Elisabeth's, because "in the family, the child is without a doubt a hardly bearable burden". These provide proof that he effectively signed their death warrants.

Nearly 800 children were killed in Am Spiegelgrund. Asperger went on to enjoy a long academic career, dying in 1980.

Both *Asperger's Children* and Czech's paper converge on the same conclusion. Personally, I no longer feel comfortable with naming the diagnosis after Hans Asperger. In any case, this is a category rendered moot in the most recent edition of the *DSM* (used in the United States). European nations will follow this diagnostic lead in 2019, with the 11th edition of the *International Classification of Diseases*.

The future use of the term, of course, is a discussion that must incorporate the views of autistic people. Many take pride in the term Asperger's syndrome as part of their identity, feeling it refers to their personality and cognitive style, which obviously do not change simply because of historical revelations. They might not, therefore, want a change. Others have already written about switching to using 'autism' (or autism spectrum disorder, or autism spectrum condition) to describe their diagnosis.

For brevity and neutrality, I favour the single term autism. However, because of the considerable heterogeneity among autistic people, I think it could be helpful for them and their families — together with autism researchers, clinicians and relevant professionals — to discuss whether subtypes should be introduced.

"The future use of the term Asperger's syndrome is a discussion that must incorporate the views of autistic people."

When Wing coined the term Asperger's syndrome, none of us was aware of Hans Asperger's active support of the Nazi programme. As a result of the historical research by Sheffer and Czech, we now need to revise our views, and probably also our language. *Asperger's Children* should be read by any student of psychology, psychiatry or medicine, so that we learn from history and do not repeat its terrifying mistakes. The revelations in this book are a chilling reminder that the highest priority in both clinical research and practice must be compassion. ■

Simon Baron-Cohen *is director of the Autism Research Centre at the University of Cambridge, UK, and president of the International Society for Autism Research.*
e-mail: sb205@cam.ac.uk

BIOTECHNOLOGY

Blood, sweat, tears and biotech

Eric Topol extols a gripping account of the rise and fall of US medical-testing company Theranos.

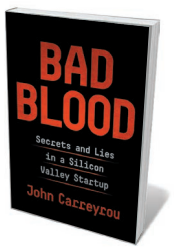
Few scandals have so gripped both the health-care and technology industries as the seismic rise and fall of blood-testing company Theranos. In *Bad Blood*, acclaimed investigative journalist John Carreyrou, who broke the story in 2015, presents comprehensive evidence of the fraud perpetrated by Theranos chief executive Elizabeth Holmes. Specifically, Holmes and the company's former president Ramesh 'Sunny' Balwani raised more than US$700 million through "elaborate, years-long fraud in which they exaggerated or made false statements about the company's technology, business, and financial performance", as the US Securities and Exchange Commission put it in March this year.

By the time Carreyrou's *Wall Street Journal* story and a long chain of follow-ups had led to regulators closing down Theranos's labs in 2016, nearly 1 million lab tests had been run in California and Arizona. A significant proportion of these were erroneous; all had to be voided. An untold number of people were harmed by the erroneous results: some underwent unnecessary procedures, received misdiagnoses of serious conditions and experienced emotional turmoil.

Carreyrou presents the scientific, human, legal and social sides of the story in full. Although some of it was previously reported in his extensive coverage, he unveils many dark secrets of Theranos that have not previously been laid bare.

The company's alluring goal, which changed as it evolved, was to quickly analyse a drop of blood for hundreds of different assays, at a fraction of prevailing costs. Collected in 'nanotainers' and allegedly tested in a diagnostic 'miniLab' the size of a microwave oven, the method was publicized as revolutionizing an industry that hadn't changed for decades. Holmes, who idolized Apple entrepreneur Steve Jobs, called it "the iPod of health care".

As a child in the 1990s in the United States, Holmes declared that she wanted to be a billionaire when she grew up. By age 30, she had achieved her goal. Highly intelligent, she had been accepted in 2002 to study chemical engineering at Stanford University in California as a President's Scholar, a prestigious programme that comes with a grant. She dropped out in her second year to start Real-Time Cures, the Palo Alto-based company that became Theranos and operated for 15 years.



