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Physics in Perspective

Book Reviews

W. Patrick McCray, *The Visioneers: How a Group of Elite Scientists Pursued Space Colonies, Nanotechnologies, and a Limitless Future*. Princeton: Princeton University Press, 2013, 351 pages. $29.95 (cloth).

This book is primarily the history of two individuals, Gerard O'Neill and Eric Drexler. Both of these late twentieth-century Americans were technically trained (O'Neill, a Ph.D. in physics from Cornell University, and Drexler, a Ph.D. in molecular nanotechnology from MIT) who championed new technology-based visions of the future and then attempted to usher in those futures with engineering design work, lobbying of government funding agencies, and campaigning to popularize it with the American public. Hence the title of the book, which is an amalgam of visionary and engineer. And both of these two visioneers had optimistic views of the long term future of humanity based on the impact of these new technologies, in contrast to the prevailing pessimistic view owing to the conflict between an ever-increasing human population and a finite earth.

O' Neill's vision of the future is space colonization—self-contained and self-supporting utopian ecosystems in space for a humanity that needs to escape a polluted planet Earth. Drexler's vision of the future is self-replicating nanofactories that manufacture new materials that solve humanity's need for unlimited energy, food and physical resources, nonpolluted environments, and enhanced health and longevity.

McCray's book does an excellent job in providing the detailed history of both men and the historical milieu these two men confronted. A historian, he describes all of the science and technology perfectly. The book is thorough, balanced (he does not fall in love with the two protagonists), insightful, and well written.

However, this book is fundamentally flawed, and the flaw is in his choice of visioneers. Virtually no scientist around the world has heard of O'Neill and Drexler and for good reason. Their visions of the future were rejected by American scientists, the American government, and the American people. It is very possible that American scientists and the American people fifty or hundred years from now will embrace these visions, but by then most likely they will be based on very different technologies and championed by different individuals who probably have not yet been born. The names of O'Neill and Drexler are already forgotten and most likely will never be resurrected.

In contrast, there are visioneers in the late twentieth century who have changed the present and the future and are worth writing and reading about. The most obvious is Steve Jobs. The second person who comes to my mind is Elon Musk, who is the part owner and driving force behind Tesla Motor, Solar City, and SpaceX companies. Unlike O'Neill and Drexler, these two visioneers had the genius to temper their visions with an understanding of technology in order to bring to market revolutionary products that have changed our society for the better. I find it incredible to read a 280-page book about late twentieth-century American technology where Steve Jobs and Elon Musk are each mentioned only once and in passing.

In closing, this book left me with the feeling that I wasted my time, and I consequently cannot recommend it to anyone else, despite its many good features. If you want to read something very worthwhile on this topic, try *Steve Jobs* by Walter Isaacson.

Birkhäuser

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Jeremy Gray, *Henri Poincaré: A Scientific Biography*. Princeton: Princeton University Press, 2013, xiii + 592 pages. $35.00 (cloth).

The meaning of the term "scientific biography" is illustrated by the entry for Jules Henri Poincaré (1854–1912) in the monumental *Complete Dictionary of Scientific Biography* (Scribner's e-book, 2007). In that 10-page essay by the French mathematician Jean Dieudonné, biography in the usual sense is disposed of in the second paragraph. Everything that follows is scientific exegesis, salted with technical jargon and peppered with equations. Jeremy Gray's 600-page book is composed along similar lines. Of its twelve chapters only the second, entitled "Poincaré's Career," tells the fascinating story of Poincare's life in plain English. (Even here the author, an eminent English historian of mathematics, cannot resist the temptation to flash a second-order partial-differential equation—elementary for physicists, but hieroglyphics for the uninitiated.) Readers should be aware, therefore, that "scientific biography" occupies a special niche between biography and scientific monography; in the level of the mathematical sophistication it demands of its readers it ranges from ignorance to mastery.

