or separately, answer "True" in unison, and then explain "Sorry. Nonexclusive 'or.'" Characters explore the Deep Web — a real but murky sector of the Internet unindexed by search engines and populated by dynamic content and entrepreneurs concerned with privacy. And they lurk in DeepArcher (say it out loud), a virtual space of Pynchon's invention. This is a virtual-reality interface that grows organically, allowing its denizens to construct sanctuaries away from the surface web with no clear instructions — "part of getting constructively lost". Characters who have met untimely ends in "meatspace" seem to linger on in DeepArcher, although it is impossible to tell who is really behind the face of an avatar.

The attacks on the World Trade Center happen about two-thirds of the way through the book. Rather than inducing a dramatic change, they lead to a slight shift in balance, pulling some notes down and bringing others to the foreground. Every type of conspiracy theory is tossed into the pot and stirred. Pynchon highlights the life-goes-on aspect of New York after the attacks, but laments the swiftness with which "forces in whose interests it compellingly lies to seize control of the narrative" work to keep people "cranked up, scared, and helpless".

Bleeding Edge is an elegiac yet compulsively readable novel. The humour crackles, eliciting chuckles on almost every page. No one works magic with words like Pynchon, and here he is at the height of his powers, by turns gripping, thought-provoking, inventive, touching and poetic, not to mention warmly human. Tarnow is a rich, believable character, and we are fortunate to be privy to her wry commentary on the rogue's gallery of characters who cross her path.

'Big data' is a modern buzzword, but a long-standing theme for Pynchon has been how the search for signals in the noise is, in part, a quest for meaning amid chaos and entropy. At the end of the novel, in a world transformed by atrocities large and small, Tarnow's boys once again head off to school. This time they make the journey without their mother. Life does go on, even as everything changes; the best we can do is care. ■

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ILYA NAYMUSHIN/ REUTERS/CORBIS

A worker using an electrolysis furnace to produce aluminium in Krasnoyarsk, Russia.

INNOVATION

Superpowered invention

Leonid Gokhberg and **Dirk Meissner** compare accounts on the trajectory of innovation in two towering economies.

Many of us believe that science is indispensable for generating innovation, and that innovation is a basis for manufacturing, which, in turn, is a must for the economy. But is the road that straight? In truth, it takes decades to recognize the fruits of scientific discovery and economic activity.

Science historian Loren Graham and environmental scientist Vaclav Smil examine this issue in two nations with economic and political models that have evolved very differently. Graham's *Lonely Ideas* tackles Russia's powerful history of scientific invention, its long-standing inability to benefit from this, and its post-Soviet potential for change. Smil's *Made in the USA* looks at the United States' innovation-led economic power, built on twentieth-century might in manufacturing everything from cars to electronics, but now weakening — and even creating trade deficits in high-tech products such as computer equipment.

What emerges are distinct challenges. The United States, Smil argues, should revitalize manufacturing (of household appliances or construction equipment, for example) to support growth and investment in health care and education, among other positive socio-economic impacts. In Russia, Graham shows, the challenge is to reshape an economy now reliant on oil and gas, and to make it competitive through technological upgrading and integration into global value chains — the interlinked processes that take a product from conception to end use.

Lonely Ideas: Can Russia Compete?
LOREN GRAHAM
MIT Press: 2013.

Made in the USA: The Rise and Retreat of American Manufacturing
VACLAV SMIL
MIT Press: 2013.

Smil notes that US innovation co-evolved with the emergence of a middle class rooted in industry, such as steel manufacture in the nineteenth century, and automobile production in the twentieth. A Russian middle class has never fully emerged, yet Graham fails to tackle this issue. Rather, he focuses on the inventiveness of Russian scientists, describing impressionistic examples such as the early work of Nikolai Basov and Alexander Prokhorov on lasers in 1954. In exploring the country's failure to turn invention into innovation, he briefly covers key factors such as the investment climate, institutional frameworks, policies and the societal mindset. His discussion of various areas of technology such as genetics is interesting, although some of his conclusions are odd. For instance, ▶

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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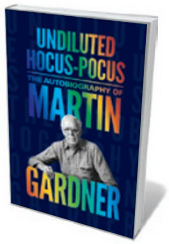
MATHEMATICS

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