative question: will the United States be able to maintain its role as one of (if not the) leading economic powerhouses by relying on digital-age business models? That question remains open.

Taking *Lonely Ideas* and *Made in the USA* together, an overarching message emerges: innovation needs to be allied to tangible outcomes, to something that people can use. No nation can survive solely on digital industry; a good living standard comes from combining innovation in the real and digital economies, and in services. But these demand clever policies and frameworks, including a favourable climate for competition and investment, property protection and the rule of law.

Both the United States and Russia are beginning to actively tackle their national innovation challenges. The leap in the US chemical industry based on shale gas and the modernization of the fuel sector and automotive industry in Russia seem to hold promise — but things may look very different in the coming decade. Sustainable growth in both countries will probably come from highly automated manufacturing, which will demand a better educated and trained labour force. The digitization of manufacturing, encompassing robots, three-dimensional printing and more, will continue apace along with the need for new skills. We will need, in short, to be ready for new twists in the road from lab to reality. ■

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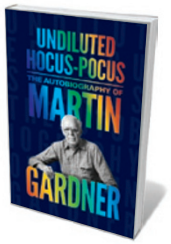
MATHEMATICS

Master puzzler

David Singmaster delights in the autobiography of Martin Gardner, whose *Scientific American* maths column enchanted tens of thousands.

For half a century, Martin Gardner (1914–2010) was an international scientific treasure. As the author of *Scientific American*'s Mathematical Games column for 25 years, he introduced many thousands to the pleasures of mathematics. He enchanted tens of thousands more with more than 100 books spanning everything from pseudoscience and magic to *Alice's Adventures in Wonderland*. To anyone who knows Gardner's work, his self-proclaimed "rambling autobiography" — the posthumously published *Undiluted Hocus-Pocus* — comes as a delightful surprise.

Gardner reveals the roots of his unusual mix of expertise in his childhood in Tulsa, Oklahoma. His father — a freelance oil prospector with a background in geology — taught Gardner basic science such as why the Moon has phases, provided him with a small laboratory and taught him some magic tricks. Gardner learned to read by looking over his mother's shoulder as she read aloud L. Frank Baum's children's classic *The Wonderful Wizard of Oz* (1900). He subscribed to *Science and Invention* magazine and *Amazing Stories*, the first science-fiction magazine, launched in 1926. He performed his first magic trick at the age of eight, later following the famous US Tarbell Course in Magic.