Henri Poincaré was a very great mathematician indeed. In France he is a national hero, but in Anglophone countries his works are better known than his story. Most famous is the *Poincaré conjecture* of 1904, which stumped mathematicians for a century until the reclusive Russian genius Grigori Perelman proved it in 2003. (A simple closed curve drawn on the surface of a ball can slide and contract like a rubber band, eventually shrinking to a point. On a donut there are two kinds of closed curves that defy this maneuver. This difference characterizes the two surfaces, which are both two-dimensional objects. The Poincaré conjecture makes an analogous distinction for three-dimensional structures.) Physicists may be more familiar with the *Poincaré group* obtained by adding translations in space and time to the group of Lorentz transformations. Before Einstein or Lorentz himself, Poincaré found "the perfect invariance of the equations of electrodynamics" (p. 373)—which he modestly named the Lorentz group. (p. 16) He was on the path toward special relativity, but since his interest was primarily mathematical, he stopped short of drawing the radical physical consequences that Einstein drew. Another mathematical discovery with profound physical implications arose from Poincaré's attempts to solve the notorious three-body problem of astronomy. Certain spectacular solutions of the equations displayed the phenomenon of "sensitive dependence on initial conditions," (p. 390) which would be rediscovered in a completely different context in 1963, and would lead to chaos theory.

On the more personal side, two Poincaré anecdotes crop up occasionally in the popular literature. The famous incident on the bus at Coutances illustrates Poincaré's maxim that "it is by logic that one proves, by intuition that one invents." (p. 121) He explained that he had been struggling in vain with a certain class of functions which he later called Fuchsian. One day he left for a geological expedition. "The circumstances of the journey made me forget my mathematical work; arrived at Coutances we boarded an omnibus for I don't know what journey. At the moment when I put my foot on the step the idea came to me, without anything in my previous thought having prepared me for it, that the transformations I had made use of to define the Fuchsian functions were identical with those of non-Euclidean geometry. I did not verify this, I did not have the time for it… but I was entirely certain at once." (p. 217) In discussions of the nature of scientific creativity, the bus story takes its place alongside Kekulé's dream of snakes biting their tails, which inspired his model of the benzene molecule.

The second anecdote about Poincaré is no less dramatic, but serves to illustrate the role of logical rigor as a complement to intuition. In January 1889 he won the mathematical competition for a prestigious prize sponsored by the King of Sweden. His contribution concerned the restricted three-body problem, an idealized version of the Sun-Earth-Moon system interacting by Newtonian gravity. His prize-winning essay claimed to prove rigorously that the "moon," assumed to have an infinitesimal mass, could never escape from its parents by running off to infinity. By December of the same year this important paper had been vetted by a number of famous mathematicians and printed in the *Acta Mathematica.* Just before the issue of the journal was to be distributed to its readers, Poincaré discovered a subtle but crucial error in his calculation. As a result, the final conclusion of his theory, though still interesting and important, was much weaker than he had originally supposed. Chagrined and embarrassed, Poincaré submitted a revised version of his article a month later and paid for reprinting the journal—at a cost that exceeded his prize money by half. (p. 279) But a scientific scandal was averted, and the seeds of chaos theory were sown.

These glimpses of Poincaré's busy life reveal but the tip of an iceberg. He published over five hundred books and articles in an astonishingly wide range of subjects in his comparatively short life. The list of his contributions to pure mathematics, physics, philosophy, engineering, science education, and popularization of science is formidable. He even weighed in on national controversies like the infamous Dreyfus Affair in his role of what today might be called a public intellectual. His method has been compared with that of a bee that flits from flower to flower, tasting deeply of its nectar but always ready to fly off to the next blossom. Jeremy Gray's impressive achievement is to follow his subject's erratic path, to read every book and paper, to understand, to compare, and to explain them. He succeeds in the aim he states at the outset, which is to paint "a picture of Poincaré as a man with a coherent view about the nature of knowledge…. What he emphasized above all was the act of human understanding."

