to the physicist, as to the layman) "boundary condition". The universal cooling and increase in order of condensed bits of the Universe, which leads in time to astronomy, geology, life and us, is a consequence not of the closed-system equilibrium that is so lovingly described, but of the loss of entropy to radiation, which causes successive breakings of the primordial symmetry, which constitute cosmic history. What he calls "signals" and "traces" would evaporate in a Universe that was heating up.

Finally, there is a comment I feel I must make: the "missing acknowledgement". The SFI in which all of this book was written, and which much of it describes, was not created by Murray Gell-Mann alone or even primarily. I would have liked to see acknowledgement of the four people (at least) who kept the machinery going for its first formative five years, and instituted many of its programmes and practices: George Cowan, president, L M Simmons, vice-president, and Ginger Richardson and Andi Sutherland, administrative facilitators. Other names are noticeably missing, but this is, of course, not a scientific treatise in which all sources of ideas must be credited.

But in conclusion, however I may carp at details, a book like this, from an intellect like Murray's, is an event!

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Newly available

The Nature of Matter? International Collaboration in Particle Physics UK Parliamentary Office of Science and Technology 1994 available from The Parliamentary Bookshop, 12 Bridge St, London SW1A 2JX, UK 50pp £10.00pb

If you are a particle physicist (or any other type of physicist for that matter) who wants to learn about the political and financial ins and outs of CERN and its Large Hadron Collider project, this thin book provides a clear overview, placing it all in the context of a general outline of the physics and of relevant facilities already operating in CERN and elsewhere. The Parliamentary Office of Science and Technology's main role is as a source of accessible background information for members of Parliament, which explains the book's emphasis on the UK perspective. But, it provides a wider view that non-UK readers could well find useful. □

Michael Berry

Matter with curiosity

The Beat of a Different Drum: The Life and Science of Richard Feynman Jagdish Mehra 1994 Oxford University Press 630pp £25.00hb

THIS is intended to be the definitive scientific biography of Feynman. Despite some virtues, it fails.

There are several reasons for its failure. There are errors: of the few equations I checked carefully, several are wrong. Some diagrams are incomprehensible (for example, that purporting to illustrate measure in the Wiener integral). There is needless repetition, sometimes of almost the same words within a few pages. Inconsistencies abound; for example, we are told the first, but not the second, of Feynman's "two sources of difficulty in welding science and religion together". There are attempts to imitate Feynman's casual style, which ring false in print ("One day ... Feynman ... felt like goofing off."). There is no list of Feynman's published papers; Mehra must possess this information (or at least a great deal of it), and even a partial bibliography would have been helpful.

All this slovenliness could have been avoided with time, care and a strict editor. One explanation for premature publication could be that Mehra felt bounced into it by the deserved success of Gleick's more popular biography (see *Physics World* December 1992 p40), which he does not mention. Feynman deserves better.

Nevertheless, the book has several merits. One is the overview it gives of the vast scope of Feynman's physics. The author has consulted widely in a largely successful attempt to give correct descriptions of all the areas he worked on. Feynman was not a physicist of the highest rank – unlike Newton, Maxwell, Einstein or Dirac, he never discovered a fundamental physical law (although he came close with his theory of beta decay). But he did stride the stage of modern physics with brilliance and style, and all his contributions were original and definitive.

He is best remembered for developing two techniques of calculation that enabled quantum electrodynamics to yield precise predictions, without the infinities which plagued that subject. Both were widely used (by Feynman and now by many others) in areas far from their original application. The first is the path-integral representation expressing quantum evolution as a sum over all conceivable histories.

Curious character – Richard Feynman

CALTECH

Almost as a by-product, this yielded the explanation, after three centuries, of classical particle paths and geometrical light rays in the appropriate limit: the paths and rays are effects of constructive interference. The second is the "Feynman diagram" way of representing the contributions to perturbation expansions in terms of physical processes. A major theme was integrating away the oscillators that often mediate physical interactions. This was the basis of his persistent attempts to eliminate the electromagnetic quantum field in favour of direct interactions between charges. Later, he used the idea in his theory of the polaron and, more generally, to eliminate the environment of a quantum system, replacing its effect by dissipation (and thereby anticipating one of the trends in modern quantum measurement theory).

