Wizard of domes

David E.H. Jones

Inventions: The Patented Works of R. Buckminster Fuller.
By R. Buckminster Fuller.
St Martin's Press: 1983. Pp.316. 1.75 kg, $40.

THE most dramatic spiritual conversion leaves the same person underneath. R. Buckminster Fuller, whose 28 patents are collected in this heavy tome, is a case in point. In 1927, at the age of 32, seeing himself as a total failure and contemplating suicide, he made instead a profound resolution to commit "ego-cide". Abandoning concern for himself, he dedicated his life to the problems of all humanity, to find out what one man could do to solve them. As the subject of this personal experiment, he nicknamed himself "Guinea Pig B" (B for Buckminster). What shines through this work is that Guinea Pig B was an outrageous egotist.

Fuller is an appalling writer. He is capable of explaining his commitment to a "never-again-for-self-use employment of my omni-experience-gained knowledge". And since this book consists of his patent applications — a forbidding literary form even in skilled hands — and his adulatory comments upon them, reading it is like trying to bicycle through sand. Furthermore, Fuller's ideas are very variable. Some of his inventions, such as his "Dymaxion car" of 1933, now seem very shallow exercises; and his thinking is often woolly. Thus he repeatedly claims that some of his structures are far stronger than stress-analysis would predict, and that a mysterious "synergy", unpredicted by the properties of their components, is at work within them. He is also given to sloppy philosophy and sixties-style eco-nut moralizing. This aspect of his thinking cannot command respect.

But Fuller was also one of the great originals of American engineering. He could imagine in three dimensions, and his most interesting patents are those concerned with three-dimensional structures: 11 geodesic domes, one space-filling girder lattice, and a world map. They were devised between 1944 and 1975; his major contribution to engineering only began to crystallize 30 years after he began his career as Guinea Pig B. Geodesic construction was not new when he came to it (Barnes Wallis had used it in the Wellington bomber). But his development of it into a practical architecture for big domes shows real engineering genius. And tensegrity construction is Fuller's alone, and it is wonderful. It produces a rigid stressed lattice with no continuous compression frame; Patent 15, which introduces this seemingly impossible form of construction, is to my mind the most compelling in the book. It is worth persevering with the convoluted description to gain an understanding of how such an audacious structure can work. The idea is a splendid vindication of Fuller's resolve of 1927: it exemplifies perfectly what one independent and original mind can contribute to the world.

And yet for engineers, tensegrity construction is still just a clever idea. Even the geodesic dome remains a specialized and rather self-conscious architectural form. And none of Fuller's other inventions has been seriously taken up, or has contributed to the idiom of modern engineering. Not much of Fuller's thinking has changed the world we live in; in a sense, his most important invention was himself. For over half a century, Guinea Pig B pursued his individual path of engineering creativity quite outside the American scientific and technological establishment. But this his last book, beginning with his relentlessly congratulatory introduction and ending with his 43 honorary degrees (each with its fulsome dedication) compels the thought that, so far at least, the main global effect of his bold and courageous career of self-effacement has been to gain renown for its author. □

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Waves, particles and paradoxes

John Stachel

The Tiger and the Shark: Empirical Roots of Wave-Particle Dualism.
By Bruce R. Wheaton.
Cambridge University Press: 1983. Pp.355. £22.50, $39.50.

X-RAYS have become a household word through their medical uses. Yet their discovery by Wilhelm Röntgen at the end of 1895 launched a tremendous publicity wave for the phenomenon, a then exotic and glamorous topic. Röntgen must have been one of the earliest physicists to pen the now familiar complaints: "I could not recognize my own work in the reports any more . . . . Gradually I became accustomed to the uproar, but the storm cost time. For exactly four weeks I have been unable to do a single experiment!". The glamour gradually wore off, but puzzlement as to the nature of the new radiation did not.

The object of Bruce Wheaton's book is

> . . .to clarify the developing understanding of X-rays and related phenomena early in the twentieth century. But it is the physicists' growing awareness that [classical] electromechanical explanations of the radiation would not work in principle that forms the real subject of this book [p.2].

The method by which he seeks to realize this goal is a detailed reconstruction of the course of experimental and theoretical studies of X- and γ-rays, and some related topics in optics and atomic structure, from the discovery of X-rays until the presentation of de Broglie's thesis in 1924, summarizing his work on the wave–particle duality for ordinary matter. One of the most striking featues of the book is the meticulous care with which experimental investigations and the theoretical controversies which they stimulated are reconstructed. The rigour with which Wheaton strives to avoid introduction of anachronistic elements into his discussion (he apologizes profusely at one point when he feels such an omission would be too confusing), helps to convey to the reader a real feeling for the "state of the art" at various periods, including the confusions and wrong turns, as well as a sense of the undoubted if irregular long-run progress made in the understanding of these new and puzzling phenomena. Here we are far indeed from sanitized text-book versions of the history of great scientific discoveries. This feature of the book should make it of interest to many readers with a general interest in the history of science, over and above its obvious appeal to specialists in the history of quantum theory.

Wheaton details the early controversies over whether X-rays were particulate or electromagnetic in nature; and, if electro-

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magnetic waves, whether transverse or longitudinal, pulse-like or periodic. He stresses the key role that the pulse interpretation played in the transition between classical and quantum viewpoints. Once the wave view predominated, studies of the ionizing properties of the new radiation confronted physicists with what Wheaton calls the paradoxes of quantity and quality: how could any wave-like disturbance, whose energy spreads out spherically from a central target, ionize only a few of the atoms in the surrounding region; and how could secondary electrons so produced each have about as much energy as the primary electrons whose deceleration at the target produced the rays in the first place?