In structure the book is unusual. Gray decided to describe Poincaré's popular articles about his professional work in Chapter 1: *The Essayist.* Consequently the reader encounters many facets of Poincaré's oeuvre twice—once in nontechnical form, and then again in a later chapter, in much greater detail. This scheme allows the book to appeal to a wider range of readers, but it creates problems of continuity. Thus the story of the royal competition is split into two parts—the prize, (p. 27) and the subsequent averted scandal. (p. 277) The 250-page gap engenders a considerable amount of leafing back and forth. A reader who stops after the broadly accessible first two chapters (on Poincaré's essays and his career) will be deprived of the fascinating denouement of the story.

The following ten chapters are divided evenly between physics and pure mathematics. (The latter, I confess, exceeded my grasp.) The sequence of chapters is more or less random, but each is organized internally in chronological order. This scheme again makes logical sense, but renders the narrative flow a bit choppy. The topics in physics are the problem of rotating fluid masses, relativity and electron theories, the impact of the theory of functions on mathematical physics, thermodynamics, and the philosophy of science. There is even a short section on Poincaré's minor contribution to the early quantum theory, (p. 378) which he encountered at the celebrated 1911 Solvay Conference a year before his death. The ever quotable Max Planck later offered this magnificent compliment: "An old man will be inclined to ignore the hypothesis, the enthusiast will welcome it uncritically, the skeptic will seek grounds to deny it, the productive man will test it and fructify it. Poincaré, in the profound paper which he dedicated to the quantum theory, proved himself youthful, critical, and productive." (p. 150)

Poincaré's philosophical outlook was astonishingly close to that of many modern students of the foundations of quantum mechanics. In the last chapter Gray writes: "We shall never know about the objects in themselves, but we can say reliable things about the relations they enter into. This was explicitly Poincaré's view," (p. 535) and "Poincaré not only did not believe that one could talk about the primitive constituents of reality, he doubted the very existence of things one could not talk about." This attitude reminds me of Asher Peres's version of the lesson of quantum theory, that "unperformed experiments have no results," and of Bohr's understanding of the nature of physics. I believe it is important to try to understand how Poincaré came to his prescient worldview.

I take away from this book the insight that while the subject matter of science evolves inexorably, so that specific observations and theories lose their urgency, the thoughts and feelings of the scientists of long ago retain their ability to inspire and illuminate. And to really appreciate them you can't avoid digging down beyond the platitudes of the folk history of science, rolling up your sleeves, and wrestling a bit with the details of the original works. That's what Jeremy Gray has done. That's the value of good scientific biography.

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Biman Nath, *The Story of Helium and the Birth of Astrophysics*. Heidelberg: Springer, 2012, 285 pages. $39.95 (cloth).

Helium is the only chemical element ever to be first found anyplace except on earth, despite transitory claims for nebulium, coronium, aldebarium, asterium, cassiopeum, and more. Because the periodic table is now filled at least as far as $Z = 112$ (Copernicium, with a very short half-life) this will remain true at least as long as the only chemists and physicists we know are confined to terrestrial labs. Biman Nath's history of the discovery of helium involves astronomy, chemistry, and physics, and so is particularly appropriate for 2013, which is the centenary both of the Bohr atom and of the first of two short papers by Henry Moseley (1887–1915) that established the primacy of Z (atomic number) over A (atomic weight) for constructing periodic tables and, in due course, for understanding the synthesis of the elements in stars.

The crucial observations in the helium story were made from Guntur and Masulipam, India, during a long total solar eclipse in August 1868 by expeditions under the leadership of Jules Janssen (for France) and James Tennant and Norman Pogson (for England). John Herschel, son of the one most astronomers know, Captain Haig, and Professor Kero Laxuman also observed from other sites in India, and George Rayet (fresh from his 1867 triumph in codiscovering stars with emission-line spectra) from the Malay Peninsula. Nath has spent most of his life and astronomical career in India, which is surely one of the reasons he has chosen to tell this very complex story.

