

been, without ever departing so far from the raw evidence as to strain the credence of the reader.

This admirable but discursive recension raises many questions about what is still unknown. Some of these can and should be answered, and soon, as far as available techniques allow.

In particular, the chronology of Avebury is still guess-work. On page 166 Burl gives a table of dates which divides the building of Avebury into three phases (interior stone circles; earthwork and main circle; avenues). This is plausible on the evidence available; but it is based wholly on the dating by analogy of pottery types, which is notoriously uncertain. The surviving finds from excavations can surely yield a suitable series for radiocarbon dating. Could not this be undertaken by the Department of the Environment, the official guardians of the monument?

Likewise, the former positions of the missing stones in the North and South circles, and in the eastern half of the great circle inside the ditch, still await identification. So do the stone-holes and buried stones of the Kennet Avenue, beyond the part excavated by Keiller and Piggott, and almost the whole of Stukeley's Beckhampton Avenue to the south-west. The latter, long regarded as the illusory product of Stukeley's perfervid imagination, has now been restored to credibility by recent finds. Further confirmation is needed, if the full extent of the Avebury complex is to be understood.

To search by excavation would be premature, because all excavation destroys more evidence, unrecognised, than it yields to the most skilled, experienced and conscientious excavator. The state of the art has not advanced so far beyond the work of the 1930s as to justify further knowing destruction.

There are, however, techniques of geophysical survey which can be applied, some of them developed specifically by the Ancient Monuments Laboratory of the Department of the Environment. There is a case here for a long-term programme of research, in which the diagnostic use of the simple hand-held probe should not be neglected. It is one of the defects of this book that these future problems are not spelled out, with non-destructive solutions (or at least programmes) of this kind.

There are other defects too. The values used by the author (page 175) in calculating the man-hours required for the building of the Avebury earthwork are grossly in error; but the corrections are largely self-cancelling, so that the result is still about 1.5 million man-hours. His second estimate (pages 175-76), which is about half of the first, is invalid because it is based on the raw evidence from the experimental earthwork on Overton Down, and makes no allowance for the scale-factor required. This is included in my own empirical formula on which the first estimate is founded.

Furthermore, although the neighbouring Neolithic causewayed camp on Windmill Hill, and the West Kennet Long Barrow, are discussed and interpreted in detail in the text, no plan is given of either. Worse still, there is no modern plan of Avebury itself, with the stones numbered, although individual

stones are often referred to by their numbers in the text. These omissions mar what would otherwise be a quite excellent book. □

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## Boswellian enthusiasm for science

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*Broca's Brain: Reflections on the Romance of Science.* By Carl Sagan. Pp.347. (Random House: New York; Hodder and Stoughton: London, UK, 1979.) \$12.95; £6.95.

By his clear and witty writing and by his willingness to write about those eternally popular subjects, the planets and life on other worlds, Carl Sagan has captured a large audience. His last book *The Dragons of Eden*, on the evolution of human intelligence, won him a Pulitzer Prize, and the present book is already high on the American bestseller list. Sagan is a real phenomenon and we have to take him seriously as a major populariser of science today.

*Broca's Brain* opens with a superb evocation of the inner recesses of the Musée de l'Homme in Paris, where Sagan finds and muses on the preserved brain of Paul Broca, a pioneer of neurosurgery and anthropology in the mid-nineteenth century. This could almost be the opening of a novel in the manner of Balzac. The themes of the book are "the joys and social consequences of the scientific endeavor; borderline and pop science; the not entirely different subject of religious doctrine; the exploration of the planets and the search for extraterrestrial life; and Albert Einstein . . .". The disparate nature of these themes is matched by an almost complete absence of continuity between the chapters of the book. This is a collection of lectures which Sagan has given on various occasions and of articles that have appeared in magazines as diverse as *Scientific American* on the one hand and *Playboy* and *TV Guide* on the other.

Although it is disappointing that these themes are not developed in the coherent and sustained way that we would expect from a purpose-written book, these essays are lively and entertaining, bubbling with amusing anecdotes about science and scientists. Sagan would make an excellent scientific Boswell. I particularly liked "A planet named George", about how the planets, satellites, and their craters and mountains, have come to have their exotic

names. Not many people will be aware that the satellites of Jupiter are named after the illicit loves of his Greek counterpart, Zeus. Sagan feels it is rather unfair that Zeus' wife Hera does not get a mention. There is a marvellous, absurd picture of the international astronomical committee which decides these matters worrying about whether the Third World is sufficiently represented in the names of craters and asteroids and deciding that maybe some other creative humans besides astronomers and astronomers' wives ought to be so honoured.

However, Sagan aspires more to the role of Johnson, the moralist. He has a rather uncritical enthusiasm for science and technology and deplores the "sparse, unimaginative and ineffective efforts at science education" of American media and schools. He sees the best protection against abuses of science as a scientifically literate populace. "In exchange for freedom of inquiry, scientists are obliged to explain their work". But Sagan, while apparently admiring the anti-militaristic activities of Einstein and Russell, does not face up to the issue of military research, that all the most dangerous research (nuclear weapons, germ warfare and so on) is controlled by governments in an atmosphere of rigid secrecy.

There are a series of essays on pseudoscience and fringe science: astral projection, spirit rapping, precognitive dreams, UFOs, Velikovskianism, and so on. There is a particularly good essay on the problem of the remarkable astronomical knowledge of the Dogon

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people of Mali. As Sagan points out, their astronomical knowledge is just not remarkable enough to have been learnt from little green men in UFOs and could all have been learnt from contacts with Europeans. Sagan has performed a useful service here in collecting together these examples of public gullibility and demonstrating how a mixture of deliberate fraud and uncritical thinking has allowed millions to be bamboozled throughout history.

