Stephen G. Brush's "major," "large" and "splendid" History of Planetary Science

A History of Modern Planetary Physics

Stephen G. Brush
Vol. I. Nebulous Earth: The Origin of the Solar System and the Core of the Earth from Laplace to Jeffreys. 311 pp. $54.95 hc ISBN 0-521-44171-4
Vol. II. Transmuted Past: The Age of the Earth and the Evolution of the Elements from Lyell to Patterson. 134 pp. $44.95 hc ISBN 0-521-55213-3
Vol. III. Fruitful Encounters: The Origin of the Solar System and of the Moon from Chamberlin to Apollo. 354 pp. $54.95 hc ISBN 0-521-55214-1
Cambridge U. P., New York, 1996.

Reviewed by Curtis Wilson

The three-volume *A History of Modern Planetary Physics* by Stephen G. Brush is a major work, large in scope and splendid in execution. Brush, well known for his detailed studies of the history of kinetic theory, thermodynamics and statistical physics, here traces the emergence of the historical science that he calls "planetogony," a study of origins. Beginning with a conjectural hypothesis two hundred years ago, this science has had its periods of uncontrolled speculation and critical rebuff, faltering advance and stalemate. In our century, powerful auxiliary sciences and technologies have been brought to bear; solid advances can be reported, and theorizing is more narrowly constrained by facts. Nonetheless, large questions remain. How to tell the story?

Brush confronts us with the detailed actuality of conflict and cooperation in scientific work. He acknowledges the winds of doctrine, the fashions that come and go and then return, the underdogs unjustly forgotten. He compares theories of scientific method with facts of scientific practice. He finds Popperian theory inapplicable to a historical science and other theories sometimes apt, sometimes not. His focus is on the science as the scientists see it, its questions and achievements. In "planetogony" these are multiple and intertwining. Not the least of his tasks has been the organizing of a vast body of material.

The 19th-century part of the story has been told before, although Brush analyzes it masterfully and documents it thoroughly. It is dominated by the nebular hypothesis, proposed by Pierre-Simon Laplace in 1796 to account for features of the Solar System that Isaac Newton had attributed to God's design. The epithet "nebular" expresses William Herschel's proposal (published in 1811) that the nebulae he had discovered exhibited progressive stages of condensation from the gaseous state to solid stars and planetary systems—an idea finally discarded only in the 1920s. In Laplace's scenario, the Solar System arose from a hot, rotating cloud of gas, which shaped itself into a flat disk and contracted upon cooling. At the periphery, as centrifugal force came to balance gravitational attraction, rings separated and somehow consolidated into planets and satellites.

Part I of Brush's first volume is devoted to the 19th-century vicissitudes of this hypothesis. Speculative thinkers such as Robert Chambers and Herbert Spencer embraced its evolutionary perspective. Physicists such as James Clerk Maxwell and Edouard Roche and astronomer George H. Darwin analyzed physical aspects of the scenario. More dramatically, from the 1860s onward, William Thomson (later Lord Kelvin) injected the second law of thermodynamics into the discussion. Assuming that the Sun's heat arose by gravitational condensation, he deduced for the Earth an age of only 100 million years. By the 1890s he had reduced the figure to about 20 million years—far too brief a time for the processes of Lyellian geology or Darwinian evolution.

Part II of the first volume concerns the Earth's interior: solid or fluid? In a descent into the Earth's crust, the temperature goes up. The nebular hypothesis suggested that the interior was gaseous or molten. Gradual cooling would lead to crinkling of the crust, mountain-building and earthquakes. Kelvin, however, claimed that the Earth must be as rigid as steel, hence quite solid, otherwise lunar tides would violently disrupt the crust. In the end, seismology disproved Kelvin's contention. Analysis of seismic waves led successively to recognition of the mantle–core transition at a depth of 2900 km (Beno Gutenberg, 1912), the fluidity of the core (Harold Jeffreys, 1926) and the solidity of an inmost core (Inge Lehmann, 1936).

Brush's second volume tells how the questions of geochronology got settled. Radioactivity, discovered by Henri Becquerel in 1896, overturned Kelvin's chronologies for both the Sun and the Earth. Radioactive dating eventually led to a consensus, articulated by Clair C. Patterson in 1956, of 4500 million years for the age of the Earth. (In the 1940s high estimates for the Hubble constant made it appear that the universe was younger than the Earth—a paradox that drove Hermann Bondi and Thomas Gold to propose a "steady-state theory of the expanding universe.") On the level of theory, radioactivity led to an understanding of the synthesis of the chemical elements in the stars—the astrophysical context for "planetogony"—to which Brush devotes a section.

In the third volume, Brush gives us his account of 20th-century "planetogony," down to 1985 (earlier accounts generally stop at mid-century). This is the *pièce de résistance* of Brush's work. The story is difficult in the telling because of its complexity; the tangled strands do not converge; there is no neat conclusion. Still unsettled are such questions as, How did the giant planets form? Do solar systems tend to form of themselves in stellar evolution, or is their emergence rare and unlikely? Brush enables us to see how small steps have led to cumulative progress. At the beginning of the century, Thomas C. Chamberlin and Forest R. Moulton promoted, in opposition to the nebular hypothesis, the planetesimal hypothesis, according to which

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planets would arise by the gravitational concretion of solid particles at low temperatures. Viktor S. Safronov revived and elaborated this hypothesis in the 1960s, and it is now accepted for the origin of the terrestrial planets.