The key observation did not consist of one or more of the expedition members peering into a spectroscope at the eclipsed sun and saying, "A ha! A previously unknown emission line. It must be a previously unknown element, and I shall call it helium!" Rather, there were three steps. First, at least five people saw, during the critical 6 minutes of eclipse, that the spectrum of solar prominences consisted only of emission lines and that some of these had more or less the same wavelengths as previously known absorption lines in the photospheric spectrum. Second was the recognition that you didn't have to wait for an eclipse. Janssen on the spot and Norman Lockyer back in England a few months later used one prism to spread out the light coming from near the solar limb (thereby much diluting the bright continuum and so rendering the emission lines of the prominences visible any old day. They then used a second prism spectrograph to spread out the prominence light and measure the wavelengths of its emission lines. This was important because they could observe for much longer than an eclipse duration, using stably mounted telescopes not subject to wild temperature fluctuations through an eclipse.

Third came identifying the lines. The reddish color of the prominences showed the dominance of hydrogen-alpha (not then called that) emission. But another emission feature was yellowishorange, close in wavelength to the pair of lines in the normal solar spectrum called D by Fraunhofer and identified with laboratory sodium emission by Bunsen and Kirchhoff. Thus the discoverer of helium was whoever first said, "A ha! That is not just a blend of the sodium pair, but a slightly different wavelength, coming from some other sort of atom." In that sense, the discoverer was, according to the author (and many other sources), Norman Lockyer, also the founding editor of *Nature*, and bearer of many other distinctions. Pogson, in writing up his results from the eclipse, expressed some doubt about whether the emission line was actually sodium D, but not loudly enough or to the right audience.

The story is confounded by a chance event. Both Janssen and Lockyer chose to announce the observability of the solar chromosphere (prominences) outside of eclipses in letters to the French Academy. These happened to arrive the same day, though the observing and writing had not been simultaneous. The Academy then struck a medal honoring them both, but for the recognition of the gaseous nature of the chromosphere, not for the discovery of helium, which Lockyer announced somewhat later. Chemists, beginning with Dimitry Ivanovich Mendeleev himself, did not accept helium unreservedly, though most of them folded it in somewhere in the scheme of the world, along with argon, after the two were found in laboratory samples by William Ramsay and Lord Rayleigh (for argon), in 1895–1897. Mendeleev held out until about 1900.

Conflating the two important advances—emission lines from the sun visible without an eclipse and the recognition of the helium line—has been fairly common, with Janssen and Lockyer both being given credit for the latter. Correcting this scientific myth (which is not universal) is one of Nath's major goals, thus the core chapters of his book are the ones dealing with the 1868 eclipse and its aftermath. But he begins with the origins of chemistry and spectroscopy, so that the reader also meets Fraunhofer and Foucault, William Fox Talbot and David Brewster, Bunsen and Kirchhoff, and Huggins and Secchi. And yes, Janssen is given credit for leaving Paris by balloon during the siege, so as to observe an 1871 eclipse from northern Africa. The story loses something when we learn that he was clouded out and that the Germans would probably have given him a free passage out anyway for the scientific purpose. It is possible, however, that he was carrying secret documents as well.

The story is carried onward to Ramsay's laboratory discovery, with a postlude on the risks of attempting to reconstruct the history of any scientific discovery, a part of which is that someone else was always there first (Stigler's Law, so called because it was discovered by Robert Merton). An example from solar spectroscopy is the "pre-discovery" of Fraunhofer lines by Wollaston of the prism.

Different readers will experience surprise, and perhaps disbelief, at different points in the text, depending on backgrounds and previous knowledge. I have given away too much already, but keep your eyes open for two Drapers, a Prevost, and perhaps a (common) misconception of what Doppler shifts in stellar spectra look like.

Do I recommend reading, and perhaps even purchasing, this book to historically-oriented colleagues in physics, chemistry, and astronomy? Definitely yes, though my copy was actually proofs sent by the author for comments. The volume is being reviewed with his permission.

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Jon Gertner, *The Idea Factory: Bell Labs and the Great Age of American Invention.* New York: The Penguin Press, 2012, 422 pages. $29.95 (cloth).