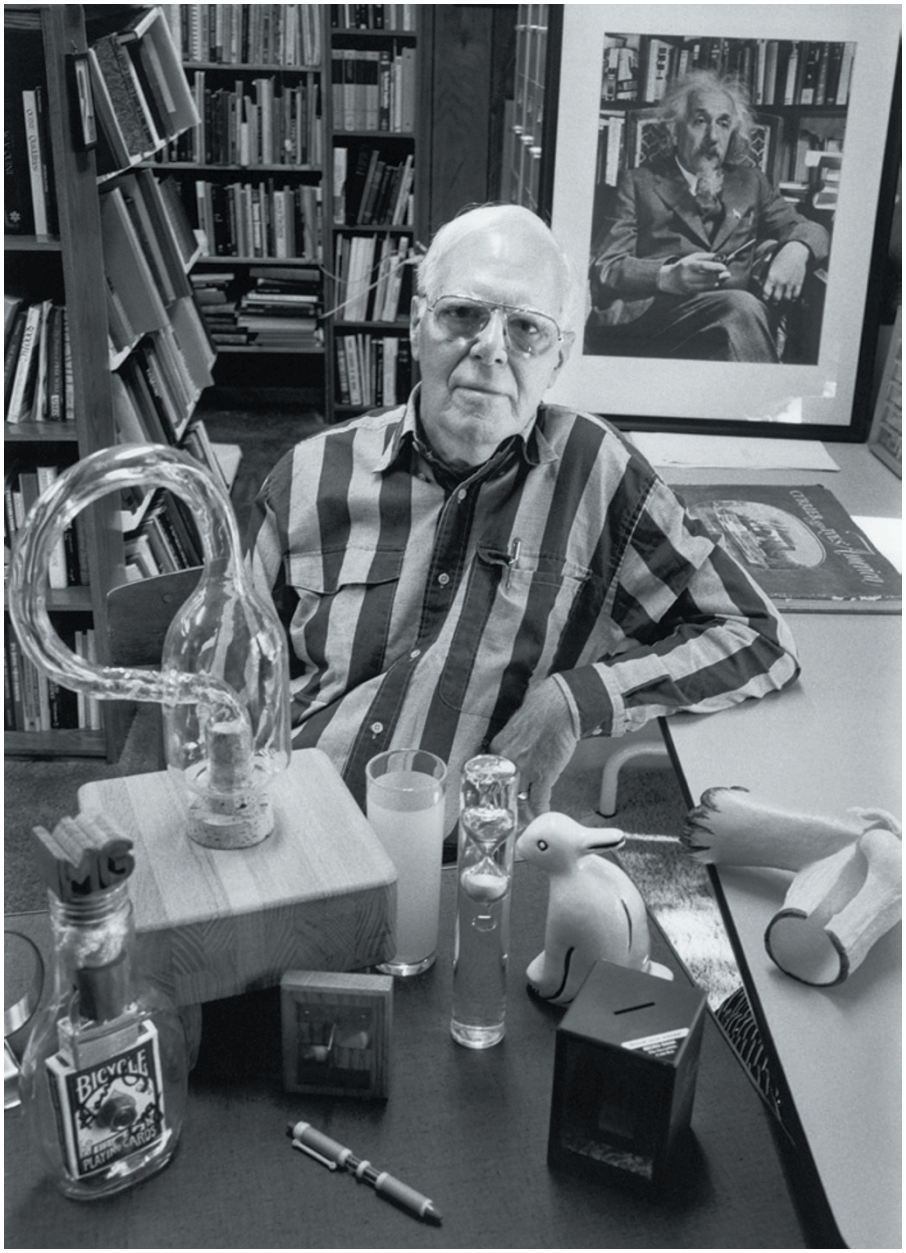


Undiluted Hocus-Pocus: The Autobiography of Martin Gardner
MARTIN GARDNER (WITH PERSI DIACONIS AND JAMES RANDI)
Princeton University Press: 2013.

Gardner hated high school, except for mathematics and physics, noting that the "important history ... was the history of science". Here, he writes, he penned "lots of mediocre poetry" and invented 'cherchez la femme', a flexagon-type puzzle — flat paper models folded different ways to reveal various images. In 1934, when Gardner was just 20, *Hobbies* magazine published his article on collecting mechanical puzzles — the first of its kind.

He had wanted to study physics, but instead read philosophy at the University of Chicago in Illinois. Its new president, Robert Hutchins, fomented an educational revolution by appointing Mortimer Adler to a chair in philosophy without consulting

ELLIOTT ERWITT/MAGNUM



Martin Gardner, pictured in 1995.

members of the department, most of whom resigned. Hutchins and Adler went on to promote the Great Books scheme — a curriculum focused on texts by scientific and literary luminaries from Archimedes to Virginia Woolf — and a highly flexible undergraduate programme. Gardner enjoyed the ferment as philosophers came and went, and recalls seeing Enrico Fermi cycling to the university's Stagg Field, where the great physicist was making the first atomic pile (an early reactor) in an underground squash court.

Gardner's complex of interests began to bear fruit in the 1950s, as he cut his writing teeth on journalism. He moved to New York to edit the quality children's monthly *Humpty Dumpty* for eight years. He published articles on maths and magic for *Scripta Mathematica*; these were gathered together for his first recreational mathematics book, *Mathematics, Magic and Mystery*, in 1956.

That same year, Gardner was shown a hexahexaflexagon, a puzzle made by folding a length of paper into a hexagonal Möbius strip; it was the work of four students at Princeton University (one of whom was Richard Feynman). Gardner thought *Scientific American* might like an article on it and the piece kick-started his much-loved column. In it, Gardner introduced or popularized a vast range of ideas, including polyominoes (the shapes formed by joining squares edge-to-edge); the Soma cube; the superellipse; M. C. Escher's iconic images, such as the *Endless Staircase*; Roger Penrose's tilings; and trapdoor ciphers and public-key cryptography, the basis of all financial transactions on the Internet. These pieces were eventually collected into 15 books.

Magic gripped Gardner throughout his life, and he may have written more on it than on mathematics. I feel that his years spent writing for children may partly account for the exceptional clarity and directness of his writing for adults. He became a leading expert on Lewis Carroll, with his *Annotated Alice* (Bramhall House, 1960) selling more than a million copies and explaining the mathematical, logical and literary associations in the book.

He also became a specialist on Baum, the prolific British writer G. K. Chesterton, and some minor poets. Gardner produced so much, on so many subjects, that it was rumoured that his name was the pseudonym of a writers' collective, such as the French mathematicians who published as Nicolas Bourbaki.

DEBUNKING PSEUDOSCIENCE

Gardner received an immense amount of correspondence and apparently replied to all of it. Many students, encouraged by his friendly and prompt replies, became mathematicians.

Among scientists, Gardner is best known for his writing debunking pseudoscience. This began with 'The Hermit Scientist' in *The Antioch Review* of winter 1950–1951. In this, he described ideas such as psychiatrist Immanuel Velikovsky's catastrophist theories about ancient history as examples of pseudosciences created by persons working alone.

He expanded these ideas in books such as *Fads and Fallacies in the Name of Science* (Dover Publications, 1957) and *Science: Good, Bad and Bogus* (Prometheus, 1981). In 1976, Gardner helped to found the Committee for Scientific Investigation of Claims of the Paranormal (now the Committee for Skeptical Inquiry), which believes that it is "the duty of scientists to debunk bad science". Amen.

Gardner's passion for writing and his warmth and humour shine forth on every page of this book, making it a memoir of a great human being — a 'rational man', as Isaac Asimov had it. Almost all of Gardner's books are still in print. They stand as a remarkable testament to the independent scientific life. ■

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