All the theories of the Moon's origin proposed before the Apollo Moon landings of 1969—fission from, capture by or co-accretion with the Earth—became untenable when the rocks returned from the Moon proved to be as old as the Earth and significantly dissimilar. "Selenogonists," again to use Brush's term, now favor a giant impact of a Mars-like object with the Earth for the Moon's origin. During the late 1970s and early 1980s, scholars adopted the idea of a supernova trigger for the formation of the Solar System to account for isotopic anomalies; the idea was given up when the anomalies proved to be explicable otherwise. Accretion disks, long a subject of theory, have now been observed. And so on. Brush's account of many of the episodes is enhanced by his personal correspondence with the scientists involved.

Brush's text (all 600 pages of it, in 9-point type—I used a Bausch and Lomb magnifier to assist my aging eyesight) is workmanlike and probingly thoughtful. His overlapping reference lists for the three volumes run to 167 pages. This will be a standard work for a long time to come.

The Pioneers of NMR and Magnetic Resonance in Medicine: The Story of MRI

James Mattson and Merrill Simon
Dean Books, Jericho, N.Y., 1996. 838 pp. $75.00 hc
ISBN 09619243-1-4

This book gives a history of nuclear magnetic resonance (NMR) and brief biographies of nine NMR researchers, each of whom receives one chapter in a book of 840 pages. Magnetic resonance in medicine is not really addressed until late in chapter 7, and the book then tells a story about MR, but not *the* story.

The Pioneers of NMR and Magnetic Resonance in Medicine was written by James Mattson and Merrill Simon to commemorate the 40th anniversary of the Bar-Ilan University in Israel and to recognize that university's current research in MR. Simon is an engineer, writer and business consultant; Mattson is a professional technical writer. The book's content, up to chapter 8, is well researched and fascinatingly presented. Reference lists that follow each chapter are extensive and will prove useful in scholarly pursuits. This book is a "must read" volume for all serious students of NMR in chemistry, physics or bioscience for its early NMR biographies. However, it contains errors specific to scientific and technical ideas and misinterpreted nomenclature; the reader should beware. I also have serious objections to chapters 8 and 9, which purport to deal with the MRI story. These chapters appear astonishingly biased, as if written to sell a political candidate.

Seven of the early NMR scientists described in the book worked with atomic beams or small-sample magnetic resonance: I. I. Rabi, Norman Ramsey, Edward Purcell, Felix Bloch, Nicolaas Bloembergen, Erwin Hahn and Richard Ernst. All but Hahn are Nobel laureates, Bloch and Purcell for first measuring NMR signals directly. Hahn, Purcell, and Ernst have biomedical research experience, including MRI experience for Ernst. The other two scientists profiled in the book, presumably for their work on MRI, are Paul Lauterbur and Raymond Damadian. I personally know and like all of the principal scientists involved in the era of MRI breakthroughs, invited both Lauterbur and Damadian to give seminars and colloquiums at the University of Wisconsin in the early 1970s, and I stayed informed of their work. But Mattson and Simon's treatment of these two men and what they accomplished rather spoils this book for me.

There is wide agreement on the *real* story of MRI among scientists who attended advanced MR conferences in the 1970s, who heard and understood the exciting technical developments then being disclosed or who read conference papers and later refereed publications. Nuclear magnetic resonance was developed as a medical imaging modality, independently and nearly contemporaneously, at two universities. That work was done primarily by Lauterbur at the State University of New York at Stony Brook and, slightly later and in a different mode, by Peter Mansfield at Nottingham University in England; each of them worked with many of their immediate and now famous colleagues. Mansfield was knighted for that outstanding scientific achievement and was celebrated internationally at a special MRI conference organized at Nottingham in the spring of 1994, when he also opened the Centre for MRI Study Nottingham, the very first such institute in a department of physics.

Lauterbur had concentrated on developing the basic scientific principles for MRI (1971) and reduced those principles to a practical demonstration in an elegantly simple way. He later worked on full MRI systems with slow acquisition but greater flexibility for research, including MRI microscopy. He announced his results very early, at the Krakow, Poland, NMR conferences, with later fully peer-refereed publication in 1973. Mansfield followed Lauterbur, and his objective was more difficult: EPI, or echo planar imaging, which generates extremely fast "snapshot" MRI; it is a stop-motion mode that in the latest machines can acquire data for a full resolution slice in less than 45 milliseconds. Both Mansfield and Lauterbur used the modern method of post-excitation field-gradient encoding to Fourier sensitize holistic MR "echo-FID" data, but employed very different temporal sequences. Mattson and Simon seem to downplay all of this, including publication submission dates.

We get less than even half of the story of MRI in *Pioneers*. Lauterbur is conspicuously not listed in this book's prologue of scientists who read and approved chapters about themselves. Mansfield and his colleagues' roles are attenuated by their portrayal as quaint, tea-sipping Upper Midlands academic onlookers—at least some comic relief to those who know the old Nottingham gang. (Ironically, all MRI scans shown in chapters 8 and 9 were taken using Lauterbur–Mansfield–Ernst field-gradient modulation methods.)

Damadian, on the other hand, published a short but very novel NMR paper in *Science* (volume 171, page 630, 1971), about T1 (spm-lattice relaxation) in a category of fast-growing tumors, compared with healthy tissues. He implied that it would be desirable if one could perform *in vivo* scans of humans. The T1 results were seminal for oncology and widely cited for some time, but unfortunately, they did not apply to human cancers. It is truly ludicrous to propose, then, that Damadian's scientific contributions even remotely approach the achievements of Lauterbur, Mansfield and their colleagues.

Nor is there any evidence presented that Damadian had the slightest clue about how actually to build an NMR scanner until well after at least a dozen other labs were installing MRI units based on the Lauterbur–Mansfield–Ernst gradient modulation methods.

I am against Damadianizing the story of MRI; it is totally unwarranted. As was the case with Sonny Klienfeld, who wrote *A Machine Called Indomitable* (Time Books, 1986), we must assume that Mattson and Simon were not