Jon Gertner, the author of this absorbing history of Bell Labs, came to book-writing through magazine journalism, focusing on what he has called "topics that presented some kind of intersection between science, business, and culture." He became interested in the question of how scientific innovations—like the transistor—give birth to new technologies that go on to have a significant impact on society, and wanted more space to explore the issue than even a long magazine feature would allow. Aware that the transistor is among the culture-transforming inventions to come out of Bell Labs in its heyday, and having been raised not far from the Murray Hill campus of the Labs, he settled on his topic. Some five years of research and writing later, rather than the two he anticipated at the outset, this fine book resulted.

As an admirer of T.S. Eliot, I was both surprised and gratified by the epigraph Gertner has chosen to introduce his study of the place where information theory was born—a line from *The Rock,* a pageant play Eliot wrote in 1934 to benefit the churches of London: "Where is the knowledge we have lost in information?" The epigraph, with its suggestion that all progress sows some seeds of destruction, prepared me not only for the institutional rise and fall that forms the dramatic arc of the book, but also for the very empathetic portraits Gertner draws as he tells his tale. While the history of Bell Labs requires Gertner to introduce many interesting men (and a few women), his main subjects are three presidents of the Labs—Mervin Kelly, Jim Fisk, and William Baker—who "served as stewards during the institution's golden age," all of whom "shared a belief in the nearly sacred mission of Bell Laboratories and the importance of technological innovation"; two brilliant and eccentric scientists associated with perhaps the two most important innovations to come out of Bell Labs in its glory days—William Shockley and the transistor, Claude Shannon and information theory; and a director of research at the Labs, John Pierce, whom Gertner calls "The Instigator," for his ability to inspire others to pursue areas of research that Pierce thought especially promising. Pierce is also known as the father of the communications satellite.

Gertner divides *The Idea Factory* into two unnamed parts. The somewhat longer Part One covers Bell Labs from its inception in the early twentieth century through its heyday in mid-century. Part Two follows the company's decline, primarily due to legal suits brought by the Department of Justice and the Federal Communications Commission against the AT&T telephone monopoly that led to its breakup in the 1980s and to its ultimate transformation from AT&T Bell Laboratories to a subsidiary of the French-owned company Alcatel-Lucent in the early twenty-first century.

Bell Telephone Laboratories was born in 1925, a spin-off of the engineering department of Western Electric, which—to my surprise—got its name from its location not on the country's west coast but on West Street, New York, on the western edge of Greenwich Village. Mervin Kelly, who in many ways is the hero of Gertner's story, came to work at Western Electric in 1917. Rising within the company from physicist to director of vacuum-tube development to director of research to executive vice president, Kelly was responsible for establishing the culture of innovation at the Labs that enabled its employees to think of themselves not as technicians but as innovators at "an institute of creative technology," as Kelly once called it. He encouraged interactions among scientists with different specialties, correctly believing that creative solutions to knotty problems could result from such encounters. I was interested to learn that Kelly's hires included many capable individuals who had only high school diplomas, but who were so good at what they did that "PhDs would often speak of them with the same respect they gave their most acclaimed colleagues." All employees, those with tertiary degrees as well as secondary ones, were expected to attend "a series of unaccredited but highly challenging graduate-level courses for employees," which were popularly referred to as "Kelly College." While Kelly expected a lot of his employees, he also encouraged them to spend some fraction of their time working on whatever interested them. By threatening to resign on more than one occasion when he thought that AT&T was not providing sufficient funds for Bell Labs projects, he ensured a reliable funding stream. The steady funding, in turn, meant that the Labs could pursue long-term projects, including the development of communications satellites, of optical fibers to carry information, and of mobile telephones. Above all, Bell Labs had a specific mission, to advance the field of modern telecommunications.

In the final thirty pages of the book, Chapters 19 (“Inheritance”) and 20 (“Echoes”), Gertner first summarizes the effects of the progressive dismantling of the Labs in the wake of several decisions against AT&T’s monopolistic hold on telephone communications and then asks whether any research institutions today can be considered the heirs of the Bell Labs tradition. The decline, which began with the breakup of the Bell System in 1984, was not too dramatic at first, with most Bell Labs employees staying within AT&T, which was now combined with Western Electric. About 10% of the staff went to Bellcore, a new research institution that was to do R&D for the regional phone companies. During this period, research done at Bell Labs led to three of the seven Nobel Prizes awarded to the Labs over the course of its history; one, involving the cooling and trapping of atoms with laser light, was shared in 1997 by Steve Chu, who would become President Obama’s first Secretary of Energy, and two colleagues. Nonetheless, as early as 1986, Bell Labs’ former head of research John Pierce wrote that “It is just plain silly to identify the new AT&T Bell Laboratories with the old Bell Telephone Laboratories just because the new Laboratories has inherited buildings, equipment and personnel from the old. The mission was absolutely essential to the research done at the old Laboratories, and that mission is gone and has not been replaced.”

