BOOK REVIEWS

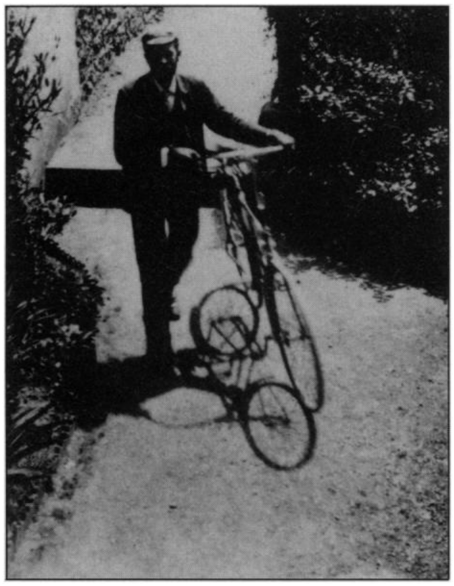
Posthumous Inspirations

The Maxwellians. BRUCE J. HUNT. Cornell University Press, Ithaca, NY, 1991. xiv, 266 pp., illus. $34.95. Cornell History of Science Series.

This excellent book is the story of three men, Oliver Lodge, Oliver Heaviside, and George Francis FitzGerald, whose lives were shaped and whose friendship was made through the study of one book, James Clerk Maxwell's *Treatise on Electricity and Magnetism*. Behind this story is another of how the premature death of one man, Maxwell, caused an intellectual dislocation in science propagating over many years.

To the modern observer used to large communities of interacting scientists it seems almost unbelievable that Maxwell in five major papers and a massive treatise, written over a period of 18 years from 1855 to 1873, could revolutionize a whole science without creating a theoretical stampede. Yet so it was. Not until Lorentz's doctoral dissertation of 1873 did anyone other than he significantly extend the electromagnetic theory of light, and not until February 1879 did Maxwell in a referee's report on FitzGerald's first paper have occasion to offer detailed advice to a younger theorist. That report, which serves as the starting point of Hunt's book, reached FitzGerald on 7 November 1879, two days after Maxwell's death. Lodge and FitzGerald were then 28 and Heaviside 29. They did not know each other, and although the "two Olivers" (as Maxwell called them) had both studied Maxwell's *Treatise* their life work had barely begun. They had the book, but not the author to discuss it with.

Of the three FitzGerald was the cleverest, Heaviside the most profound, and Lodge the most unlucky. Lodge's life teaches the depressing moral that physicists should not take vacations. Early in 1888 he discovered electromagnetic waves. He demonstrated their propagation and reflection along wires and made accurate measurements of their wavelength. Instead of rushing into print he went off to the Alps, confident as Hunt says that "his wave experiments would be the hit of the upcoming meeting" of the British Association for the Advancement of Science in September 1888. That was the meeting at which FitzGerald, unaware then of Lodge's work, dramatically announced that an unknown German, Heinrich Hertz by name, had generated and detected electromagnetic waves in free space.



Oliver Heaviside with his bicycle, early 1890s. "Idiots consider me a madman about the bike; I ride every day," Heaviside wrote to G. F. FitzGerald in May 1899. [From *The Maxwellians*; IEE Library]

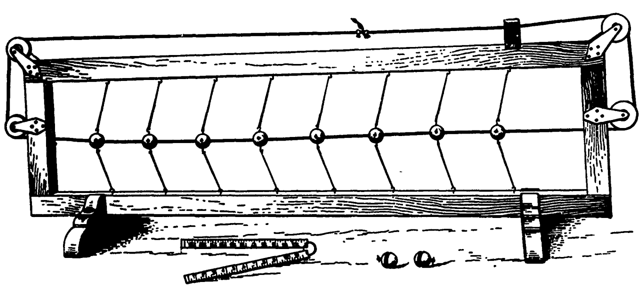
Oliver Lodge and G. F. FitzGerald (with unidentified woman and young man), 1890s. [From *The Maxwellians*; University of Birmingham Library]

The story of Lodge and Hertz, and of the background to Lodge's researches in Heaviside's work on telegraphy, is told in the sixth and seventh chapters of Hunt's book. It is, like most tales of discovery, far more complex than our easy hindsight would suppose. It had its human side, pleasant and unpleasant—the ugly treatment Heaviside received from William Preece, the head of the British Post Office Telegraph Department, the generous response of Lodge to Hertz's triumph. The later brief correspondence between Heaviside and Hertz is among the most interesting in the history of physics.

Heaviside was "a first rate oddity," a scientific hermit. FitzGerald was among his best friends, yet the two men only met twice. Hunt describes Heaviside's Dickensian childhood in London and then the way in which at 17 he had laid the foundation of a rich scientific education through reading the works of Newton, Laplace, and Hamilton. Too poor to attend a university, too antisocial to attend scientific meetings, he slowly made himself master of Maxwell's ideas, and with help from FitzGerald and Lodge gained the reputation he deserved. It was he who first recast Maxwell's eight equations of the electromagnetic field into the four now called "Maxwell's equations." It was he, before Gibbs, who developed vector analysis. He invented the crucial idea of the inductive loading of cables and contributed significantly to the theory of duplex telegraphy (the beginning of communications theory). His mathematical methods have been much praised, though two of the best-known—the operator calculus and the "Heaviside step function" (from which came Dirac's delta function)—are not strictly his. The step function appears in Maxwell's *Treatise*, and the operator calculus was developed by D. F. Gregory and others at Cambridge in the 1830s.

