researched book *The Brain in Search of Itself*. The first major English-language biography of Cajal, it maps out his scientific work in broad strokes and describes his politically turbulent times. Such is the wealth of detail, however, that the narrative sometimes struggles to maintain its thread.

Cajal's domineering father was determined that his son should follow in his footsteps as a physician. But Cajal was a reluctant pupil: he found rote learning difficult and kicked against discipline, resulting in beatings from his father. When he declared that he wanted to be a professional artist – he drew and painted obsessively – his father confiscated his brushes and sent him to a remote and harsh Jesuit secondary school, from which he absconded after a few months. At his next school, one teacher described him as "inattentive, lazy, disobedient, and annoying". Another said he would end up in jail "if they do not hang him first". Once, he taught himself to make gunpowder, constructed a cannon from junk and fired it at a neighbour's house. That escapade earnt him a few days in jail.

Somehow, Cajal scraped his baccalaureate, and enrolled in medical school in Zaragoza, the region's largest town. There, he came across the cell theory of German pathologist Rudolf Virchow, which held that the body, at least outside the brain, is composed of individual basic units of life. Excited, Cajal sought out the university's only microscope and looked down at a frog whose cells were rendered visible by a pink stain derived from cochineal insects.

Revolution was rumbling during the years of Cajal's education, and Spain's colonies, particularly Cuba, were struggling for their independence. In 1873, when he graduated, the first Spanish republic was declared and Cajal was conscripted into the army's medical corps. Dispatched to Cuba, he became so ill with malaria that he requested discharge.

Thin and in poor health, he taught at his alma mater and prepared for his doctorate. Browsing a medical supply shop while in Madrid for an exam, he saw the most advanced microscope then available. It cost more than half his yearly income; he used his army discharge money to help buy it.

Microscopy methods

Cajal shut himself in the attic of the family home, learning how to prepare tissue for microscopy and drawing or photographing his preparations. At 31, he landed his first faculty position, in Valencia. He wrote a textbook of histology, which surveyed all tissues of the human body except the brain. That was too difficult to stain. On another fateful visit to Madrid, he was introduced to a staining technique called *la reazione nera* – the black reaction – developed by Golgi some years earlier. It displayed nerve cells beautifully.

Cajal refined the highly unreliable method. Now in Barcelona, he isolated himself with his microscope and brain preparations and saw individual cells wherever he looked. He founded a journal, *The Trimonthly Review of Normal and Pathological Histology*. Its inaugural issue, in May 1888, described the first unequivocal evidence that the brain was made of individual cells. Cajal sent copies to leading scientists abroad; he got no response. The next year, at an international congress in Berlin, his work was finally recognized. He shot to fame. Golgi was enraged that his own method had been used, as he saw it, against him.

Cajal was a prolific, flowery writer who published popular science and novels as well as innumerable academic papers. He developed new stains for nerve cells and described the development and evolution of the nervous systems in other species. He elaborated all this in the two-volume *Textura del sistema nervioso del hombre y los vertebrados* (*Texture of the Nervous System of Man and the Vertebrates*, 1899–1904) – 2,000 pages of text with nearly 1,000 of his own illustrations.

Ehrlich paints a vivid picture of a strong, driven character, anti-authoritarian, anti-elite and brash. But he doesn't develop how and why Cajal's discoveries have been so fundamental to modern neuroscience. None of Cajal's drawings is included, an incomprehensible omission. There is an occasional misinterpretation; for example, he implies that Cajal had a dig at Golgi in his Nobel acceptance speech, but the passage he quotes refers to other scientists.

Still, the narrative is charming. In his late sixties, Cajal found himself behaving like Golgi. A younger colleague developed a new stain that enabled him to see even finer structures than Cajal had been able to see. He used it to show two distinct types of glial cell – non-neuronal brain cells. Cajal had judged these cells, which he called the "third element", to be homogeneous. Incensed, Cajal dismissed the discovery. Unlike Golgi, he later reflected on his behaviour and apologized.

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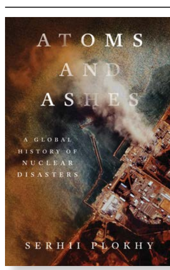
A global history of six nuclear disasters

Key context in the search for alternative energy sources amid decarbonization. By Alexandra Witze

In February, soon after Russian forces invaded Ukraine, they reportedly dug trenches in the radioactive soil at Chernobyl and drove heavy vehicles in the area, kicking up contaminated dust. Thirty-six years after a reactor core exploded at the Chernobyl nuclear power plant, fallout from the world's worst nuclear accident still permeates the environment. Amid all the atrocities committed by Russian troops during the war in Ukraine, ignorance of this history does not rank high. But it underscores the lasting, dangerous and frequently unforeseen consequences of nuclear disasters.



Atoms and Ashes: A Global History of Nuclear Disasters
Serhii Plokhy
W. W. Norton (2022)

One of the leading chroniclers of this nuclear legacy is Serhii Plokhy, a historian of Ukraine and author of *Chernobyl* (2018), a definitive account of that fateful day in April 1986. In *Atoms and Ashes*, he places that disaster in a broader, more global history of six nuclear accidents – from explosions at plutonium production plants to meltdowns at nuclear power stations. The result is a revealing tour of some of the most terrifying experiences involving nuclear power. It is also useful context for today's discussions about whether nuclear energy deserves a major role in the push to decarbonize the global economy.