Yet when later in the book Sagan turns to discuss religion, his own critical apparatus seems to be switched off. "These mystical insights must mean something . . . If religions are fundamentally silly, why is it that so many people believe in them?" — an argument which could equally be applied to belief in UFOs or astral projection. Sagan's excitement by the phenomenon of mystical visions, and his curious attempt in the last chapter of the book to link these and all religious ideas to experiences associated with birth, suggest that Sagan is about to become a "born-again" believer in — something.

Although Sagan is rightly caustic about some of the absurdities of the popular pseudosciences he makes no effort to discuss the problem of demarcation between science and pseudoscience, which has so occupied the attention of Karl Popper and his followers. Sagan's championing of science seems positively naive at times. Compared with the doctrines of pseudoscience ". . . science is more intricate and subtle, reveals a much richer universe and powerfully evokes our sense of wonder. And it has the additional and important virtue — to whatever extent the word has any meaning — of being true". Astrologers would obviously be happy with this statement with the word "astrology" substituted for "science". That is not what distinguishes science from pseudoscience.

On the exploration of the Solar System, Sagan is naturally interesting and thorough, for this is his own area of expertise. It would be interesting some day to hear what it is like for a scientist to work on one of these NASA missions. I find it rather touching that Sagan's belief in the existence of life elsewhere in the Universe is so passionate that he cannot bring himself to mention NASA's official interpretation of the Viking Lander mission to Mars, namely that Mars is chemically but not biologically active.

In comparing Sagan with popularisers of astronomy like Hoyle or those grand old rivals Eddington and Jeans, it has to be said that he has so far set himself an easier task. Those earlier masters set out to popularise the astronomical research of their times: they were ahead of the tastes of their public and tried to take their readers with them into the world of the modern astronomer. Carl Sagan, like the effervescent Patrick Moore, talks for the most part about the areas already popular with the public: the

Solar System, space travel, life in the Universe. Sagan's references to the "new" astronomies, radio, infrared, X-ray, and so on, seem to me to be perfunctory. He is not even particularly good on a topic which might be expected to have appealed to him, astronomy from space platforms. He refers to "an astronomical telescope in earth orbit called Copernicus", without mentioning that it is primarily the ultraviolet band that the instruments on the Copernicus satellite have opened up. He seems to think that X-ray emission from gas in clusters of galaxies was discovered by the recent HEAO satellites, whereas this was one of the achievements of the pioneering Uhuru satellite launched in 1970.

Considering that most of this material has been seen or heard by the public before,

there are a couple of minor errors that ought to have been removed by now. It is not the orientation in space of a molecule that is quantised (page 17) but its angular momentum or energy. And galaxies do not disappear from view over the event horizon (page 296): on the contrary they swim into view over it. And as for the suggestion that psychedelic molecules exist in great abundance in plants because of artificial selection as a result of cultivation by human beings. . .

But these reservations do not diminish my enjoyment of the book. *Broca's Brain* is an entertaining collection of essays by a very good popular-science writer. □

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## In the conflux of eternities

Freeman J. Dyson

*In the Centre of Immensities.* By Bernard Lovell. Pp. 174. (Hutchinson: London; Harper and Row: New York, 1979.) £5.50.

LOVELL'S life-work has been the exploration of the Universe by means of radio-telescopes. He was one of the small group of pioneers who understood thirty years ago that the new science of radio-astronomy would give us a wider and deeper view of the Universe than optical observations alone could provide. The achievements of the telescopes which he built have proved his vision right. In our modern theories of the structure and development of the Universe, the evidence obtained from radio observations plays a central and indispensable role.

In this book Lovell is not concerned with his own work as an observer. He is describing the historical growth of our understanding of the size and shape of the Universe and of our own situation within it. He puts this astronomical history within the context of the wider philosophical and religious struggles which have raged around the growth of modern science. He believes, in opposition to the prevailing fashion of scientific positivism, that the creative interaction between astronomy, philosophy and religion is not yet at an end. His purpose is to demonstrate that the discoveries of the past fifty years have confirmed rather than contradicted the words spoken by the mathematician-philosopher Whitehead in 1925: "When we consider what religion is for mankind, and what science is, it is no exaggeration to say

that the future course of history depends upon the decision of this generation as to the relations between them."

To readers moderately conversant with the facts of astronomy, Lovell's expository chapters describing the growth of astronomical knowledge will be easy to follow but not particularly novel. On the technical level, his exposition does not differ substantially from the accounts given in other popular books such as Steven Weinberg's *The First Three Minutes* (André Deutsch/Fontana: London; Basic Books: New York; for review, see *Nature*, 267, 291; 1977). The exciting things in Lovell's book are non-technical. His unique quality as a thinker is displayed in the philosophical and ethical discussions with which the book begins and ends, and in the breadth of his knowledge of history and literature. Chapter 1 starts with Saint Thomas Aquinas and ends with Thomas Carlyle, both of them great writers and profound thinkers, both of them synthesisers who tried to reconcile scientific truth with religious vision, both of them destined to be pushed aside by a younger generation of impatient fact-finders.

Lovell takes his title from Thomas Carlyle's "Sartor Resartus". Man, according to Carlyle, "sees and fashions for himself a Universe, with azure Starry Spaces, and long Thousands of Years. . . as it were, swathed in, and inextricably over-shrouded; yet it is sky-woven and worthy of a God. Stands he not thereby in the centre of Immensities, in the conflux of Eternities?" If Lovell's book succeeds in persuading a new generation of readers to look at the Universe through the eyes of Thomas Carlyle, it will have done us all a great service. □

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