excludes figures like the inventor Nicola Tesla, who worked for Edison when he first came to America and blamed Edison for his frustrations in selling the superiority of alternating current. The apparent decision to limit this narrative to evidence from the voluminous papers in the Edison archive narrows Israel's biography, making it very much like a memoir written by a wise and sympathetic observer.

BOOKS: PHYSICS

The Long Life of a Thoughtful Teacher

Frank Wilczek

The content of this book is more accurately conveyed by its subtitle, *A Life in Physics*, than by *Geons, Black Holes, and Quantum Foam* because it is very much an account of John Wheeler's life. Physics is the central strand, but no topic is presented in depth and there are few substantial departures from a straight biographical narrative. In particular, the farther reaches of general relativity appear only in the last third of the book, and then only in very soft focus. The false advertising is unnecessary: Wheeler is such a remarkable scientist and has so many students, friends, and admirers that his autobiography will attract a wide audience.

Geons, Black Holes, and Quantum Foam
A Life in Physics
by John Archibald Wheeler with Kenneth Ford
Norton, New York, 1998. 380 pp. $27.95, C$39.99. ISBN 0-393-04642-7.

Wheeler's early research was mainly in nuclear physics. Notably, he collaborated closely with Niels Bohr on the liquid drop model of nuclear fission. Their work was of immense practical importance, since it guided efforts leading to the atomic bomb. Moreover, it was among the first where dynamics of "medium sized" (in the current jargon, mesoscopic) objects, at the border between quantum and classical behavior, were analyzed. This subject is undergoing something of a renaissance in the new context of microelectronics, and the beautiful mathematical methods Wheeler developed retain their vitality.

Wheeler strikes a rare wistful note in discussing the development of the "unified model" of nuclei. Roughly speaking, this approach constructs a flexible mathematical description that accommodates both the continuum, liquid drop, picture of a nucleus and the alternative, seemingly very different, picture based on a gas of protons and neutrons. The consistent scheme also supports the formulation of fruitful pictures combining gas and liquid aspects. Wheeler started to develop this idea, but got delayed awaiting Bohr's reactions and was distracted by the whirl of wartime and immediate postwar activity. In the end he was scooped by Rainwater, Aage Bohr, and Mottleson, who received Nobel Prizes for their work.

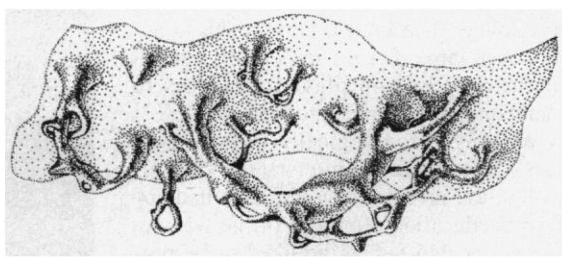
Unlike most of his colleagues, Wheeler continued to be heavily involved in government and military work after the war years. He brought real passion to his research on thermonuclear weapons, partly stemming from the death of his younger brother toward the end of World War II (one of many deaths that Wheeler thinks might have been avoided with a more vigorous scientific effort). The book contains much material on his experiences in this work, which will be of value to historians and policy-makers.

A second main strand in Wheeler's scientific career was quantum electrodynamics. In the early 1940s his world-line intersected that of Richard Feynman, who became his graduate student. The two obviously enjoyed one another immensely, and in their individual papers they frequently refer to each other. Their main collaboration concerned a novel formulation of electrodynamics, in which one eliminates the electromagnetic fields and formulates a self-contained theory of charged particles alone. The finite speed of propagation of influence, which ordinarily appears in the equations for how fast the fields respond to perturbations, is instead encoded in forces that depend on where other particles were in the past. But the most startling feature of their formulation is this: Due to the time-reversal symmetry of the basic equations, the forces also depend on where other particles will be in the future! Wheeler and Feynman showed that under most circumstances the conventional behavior would nevertheless emerge statistically. This work has so far not had much impact on the progress of physics, but it may yet. For although the working assumption of current physical theory is that, early on, our present complicated universe emerged from a much simpler state, there is one notoriously puzzling case where the future seems to be simpler than the past—apparently it is in late history of the universe, not at its origin, that the cosmological term vanishes.

Another startling Wheeler idea from this period is that positrons are electrons traveling backward in time. Then there could be in the universe just one ur-electron, which travels both forward and backward in time to look like many electrons and as many positrons. That would explain why all electrons are alike. In its naïve, cosmological application this idea is certainly wrong, but Feynman exploited Wheeler's backwards-in-time picture of positrons in his great work on quantum electrodynamics.

The third phase of Wheeler's research began in his late 40s, when he took up general relativity. Ironically, his initial goal was to show that something as absurd as the singularities that Oppenheimer and Snyder predicted would arise from stellar collapse could not exist. After lengthy struggles probing all loopholes, Wheeler became convinced that, in fact, their analysis could not be avoided. He named, and became an eloquent advocate for, "black holes." Through his own work, by training a remarkable group of students, and by his extravagantly eloquent writings, Wheeler helped bring what had been a backwater of physics into vibrant new life. This story, only sketched here, is spelled out in his wonderful, accessible books *Spacetime Physics* (with Taylor), *Gravitation* (with Misner and Thorne), and *A Journey into Gravitation and Spacetime*.

Many scientific autobiographies are spiced with sharply expressed views of historical events, gossip, and critical judgments on current scientific issues. In Wheeler's book there is relatively little of this (a mild exception was mentioned above). Instead we find extended tributes to his parents, many briefer ones to colleagues and students, a celebration of his long and harmonious marriage, and many happy photographs. We sense the essential sweetness of a life in which great gifts were fulfilled. Those who know "Johnny" will recognize him here, and others now have the chance to see how a remarkable man achieved seemingly eternal, joyful youth.



Quantum foam. At 10^{20} times smaller than the size of a proton, spacetime is stirred into a "writhing turbulence of myriad multiply connected domains," ordinary ideas of length are lost, and ordinary ideas of time evaporate.

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