A second stage of dismantlement took place in 1996, when a new Telecommunications Act allowed the former regional phone companies, which had contributed to the funding of Bell Labs, to compete with AT&T. Most of the Bell Labs staff went to a new company, Lucent, which maintained both the old Murray Hill campus and the name Bell Labs for its research and development. Within a few years, however, as Lucent began hemorrhaging money, it was bought by Alcatel. In summer 2008, *Nature* journalists discovered that only four physicists were working at the new Bell Labs, leading that august journal to publish an article entitled “Bell Labs Bottoms Out.”

Gertner’s final chapter begins with an elegiac tone, by pointing to the wooden telephone poles that we still see around us as among the “enduring aspects” of the empire built by Mervin Kelly and his colleagues. The sense of loss also inheres in the crucial difference that Gertner notes between today’s Silicon Valley venture-capital-based enterprises and Bell Labs: venture firms are “averse, understandably, to funding an entrepreneur seeking out new and fundamental knowledge,” while “The value of the old Bell Labs was its patience in searching out new and fundamental ideas, and its ability to use its immense engineering staff to develop and perfect those ideas.” He thinks that the current Google Labs is a parallel only in that employees are encouraged to spend 20% of their time on projects of personal interest to them.

The book, however, ends on a different, more upbeat note, which took me by surprise. Gertner suggests that the culture at two enterprises in the US today, both of which were totally unfamiliar to me, might be compared to that of the Labs in its heyday. The first is the Howard Hughes Medical Institute’s Janelia Farm Research Campus, located in Loudoun County, Virginia, which opened in 2006, with a focus on interdisciplinary research in neurobiology. With a reliable internal funding stream and a collaborative environment, it emulates two of the important cultural traits of Bell Labs. The second enterprise that Gertner links to Bell Labs is actually the product of a Bell Labs alumnus, Nobel Laureate Steve Chu, who, as Secretary of Energy from 2009 to 2013, set up a number of “innovation hubs” to spur clean energy innovation. In an address to a Senate committee in 2009 Chu specifically said that “the Department of Energy must strive to be the modern version of Bell Labs in energy research.” Coincidentally, on the day I finished reading Gertner’s book and came across this quotation, I also read as breaking news over the Web of Chu’s announcement that he would step down from his Cabinet post in 2013. It remains to be seen if his successor at DoE, Ernest Moniz, a physicist from MIT, will follow through with the Bell Labs-based innovation hubs.

Although my overview of Gertner’s book necessarily leaves out a lot of the human drama on which he builds his story, I hope readers of this review will turn to the book itself to fill in what I have left out. Before concluding, however, I would like to point out some of the many strengths I find in *The Idea Factory*, as well as the very few weaknesses. First of all, Gertner is a very fine writer, capable of crafting sentences like "The history of technology tends to remain stuffed in attic trunks and the minds of aging scientists." He is also a skillful user of analogies, such as the vivid one he uses to describe the effect on Bell Labs of the breakup of AT&T: "One way to think about the fate of Bell Labs is to think of the institution as something akin to a vast inheritance. While staggering as a combined sum, it somehow becomes more modest once it is split, and then split again, in various ways over time among various descendants."

