and hopefully, one imagines, more digestible ones. On the whole I like this, but it does seem a bit of a cheat if readers get through the same amount of material before giving up, only now boasting of having seen off three chapters instead of one.

The new book is certainly easier going. The old third chapter ("The expanding Universe") of 11 in the original is now the seventh chapter of 12, highlighting the additional weighting given to introductory material. The three middle chapters ("Black holes", "Black holes ain't so black" and "The origin and fate of the Universe"), which together made up a total of 70 pages in the original, are now lumped into one chapter just 18 pages long. Elsewhere, every attempt has been made to clarify those passages deemed to be hard going. Finally, out goes the chapter on the arrows of time, the diagrams of light cones and event horizons, and discussions of chaotic boundary conditions, and in comes a new crowd-pleasing chapter on time machines.

I find myself unconvinced by this valiant effort, however. Clearly, the incredible success of *A Brief History of Time* was due to a combination of timing, marketing and the persona of the author. It can never be repeated. But what is often overlooked is that its major, paradoxical attraction was its charming incomprehensibility to the non-physicist — the idea that anyone could take a peak inside one of the greatest minds in science. This is lost in the new book. For millions of people around the world, *A Brief History of Time* would have been the only science book they have ever read or attempted to read. But with the briefer version, I feel the baby has been thrown out with the bathwater. It is just another run-of-the-mill popular science book on modern physics. The topics that it claims to treat more carefully have been covered better elsewhere. In any case, many of the topics left in and flagged as more introductory are just as baffling, abstract and abstruse to non-scientists as those left out. Just because quantum mechanics and the special theory of relativity are not at the cutting edge of current thinking doesn't mean they are any less counter-intuitive. The two-slit experiment and the notion of the relativity of simultaneity could have been explained better, especially as the latter receives just a single paragraph.

Fresh material, based on advances made over the past two decades, has been included, such as the concept of 'dark energy' and advances in string theory. I am also pleased to see that the discussion of the anthropic principle is retained. This is a hot topic of discussion at the moment in connection with multiverse theories. However, I found it a little surprising that the idea is still treated rather cautiously here.

I have no doubt that *A Briefer History of Time* will soon be on the shelves of every high-street bookstore around the world. This is surely to be welcomed: any book that can reach a wide audience and get across the excitement of science has to be a good thing. And with Hawking enjoying an iconic status not seen in a scientist since Einstein, his role as an ambassador for science should not be underestimated. ■

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Science in society

Victory and Vexation in Science: Einstein, Bohr, Heisenberg and Others
by Gerald Holton
Harvard University Press: 2005. 244 pp.
$35, £22.95

Daniel J. Kevles

In *Victory and Vexation in Science*, Gerald Holton, a physicist and historian of science at Harvard University, provides a series of illuminating historical and biographical essays on science and scientists in the twentieth century. This thought-provoking book mixes reminiscence with scholarly reflection, drawing on Holton's deep knowledge of scientists and their intellectual, religious and social engagements.

The 14 essays range over a variety of topics and are organized into two sections: 'Scientists' and 'Science in context'. The first part covers, in addition to the icons in the book's subtitle, the physicists Enrico Fermi, Percy Bridgman and Isidor Isaac Rabi, and the psychologist B. F. Skinner. The subjects in the second section include innovation in science and art, policy for basic science, postmodernism and science, and women in science. The subjects are disparate, but several arresting topics appear and reappear in the volume.

Among them is the religious impulse that Holton finds behind the science of Einstein and Rabi. As a youth, Einstein was deeply religious in some profound non-sectarian sense, even though he was raised in an irreligious household. After the age of 12, when he began encountering science, his religious inclination was transformed into a strongly felt quest to comprehend the physical world. This drive, Holton says, constituted a flight from "personal, everyday life, with all its dreary disappointments, and escape into the world of objective perception and thought". Indeed Einstein once remarked that the tenacious pursuit of a difficult scientific problem demanded "a state of feeling similar to that of a religious person or a lover".

Einstein ultimately embraced a transcendent spiritualism, free of anthropomorphic and what he considered primitive elements. His views irritated the theologian Paul Tillich and angered clerics such as a Roman Catholic cardinal in Boston, who found intimations of atheism in Einstein's theories of space-time. Queried on the point, Einstein declared that he believed in "Spinoza's God, Who concerns Himself in the lawful harmony of the world, not in a God Who concerns Himself with the fate and the doings of mankind".

Unlike Einstein, Rabi was raised as an orthodox Jew, but while he separated from orthodoxy, Holton notes that deep down he remained "God-struck throughout his life". Like Einstein, Rabi saw science as a means of transcendence beyond the visceral concerns of the human species. He once recalled that physics filled him with awe and put him in touch with a sense of original causes. "Whenever one of my students came to me with a scientific project, I asked only one question, 'Will it bring you nearer to God?'."