Bad Blood: Secrets and Lies in a Silicon Valley Startup
JOHN CARREYROU
Knopf (2018)

Carreyrou explores Holmes's talents and liabilities. Driven, and with an exceptional gift for selling ideas, she built up a board of high-level political figures, such as former secretaries of state George Shultz and Henry Kissinger, former secretary of defence William Perry, Marine Corps general (now secretary of defence) James 'Mad Dog' Mattis, and former senator Sam Nunn. Investors included media magnate Rupert Murdoch; partners numbered supermarket giant Safeway and pharmacy chain Walgreens. Channing Robertson, a professor of Holmes's at Stanford, was a board member and adviser to the company. In 2015, Holmes was recognized by then-president Barack Obama as a US ambassador for global entrepreneurship. The same year, vice-president Joe Biden sang her praises at a launch of the miniLab (which Carreyrou uncovers as completely fake; the lab was not operational at the time).

All the while, as Carreyrou reports, Holmes was lying about the nanotainer, contracts with the pharmaceutical industry and assay validation. She made false statements to the US Federal Drug Administration (FDA) and to the US government agency that regulates blood-testing labs, the Centers for Medicare and Medicaid Services. And she claimed that Theranos was being used on the battlefield in Afghanistan, saving soldiers' lives.

Holmes described the miniLab as "the most important thing humanity has ever built". But at best, the lab could do

Elizabeth Holmes, chief executive of Theranos, in a company facility in Newark, California.

CARLOS CHAVARRIA/NYT/REDUX/EYEVINE

immunoassays using microfluidics. The tiny blood sample had to be diluted extensively (for which there are no reference standards or precedents), leading to artefacts and spurious results. Later inspections by the FDA demonstrated poor quality control of multiple lab tests using Theranos equipment, and several examples of failed proficiency testing. The rest of the hundreds of routine assays the lab was supposed to deliver would require cytometry, general chemistry and DNA amplification. These were done using routine commercially available lab equipment, or were hived off to other facilities. That was the well-kept secret inside the toxic work environment that *Bad Blood* exposes.

Carreyrou describes firings and legal threats to and serious intimidation of employees, as well as industrial espionage involving spying on employees' social-media accounts. The book even goes into the suicide of a former leader of the company's chemistry group.

I met Holmes twice and conducted a video interview with her in 2013, for the medical-information website Medscape. At the time, I gave a fingerstick nanotainer blood sample and within 30 minutes received my results for many routine tests — allegedly showing, for instance, normal glucose and lipid levels in accordance with previous testing. Little did I know that they were run on a standard Siemens machine (I was not allowed to see the lab area) in the back room of Theranos, and had nothing to do with the miniLab. Like so many others, I had confirmation bias, wanting this young, ambitious woman with a great idea to succeed. The following year, in an interview with *The New Yorker*, I expressed my deep concern about the lack of any Theranos transparency or peer-reviewed research.

> ***"An untold number of people were harmed by the erroneous results."***

Near the end of *Bad Blood*, Carreyrou describes how, in 2015, litigator David Boies — then Theranos's legal counsel — attempted to prevent *The Wall Street Journal* from publishing Carreyrou's reportage. For instance, Boies accused the paper of publishing Theranos trade secrets and making false and defamatory statements. Despite the $125 million invested in Theranos by Murdoch, the newspaper's owner, the pieces were published. We also learn about Carreyrou's tipster, a pathologist and blogger, along with so many employees who were rightfully afraid of hurting patients with fraudulent lab results. The combination of these brave whistle-blowers, and a tenacious journalist who interviewed 150 people (including 60 former employees) makes for a veritable page-turner.

My only criticism is the book's lack of reflection about lessons learnt from this debacle. How did a company rise to a valuation of $9 billion in a network of so many influential people, even as people were endangered? In my view, letting this technology loose (despite grand claims) without a single publication by independent scientists, never mind replication, was a recipe for jeopardy. Had the medical community and regulators held the company accountable, this could have been pre-empted. There have been other examples of Silicon Valley companies that rose meteorically, but none has put patients' health at risk. Hopefully, the evidence in *Bad Blood* will stop it happening again. ■

Eric Topol *is executive vice-president of the Scripps Research Institute in La Jolla, California.*
e-mail: etopol@scripps.edu