Second, the footnotes at the end of the book are well worth reading. I have long been a fan of Robert Millikan, who was Mervin Kelly's PhD advisor at the University of Chicago, and went on not only to win the Nobel Prize in Physics for 1923 partly on the basis of his oil-drop experiment but also to help found Caltech, where my husband and I have spent two recent sabbaticals. Reading about Millikan's treatment of his graduate assistant Harvey Fletcher in Gertner's footnotes to Chapter 1, however, uncovered Millikan's clay feet for me. It was Fletcher who suggested that they should use oil, not water, to determine the charge of the electron, and who made other crucial changes to the testing apparatus. Today Fletcher would likely have shared the Nobel Prize with his mentor, but Gertner's footnote reveals that "Millikan showed up at [Fletcher's] apartment just before the publication of their results in the journal *Science* to inform Fletcher that he could not earn his PhD through a cowritten paper; Millikan would thus take full credit for the primary oil-drop write-up, he suggested, and Fletcher could earn his doctorate on a different experiment they did together—one for which he could take the sole credit." Although overall Millikan "nurtured Fletcher's talents and made his career in physics possible," Fletcher, a devout Mormon, was unhappy with the ultimatum, but "saw that he had no real alternative," and kept mum about the episode, about which he wrote in his autobiography, available in the Brigham Young University archives.

Third, although all the protagonists in Gertner's story are male, and the main period the book covers certainly predates the rise of feminism and the inclusion of large numbers of women anywhere in the American workplace, much less in scientific roles, Gertner makes a point of mentioning the contributions of women when he can. I was interested to read, for example, that by the late 1930s, the mathematics department at Bell Labs included "several women," and that Claude Shannon's second wife, née Betty Moore, worked in the Labs' computational department, and was thus capable of appreciating her eccentric husband's professional and avocational undertakings. Gertner also takes pains to point out that Bell Labs director of research John Pierce believed that his mother "had a sharper mind than his father." The woman whose work receives fullest coverage in Gertner's treatment, however, is Helen Baker, mother of Bell Labs president William Baker. When she and her husband started a turkey farm in 1913, at a time when the birds were expensive and rarely consumed by American families, she decided to become "an innovator." She collaborated with pathologists at Harvard and Merck to develop medical interventions to protect the birds from the parasitic diseases that frequently afflicted them. Within two decades, Helen Baker's ideas on raising turkeys not only resulted in her own flock of a thousand "Baker's Bronze Beauties" but also led to the techniques later used at industrial turkey producers like Perdue and Butterball. "Other Bell Labs scientists would attribute their laboratory aptitude to their youthful efforts to take apart car engines or rebuild radios. But in helping Helen Baker pursue the perfect turkey feed, her son had found a crude but effective introduction to the precision of chemistry."

A fourth admirable quality of Gertner's coverage is his inclusion not only of Bell Labs' successes but also of its failures. He devotes considerable coverage, for example, to the Picturephone, whose failure to excite the public followed market research that turned out to be flawed. Bell Labs president Jim Fisk's decision to pursue the ill-fated product even when there were clear signs that the public found the device too expensive and not that useful marked a major lapse of judgment on Fisk's part.

Perhaps the most touching aspect of Gertner's writerly skills is the empathy he shows in his portraits of the people through whom he conveys the history of Bell Labs. Particularly after reading in Gertner's Acknowledgments that his father, "the true scientist in the family, died unexpectedly a week before I finished this manuscript," I find his treatment of the end of life of his subjects especially moving, including the deaths of both Claude Shannon and Walter Brattain (one of the inventors of the transistor) following struggles with Alzheimer's, and of Kelly after choking on a piece of steak at dinner in a country club. To Gertner's credit, he also tells the story of William Shockley with great sensitivity, despite the unsavory aspects of this brilliant scientist's unusual career.

By contrast with its many strengths, I find very few flaws, and only small ones at that, in *The Idea Factory*. As the wife of an astronomer, though clearly Gertner couldn't discuss every single innovation of Bell Labs, I missed seeing mentions of the Bell Labs' founding of radio astronomy by Karl Jansky in the 1930s and of Arno Penzias and Robert Wilson's discovery of the cosmic background radiation in the 1960s. Although Gertner tells us that his focus is on six representative personalities whose contributions made Bell Labs what it was, I find his profile of Jim Fisk very thin by comparison with those of the other five. On almost every page I found myself wishing he had provided more dates, so that I would know, for example, how old individuals were, at the time of different events under discussion. I would also have liked a chronology of important dates associated with the Labs included as a feature at the end of the book. And given that Gertner makes interesting connections between invention and creativity at the Labs and the earlier work of Thomas Edison, it would have been nice if he had mentioned that Claude Shannon was a distant relative of Edison's, a fact that I learned from the obituary MIT issued upon Shannon's death in 2001.