The role that intuition plays in science is

also discussed. Holton raises the issue in a captivating essay on the origins of the Fermi group's research with slow neutrons in Rome during the 1930s. The decisive experimental step was taken by Fermi himself, when he interposed paraffin between the fast-neutron source and the target. Fermi turned to the paraffin with neither forethought nor announcement. He was guided, Holton writes, by brilliant intuition, a speculative move "below the level of consciousness". In the course of mathematical invention, Henri Poincaré knew similar moments of deep intuition that arrived unbidden, "a manifest sign", he thought, "of long, unconscious prior work".

Holton writes with relish of a conversation on the origins of the uncertainty principle between Heisenberg and Einstein in the mid-1920s that Heisenberg recounted to him in 1956. But Holton finds Heisenberg's politics appalling, and rebukes him for his willingness to collaborate with the Nazi regime and for issuing "astonishing exaggerations" about Einstein's role in the atomic-bomb project while claiming that he had declined on moral grounds to build an atomic bomb for Hitler. Holton rightly insists that the Heisenberg in Michael Frayn's play *Copenhagen*, who said he knew how to build a bomb but refrained, is a fictional character and ought to be viewed as such.

Holton is dismissive of the postmodern critique of science, saying it holds that the aim of achieving objective truth is unrealizable "because there is no difference between the laws scientists find in nature and the arbitrary rules that govern baseball games". He finds part of its roots in nineteenth-century European romanticism, which was at times scientifically productive. But he also sees shades of it in Hitler's declaration that "there is no truth, in either the moral or the scientific sense". For Holton, truth emphatically exists in both senses. It is clear from these graceful essays that he stands with Rabi, admiring his insistence that science is an essential part of culture, an ennobling activity, a guide to objective thinking and a "unifying force for all of humanity". ■

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The making of a genius

The Creating Brain: The Neuroscience of Genius
by Nancy C. Andreasen
Dana Press: 2005. 225 pp. $23.95

Mark Lythgoe

Ever since the first bright spark discovered how to make fire, the recipe for genius has been one of culture's most alluring quests. Yet historically, our conception of genius has been mysterious. The very idea that it could be explained seems to run counter to its essence. From antiquity until the Enlightenment and beyond, genius was seen as an innate trait bestowed by the gods. But as the gods lost their power, it has fallen to others to do the explaining. Even modern science has been reluctant to take up the challenge, as the apparent unpredictability of creative genius seems to elude any singular systemic explanation.

Part of the problem for science has been attempting to distil a working definition of genius that removes its more subjective and untestable historical and cultural associations, while still retaining our idea of it. This is far from easy. One tenet is that a genius must be recognized as such by the relevant experts in the field — but by that reckoning, if Einstein hadn't published his theories, he would have been barred from the title. Despite the many difficulties with investigating genius (hence the mixed results), science has tried to break it down it into components such as intelligence, structure and function of the brain, madness, level of disinhibition, even genetic inheritance.

Because of the somewhat elusive definition of creativity, Nancy Andreasen opts for a case-study approach in her book *The Creating Brain*. Andreasen is an MD with a PhD in Renaissance English literature, which formed the basis for her first book, *John Donne* (Princeton University Press, 1967). From Mozart to August Kekulé, and Henri Poincaré to Samuel Taylor Coleridge, she unravels the insights, accounts and descriptions of their moments of revelation. After dissecting their multifarious personality traits, she attributes their extraordinary creativity in part to "brains that are more facile at creating free associations", and to contributions from the "unconscious mind". Her accounts suggest that unconscious processes are at work, but as the US writer Gertrude Stein warned us, they cannot be summoned at will: "It takes a lot of time to be a genius, you have to sit around so much doing nothing, really doing nothing." Perhaps that's some comfort for us mere mortals.

No account of creativity would be complete without a departure into the notion that genius and mental illness are inextricably linked. There is a pervasive belief that creativity and bipolar disorder, in particular, have a strong connection — perhaps we like to think that in order to be creative one must, at the very least, have a touch of madness. Andreasen recounts her own experience investigating individuals from the Iowa Writers' Workshop, who to her surprise had an increased incidence of depression, either bipolar or unipolar, suggesting a "relationship between artistic creativity and mood disorders". It is interesting to speculate whether this relationship is causal, is specific to certain subpopulations of mental illness, or whether the arts provide a suitable home for those with a particular illness. Whatever the reason, the link is compelling, and it is easy to produce a list of names that provide anecdotal support. But why do so few of those who are debilitated by bipolar disorder receive the benefits of this extraordinary artistic creativity?

It is well recognized that brain development occurs on a hectic timetable, given that several trillion synaptic connections must be laid down for the brain to function at average levels. During early pregnancy, 250,000 brain cells are created every minute, and this continues at a ferocious rate during infancy, when