Atoms for war

Nuclear power is a child of war, birthed in the world's first artificial self-sustaining nuclear reaction inside a stack of graphite and uranium bricks in Chicago, Illinois, in December 1942. That was a key early milestone in the Manhattan Project, which developed the atomic bombs that devastated Hiroshima and Nagasaki in Japan, and brought an end to the Second

World War — and instigated the deadly competition between the United States and the Soviet Union as they built up their nuclear arsenals.

While global superpowers battled, remote communities with little geopolitical power often suffered the public-health consequences. Before the 1963 treaty that banned atmospheric nuclear tests, the United States, Soviet Union and United Kingdom regularly showered radioactivity into the air during test blasts. One of the most shocking was a March 1954 test in the Marshall Islands in the Pacific Ocean. Nicknamed Castle Bravo, it was the first US test of a hydrogen bomb using a new type of fuel; its designers badly miscalculated how big the blast would be. The bomb detonated over Bikini Atoll with a yield of 15 megatons, 2.5 times what was expected. And weather forecasters misjudged where and how strongly the winds were blowing.

Radioactivity spread over inhabited islands including Rongelap, 157 kilometres away. People reported a whitish substance resembling snow falling on them. It was irradiated coral, vaporized in the blast. Given no warning or advice by the US government, people stayed outside until their skin began to burn and itch. Hundreds were unknowingly exposed to radiation.

This theme of distance — of radioactivity traveling far beyond the supposedly secure confines of a nuclear testing ground or power plant — is part of what makes nuclear accidents so terrifying. Everything seems to be under control, until it's not. That was what happened in two plutonium-production accidents in 1957.

At Kyshtym, a plutonium-processing facility in the Soviet Union's Ural Mountains, a tank storing nuclear waste exploded and sent a plume of radioactivity drifting widely. Days later, the nuclear facility of Windscale in the United Kingdom saw thousands of tonnes of graphite ignite and release radioactive material. In both cases, delays to maintenance tasks involving complicated engineering, combined with stressed workers, led to cascading failures. In both cases, national governments covered up the scale and scope of the disasters.

Atoms for peace

These disasters all involved military "atoms for war" projects. Similar mistakes were repeated in civilian "atoms for peace" projects, starting in the 1950s, in which nuclear power was repurposed to provide energy. "Looking closely at what led to these accidents and the ways in which the industry and governments dealt with them," writes Plokhy, "is the most effective way of understanding the perils associated with reliance on nuclear energy."

At the Three Mile Island nuclear power plant in Pennsylvania, a minor failure in a valve in 1979 led to a loss of coolant and the start of a reactor meltdown. Ultimately, plant operators vented radioactive gases into the air, at much lower levels than at Kyshtym but enough to cause widespread panic in local communities. (Here, as elsewhere, Plokhy valiantly attempts to be clear about public risk while juggling the many units of radioactivity exposure, from rems to roentgens to sieverts.) Then-US president Jimmy Carter, a Navy veteran who had worked on a damaged reactor in Chalk River, Canada, tried to take charge of the Three Mile Island response and messaging, but ultimately did not hold the US nuclear regulatory agency fully to account.

"Delays to maintenance tasks, combined with stressed workers, led to cascading failures."

Plokhy excels in unpacking the human and systemic factors that contribute to nuclear disasters. At Chernobyl, it was a long-overdue test, conducted by exhausted workers around midnight, that led to the catastrophic explosion of reactor number four. Even that accident did not stem the rise of nuclear power in countries that had made it a strategic part of their energy portfolio, such as Japan.

And so, on the afternoon of 11 March 2011, reactors at the Fukushima Daiichi nuclear power plant were operating when a magnitude-9 earthquake rocked the eastern coast of Japan. Emergency generators kicked in to keep coolant flowing, but they were swamped when an enormous tsunami arrived. The plant's designers had anticipated an earthquake but not a tsunami. Three reactors melted down.

BEHROUZ MEHRI/AFP/GETTY

Workers gather outside one of the reactors that melted down in the 2011 Fukushima disaster.

Nuclear power is one of the most complex systems that humanity has tried to harness. What looks like a straightforward science and engineering project turns out to be an intricate interplay of commercial and government interests, with plenty of opportunities for bad decisions. Collectively, these six nuclear accidents are a cautionary tale for any Prometheus looking to play with nuclear fire.

They also raise questions about what part nuclear power should play in slashing emissions. Around 10% of the world's electricity comes from approximately 440 nuclear plants around the globe. Industry leaders and supporters point to the long record of reliability for most nuclear power plants, and the importance of generating energy domestically instead of importing fossil fuels from nations such as, for example, Russia.

Yet Plokhy notes correlations between the fate of the nuclear industry and the history of nuclear disasters. In 1979, the year of Three Mile Island, the number of reactors under construction peaked. The year before Chernobyl, 1985, saw the peak of reactors starting up. And the industry has been in a slide ever since Fukushima.

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