These small failings notwithstanding, I highly recommend this book to anyone interested in the history of science and technology. *The Idea Factory* is Gertner's first book, and I hope we can look forward to others in the future.

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W. Bernard Carlson, *Tesla: Inventor of the Electric Age*. Princeton: Princeton University Press, 2013, xiii + 499 pages. $29.95 (cloth).

Nikola Tesla was truly like no one else. Born to Serbian parents in 1856 in the Austrian-Hungarian Empire, he studied engineering at the university in Graz and then made his way to Prague, Budapest, and Paris and eventually the United States. He arrived as a penniless 28-year-old in New York but, trained as an engineer, he quickly found employment in the burgeoning field of electricity and shortly afterwards struck out on his own with great success.

This was the dawn of electrification, the time when practical inventions were numerous and electricity was reshaping both industry and the home. And Tesla was a genius of sorts, both a visionary and a man capable of devising improvements in the machinery for everyday use. His most lasting contribution was in the development of motors facilitating the conversion from direct to alternating current that reshaped the transmission and usage of electricity. This, however, is only a small part of his contributions to scientific creations.

He received many patents for his inventions and regularly found financial backers, including the legendary J.P. Morgan. He succeeded in doing this because he could be very persuasive and was as well a remarkable showman throughout his life. Tall, elegant, impeccably dressed, he lived for much of his early days in New York City at the Waldorf-Astoria Hotel and dined at ultra fashionable Delmonico's though deep down he remained a loner, no known emotional entanglements in his adult life. Along the way he made and lost several fortunes for both himself and his investors.

Deciding that his research needed more space than New York could afford him, he built at one point a large laboratory in Colorado Springs and later one on Long Island. Both were eventual failures because he lacked the practical sense of a man like Edison and, mixed with his visionary genius, there was often what one can only call a certain crackpot element. He actively pursued communication with Mars, though I hesitate to call this crackpot since the existence of intelligent life on the red planet was a common belief. But later in life he would carry on about disproving Einstein's theory of relativity and peculiar notions about atom splitting.

His greatest failure was in the development of wireless communication. Though many of the ideas that went into its realization were Tesla's, it was a far less able man who ultimately succeeded in the venture. Marconi would gain fame and wealth, win the Nobel Prize in Physics, and be ennobled in his native Italy while Tesla lived impoverished in less elegant New York hotels than his early quarters, a largely forgotten man.

Carlson has written an exhaustive biography of Tesla, remarkable for its breadth and thoroughness. He explores and details all his major inventions, providing illustrations and in some cases even reproductions of the patent applications. This is as fair and balanced a biography of Tesla as one could hope for, no mean feat for a man so full of contradictions.

With a deep knowledge of both the history of technology and of the period, Carlson places Tesla in context within the pantheon of scientists of the period, showing how unusual and imaginative he was as well as how wrongheaded he could occasionally be, as in his criticism of Maxwell and Hertz. But Tesla was at root both a dreamer and an inventor, often succeeding and often failing in ways that ultimately made him a tragic figure for many.

In his day Tesla was the forerunner of the creators of Silicon Valley, an individual with a dream, and Carlson ably shows how and why there has been a resurgence of interest in him as the maverick loner, including by some who regard him as the original antiestablishment figure.

My only caveat is, that as an outsider to the field, I occasionally found myself wishing Carlson had let this story be less of a scholarly book and emphasized more its thrilling aspects, thereby opening it up for an even wider audience. But I do realize that Carlson was aiming foremost for an authoritative picture of the man, the field and the times. One must be grateful to him and appreciative for what he has achieved, the writing of a very fine book.

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