Recently I met a distinguished physicist who told me he had proved that crystals with certain optical properties fall into 42 classes. When I asked, "How many of these classes exist?", he replied: "I don't know; I'm a theoretician." Such a hands-off approach was anathema to Feynman, who pursued every detail of experiments performed to test his ideas. In particular, this meant he had a facility for, and was fascinated by, numerical calculations. As is well described here, he followed the development of computers and, in his last years, worked on the theory of computation. With small computing elements, it is important to avoid heat generated by dissipation. It was known that this is possible; indeed there can, in principle, be reversible – i.e. dissipation-free – computers. These were envisaged as classical machines, whose definite internal states are zeros or ones. Feynman realized that very small reversible computers would be quantum devices, the internal states of which could be coherent superpositions of zeros and ones, and made an influential contribution to what is now the thriving (if still theoretical) subject of quantum computation.

Feynman was a visionary who anticipated several sciences of today. In 1959 he envisaged quantum technology involving the manipulation of individual atoms. His lecture "There's plenty of room at the bottom", extensively cited here, prompted an IBM nanofabrication scientist to exclaim: "I felt the ghost of Feynman behind me while I was reading, saying, 'Look, I thought of those things 30 years ago'". In 1963 he foresaw the current explorations of pattern and chaos: "The next great era of human intellect may well produce a method of understanding the *qualitative* content of equations". And at the same time he understood the individuality and diversity now being revealed as space probes study the planets in detail: "A salutary lesson it will be when we learn of all that goes on on each of those dead planets – those eight or ten balls, each ... obeying exactly the same laws of physics."

Another merit of Mehra's book is his careful account of Feynman's philosophy of physics and its relation to society, and his views on education. His advice – in public lectures and in conversations with Mehra, extensively reported here – was always to doubt authority, examine the evidence, think for oneself and, above all, be unafraid to live with uncertainty. He was disappointed at the continued popularity of astrology, faith-healing and key-bending (Uri Geller failed to perform in his presence) and attributed this to the fact that for most people, "... science is irrelevant [to society]. It is not that it has to be, but we *let* it be."

Feynman never ceased to marvel at how agglomerations of atoms could evolve and organize themselves:

> Growing in size and complexity...
> Living things ...
> Dancing a pattern ever more intricate.
> Out of the cradle onto the dry land
> Here it is standing... atoms with
> consciousness
> Matter with curiosity...
> Wonders at wondering...

For him, seeing an individual atom – or, indeed, the scientific understanding of anything – was a "particular type of religious experience. Our poets do not write about it, our artists do not portray this remarkable thing, and the value of science remains unsung.... This is not yet a scientific age."

Although I have serious criticisms of Mehra's book, I do recommend it for its wealth of Feynman material (much of which is new), feeding our endless fascination with this irresistable character.

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Jim Matthew

Science as a professional venture

To Be A Scientist Don Braben 1994 Oxford University Press 166pp £9.99pb

WHEN undergraduates enrol for science degrees and proud graduates sign up for doctoral research, it is amazing how little they usually know of science as a professional activity. Don Braben has produced a useful little book to guide them on their way, and to acquaint a wider audience with what it is like to be a scientist. The special backcloth to his perspective is Braben's experience of managing the BP Venture Research Unit, which, for 10 years, provided a significant complement to mainstream peer-reviewed research funding channels, and which set out to support and encourage unconventional approaches.

In chapters on Playing with Nature and Playing with Design, Braben mixes outstanding historical achievements in science and engineering with accounts of recent Venture Research Unit projects. His customers make interesting reading: although some young scientists just beginning to make their way were funded, the majority of research teams had a well established professor at the helm, with two Nobel laureates and several FRSs amongst them. Was it a case of "To them that hath it shall be given"? Not entirely, for it is surprising to see how some of the best scientists in the world have difficulty in getting support when they stray from their own high-quality cabbage patches.

Next, an account of building an academic career combines anecdote with the stark realism of the difficulties of funding one's own research in the 1990s. The book then moves to the industrial scene, with nice examples of industrial innovation from George Stephenson through Irving Langmuir to Georg Bednorz and Alex Müller, counterbalanced by a cautionary tale on the complex relationship between science and economic growth. Written at the end of a deep recession, the analysis emphasizes how conservatism, accompanied by the large capital investment required to promote innovation, has somewhat dulled industry's attitude to research and development.

The final chapter on "Science and the Future" puts in a strong plea for maintaining funding to creative heretics whose ideas are orthogonal to conventional wisdom.

The achievements and precise approach of the BP Venture Research Unit are perhaps overemphasized in the thesis presented by the author, but the case for diversity in science research funding is well made. Such a philosophy does not feature prominently in the Government White Paper *Realising Our Potential*, so the book may provide useful reading for the new research councils.

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