Physicists here faced the fundamental paradox which was to remain unresolved for two decades: a wave-like disturbance manifested properties most readily explained by the assumption that the disturbance consisted of particles! Attempts to dodge this paradox are considered by Wheaton, notably the triggering hypothesis (X-rays only trigger the release of energy stored within the atom) and Bragg's attempt to suppress the wave aspect of the paradox by asserting that X-rays were nothing but a particle beam. Such attempts were definitively ruled out by the discovery in 1912 of X-ray diffraction by crystals.

Similarly paradoxical features of visible light had been elucidated since 1905 by Einstein who, by 1909, was publicly calling for a theory of light which somehow united wave and corpuscular aspects. Wheaton suggests that "our story developed quite independently" of Einstein's "imaginative and prescient statistical treatment of light" (p.xvii). But recently discovered letters from Einstein to Sommerfeld (*Physikalische Blätter* **40**, 29; 1984) show that Einstein was involved in the discussion, during 1909 and 1910, between Stark and Sommerfeld over the interpretation of the observed angular asymmetry in X-ray intensity. Einstein stressed the paradoxical features, insisting (at a time when this was not clear to everyone) that light and X-rays differ "only quantitatively".

The little Wheaton has to say about Einstein's role in the quantum story includes one major inaccuracy. He insists that Einstein's special theory of relativity was "diametrically opposed to the aether ontology", and succeeded in "eliminating the aether altogether" (p.106). Einstein was at pains to stress (in one of the aforementioned letters to Sommerfeld, among other places) that relativity theory required no stand on such ontological issues. It forced relinquishment of a *mechanically* interpreted aether, but was quite compatible with a non-mechanical aether. Indeed, Einstein's earliest attempt to resolve the wave–particle paradox was a unified theory (of electrons and light quanta) based on such a non-mechanical aether field.

X-ray diffraction work, together with the inhibiting effects on research of the First World War, put a temporary stop to most experimental studies of the particulate aspects of radiation (with the notable exception of Millikan's work on the photoelectric effect). The great successes of the Bohr theory from 1913 on in understanding atomic structure and identifying atomic energy levels posed most acutely the question of the photoelectric effect and its X-ray and γ-ray analogues. Post-war work on these problems made it more and more difficult to avoid facing up to the wave–particle paradoxes, first glimpsed over a decade earlier. Maurice de Broglie's group in Paris, which included his younger brother Louis, played a prominent role in this research. Wheaton shows how this work formed a natural background out of which Louis's brilliant idea of transferring the wave–particle paradox from radiation to matter could emerge. With a brief indication of the stimulating effect of de Broglie's work on the ideas of Einstein and Schrödinger and the experiments of Davisson and Germer the book ends. Readers may want to consult Vol.1 of Mehra and Rechenberg's recent *Historical Development of Quantum Theory* (Springer-Verlag, 1983) for additional details on and somewhat different interpretations of de Broglie's work and various other topics treated by Wheaton.

Wheaton tries to weave into the book a running contrast between "the mechanistic bias of British physicists" leading to the "British proclivity to seek mechanical models" (pp.5–6) and "German mathematical physicists" who "were not deterred by an inability to represent physical concepts mechanically" (p.7). He himself notes that "Larmor in Britain held views similar to those of many Germans" (p.7) and we can at once add the names of Poynting, Campbell, Pearson and Eddington to the list of British crusaders against mechanism. On the other hand, prominent German theoretical physicists such as Voigt, Boltzmann and Helmholtz (and the adolescent Einstein in his first scientific essay!) expended considerable effort to construct mechanical models of the electromagnetic aether. Given that we are talking about a small number of physicists in each country, it is hard to see which names go to make up the rule and which constitute the exceptions. It would seem wiser at this time to try to trace out the growth and interrelationship of smaller units, such as schools centred around leading figures or centres of physics research, rather than attempt to make sweeping generalizations about national styles of scientific research. For example, how would Wheaton explain the fact that "Deutsche Physik", of which Lenard and Stark were to boast a decade after Wheaton's story ends, prided itself on just those characteristics he attributes to British proclivities? □

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Putting the heavens to order

Owen Gingerich

Ptolemy's Almagest.
Translated and annotated by G.J. Toomer.
Duckworth, London/Springer-Verlag, New York: 1984. Pp.693. £55, $64.

CLAUDIUS Ptolemy's geocentric system has long since been dumped into the dustbin of discarded theories. Why, then, is anyone still concerned with his hoary treatise? It is because Ptolemy's *Almagest*, more than any other book, convinced people that the seemingly complex phenomena of the heavens could be represented by a simple

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Star gazer — Ptolemy depicted on the Campanile del Duomo, Florence.

underlying mathematical description, one that afforded the possibility of continuing prediction of celestial events. Certainly this was a milestone in the development of science.

G.J. Toomer's new English edition of Ptolemy's classic treatise is more than just a fresh translation. It is a most intelligently arranged presentation with a running, critical commentary at the foot of nearly every page, and it is based on a new reading of both the Greek and Arabic manuscripts. Included are a score of supplementary diagrams that clarify (especially) Ptolemy's instruments and his complex latitude theory, a brief introductory section that clues in the reader with respect to the technical background that Ptolemy assumes (such as ancient calendarial systems), and three appendices that give examples of numerical problems and textual variants. What Toomer has produced is the best edition in any language, one that will remain the standard preferred text for years to come. *Ptolemy's Almagest* is clearly the most important volume for the history of ancient science since O.

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