Maxwell founded the Cavendish Laboratory at Cambridge, and most of his British followers were Cambridge men. Hunt's trio were not. Heaviside had no university connection; Lodge gained an external degree (that is, one based on part-time study) at London University and went on to become a professor at Liverpool; FitzGerald lived all his life in Ireland. Hunt argues persuasively that this outsidedness drew them together, though FitzGerald was anything but a social or academic outsider. He was from one of the high Irish Protestant families with connections to Trinity College, Dublin, in its greatest days. His father had been a professor there before becoming a bishop in the Church of Ireland. His uncle, George Johnstone Stoney, also a Trinity man, was a physicist of distinction who deserves remembrance as a pioneer in molecular physics, theoretical spectroscopy, and electron theory. (He invented the word *electron*.) It was from this privileged background that FitzGerald, himself a professor at Trinity College from the age of 30, came to play his special role.

FitzGerald is now remembered for his "contraction" hypothesis to explain the null result of the Michelson-Morley experiment. In reality he did much more. He pioneered the electromagnetic theory of metallic reflection, introduced "retarded potentials" into Maxwell's theory, and derived in 1883 the fundamental equation of radio according to which the radiated power from an oscillating electric charge is proportional to the fourth power of its frequency. Still the contraction hypothesis was his most brilliant idea. The problem is well known. If, as Fresnel had supposed, the earth moves through a fixed ether, then the round-trip travel time for light as measured in an interferometer moving with the earth should be greater for along-track than for cross-track signals. In 1887 Michelson and Morley conclusively demonstrated that the two times are the same. The obvious explanation was that the ether is "convected" (that is, dragged along with the earth) as Stokes had hypothesized for other reasons in 1849; and that was what Michelson thought he had proved. FitzGerald advanced the much more daring idea that the interferometer contracts along the direction of motion by an amount that exactly compensates for the expected delay.



Oliver Lodge's string-and-button model of an electric circuit, devised in the 1870s to illustrate Maxwell's theory of electric conduction and dielectric polarization. "The string runs through slots in the buttons, which are attached by rubber bands to the wooden frame. By tightening or loosening the screws holding the buttons to the string, the model can be made to represent either a dielectric or a conducting circuit." [From *The Maxwellians*]

Most physicists hear of this, dismissively, as an ad hoc guess to be contrasted with Einstein's profound kinematical deduction of the relativistic contraction in 1905. In fact, as Hunt demonstrates in one of his most rewarding sections, it followed a fascinating exchange between Heaviside, FitzGerald, and Lodge, at which Heaviside during his first meeting with FitzGerald (8 February 1889) explained a recent result of his, to the effect that the equipotentials around a moving electric charge assume an elliptical shape proportional to $\sqrt{1 - v^2/c^2}$. FitzGerald argued that matter is held together by electric forces and undergoes the same contraction. *Science* should take pride in being the journal in which FitzGerald chose to publish this result, in a letter dated 2 May 1889. So careless was FitzGerald of his jewels, however, that he never bothered to find out whether the letter had appeared (as it did; *Science* **13**, 390 [17 May 1889]).

FitzGerald died at 50 in 1901. With his death the inspiration went out of the little group of friends. Heaviside's reclusiveness got the better of him; Lodge, who lived on to 1940, contributed to the development of radio but achieved most fame as a scientific popularizer and advocate of spiritualism. The personal dynamics of physicists as of other people is mysterious. Sometimes the full power of the individual human spirit is only apparent after it has been removed. That is one of the unexpected lessons of *The Maxwellians.*

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Complexities of Feynman

Genius. The Life and Science of Richard Feynman. JAMES GLEICK. Pantheon, New York, 1992. x, 533 pp., illus., + plates.

Richard Feynman, the subject of this extraordinary, complex, but very readable book, was, of course, not just the joker and self-created legend of *Surely You're Joking, Mr. Feynman!*, nor was the celebrated incident of the Challenger Commission, described in its sequel, *What Do You Care What Other People Think?*, more than a footnote to his real career. Feynman was undoubtedly one of the great geniuses of modern physics, one of the finest among an extraordinary generation who built, on the basic framework of quantum theory and relativity, the accurate, detailed, wide-ranging, and beautiful edifice that is modern physics. His personal aura was such that, as Gleick relates, his mere presence changed the sound level in an auditorium or caused a visible stir in a student cafeteria. And for all his determined pose as a "natural man" with the unmistakable accents of Far Rockaway in his voice, Feynman was one of the greatest expositors of the methodology and of the beauty of science.

In Gleick's account we follow Feynman from Far Rockaway, M.I.T., and Princeton to his extraordinary two years of leading the computational group that made the crucial calculations for the atomic bombs (calculations that, incidentally, were unprecedented in method and scope). Feynman's wartime boss, Hans Bethe, then persuaded him to come to Cornell, where after a brief sterile period of decompression he solved the difficulties of quantum electrodynamics in a burst of renewed energy, using a revolutionary methodology that remains at the core of all of quantum physics (which is of course all of physics, in a sense). Then to Caltech, via an episode in Brazil that included a stretch in a samba band, and to a long career of further research that alone would have been distinguished enough to win him the Nobel Prize—say, for his quantized vortices in liquid helium, or for the theory of the weak interactions, for which Murray Gell-Mann and he invented the crucial apparatus of current algebra.