we are, so one can argue that the fact that they're not *here* is strong prima facie evidence that they're not *there*, either.

These two types of evidence — one from the study of the origin of life, the other from consideration of the human future in space — have convinced many members of the scientific community that the optimistic estimates of the abundance of extraterrestrial life bandied about in the 1960s and 1970s were simply wrong. As so often happens when new evidence arrives on the scene, old orthodoxies must give way to new. The "galactic club", conducive as it may be to good science fiction, is no exception to the rule.

Contact With the Stars must be understood, then, in the context of the general scientific counter-revolution on the subject of extraterrestrial civilizations. The new ideas have yet to percolate through to the general public, of course, but they are already well known to the experts. The book touches on all of the main topics related to the development of life — stellar evolution, genetic coding, space colonies, UFOs and so on. Some of the topics are treated very well. For example, I got a great deal out of Breuer's discussion of the debate on whether or not we have reached the end of the line in biological evolution. Unlike some who claim that a vastly superior human race will result from genetic engineering, Breuer argues that the genetic code is already carrying just about all the information it can, given the unavoidable copying errors which must occur in replication. This general attitude of informed scepticism is the greatest strength of the book.

On the debit side, the book reads more like a series of unconnected lectures than a single, cohesive document. The author often ventures into asides that range far from the topic under consideration. For example, after having repeatedly asserted his belief that we are alone in the galaxy, he launches into a lengthy and detailed discussion of strategies for communicating with the very extraterrestrials who aren't supposed to be listening. One can only wonder as to why so much effort has been spent devising complex pictographic codes if attempts to communicate are necessarily doomed to failure. □

James S. Trefil is a Professor of Physics at the University of Virginia, Charlottesville, and co-author with Robert T. Rood of Are We Alone? *(Charles Scribner's Sons, 1981).*

Books for Christmas

THE next review supplement to be published in *Nature* is Christmas Books, which will appear in the issue of December 9th.

As well as articles on recent science books for children, and on bird books and space science/astronomy books, the supplement will include reviews of *Aha! Gotcha, Darwin for Beginners, More Random Walks in Science, The Cult of the Expert* and *A Geological Miscellany.*

Time as time out of sight and mind

P.W. Atkins

On Time: An Investigation into Scientific Knowledge and Human Experience. By Michael Shallis. Pp.208. ISBN 0-09-148950-4. (Burnett Books/Hutchinson: 1982.) £8.95.

THERE are three types of scientist. One type believes that the whole of human experience is open to scientific investigation and rationalization. Another type believes that there are aspects of the world that lie outside the scope of science. The third type doesn't care one way or the other, and simply gets on with the job. The author of *On Time* is a member of Class 2; I am a member of Class 1, and therein lies a profound disagreement.

Dr Shallis has addressed himself to one of the most elusive aspects of the world: the nature of time. He takes us through a sequence of attitudes to time, ranging from its measurement, through its role in physics (encompassing relativity, entropy and causality), and ends with a series of chapters dealing with what most hard-nosed scientists regard as outside their domain, and lying beyond credulity. All this he treats with an engaging earnestness that fully captures his intention of approaching his subject with "the scientific attitude . . . of a wide-eyed child".

I suspect that you will like this book if you believe that there are aspects of the world outside science; for all *aficionados* of the paranormal warm to support from within the ranks of practising scientists. I suspect, also, that if you do not believe that science is incapable of dealing with these purported phenomena, such as by dismissing them as hoaxes or by explaining them in terms of established physics, then you will find this book a distressing mish-mash of credulity and passion. What you will not be able to complain about is, as the author so disingenuously reminds us, the impossibility of not going the whole hog on the paranormal once you have embarked on its foothills.

I was particularly struck by one phrase that occurs early on, where Dr Shallis remarks that, by extending conventional "instructional" science to encompass the unreproducible, occasional events that he thinks sometimes obtrude into the world too spasmodically to be captured by scientific method, he provides a description of reality which "will inevitably be richer than the former one". It seems to me that exactly the same remarks are made in favour of the use of hallucinogenic drugs; and with as much force. The heightened richness Dr Shallis asks us to accept (while acknowledging that it may inspire scorn) includes just about everything that may be regarded as symptomatic of crackpots: astrology, precognition, angels and gods (with, I think, fairies and bent teaspoons thrown in for good measure). Some idea of the style of argument is captured by the manner in which the book speaks of α-emission. Apparently, this process is "absolutely causeless" (p.119) except for the possibility that it may be "influenced by mind" (p.125) — particularly, it seems, the minds of young chicks.

I hope that enough has been said to represent without distortion the thrust of Dr Shallis's argument: be totally credulous, swallow the whole of the paranormal, give weight to the hallucinations of the wishful thinking and the downright potty, and disregard the successful continuing progress of modern science. If you accept that argument then you will indeed accompany the author as far as his conclusion, that time is intrinsically paradoxical and must for ever remain elusive. The rejection of that argument, which in the face of the evidence presented here doesn't seem to present much difficulty, keeps open the path to comprehension. □

P. W. Atkins is a Fellow of Lincoln College and Lecturer in Physical Chemistry at the University of Oxford. He is author of The Creation *(W.H. Freeman, 1981).*

Breaking the laws

Michael Berry

The Accidental Universe. By P.C.W. Davies. Pp.139. Hbk ISBN 0-521-24212-6; pbk ISBN 0-521-28692-1. (Cambridge University Press: 1982.) Hbk £10, $19.95; pbk £4.95, $9.95.

WHAT would the world be like if the force of gravity were a little stronger? If the proton were a little lighter? It is the purpose of Paul Davies's latest book to study questions such as these and, more generally, to explore the sensitivity of various features of the Universe to the values of the fundamental constants of nature. As groundwork the book begins with an account of the laws of physics and the scales on which they operate, from the shortest "Planck" lengths and times, through those characteristic of nuclear physics, up to cosmological ones.

The main body of the work is devoted to showing how these levels of structure are exquisitely interlocked, so that a change in one level can have astonishing repercussions elsewhere. For example, if the strength of the weak nuclear force (compared to gravity) were slightly different, this would greatly affect energy transport in stars, and probably prevent supernova explosions spewing forth the heavy elements which condense into planets and

ultimately ourselves. If the strong nuclear force were a few per cent stronger or weaker there would probably be no stars at all. And if the primordial energy density had been minutely different, the Universe would either have re-contracted implosively long ago (and long before stars and planets could have formed) or exploded so violently as to inhibit condensation into galaxies. Related to this sensitivity are the celebrated "coincidences" involving large numbers; for example, the ratios of the age of the Universe to the time for light to cross a nucleus, and of the strength of gravity to the strength of electromagnetism, are both about 10^{40}.

By examining an impressive variety of such cases (basing his arguments largely on a review article by B.J. Carr and M.J. Rees — *Nature* **278**, 605; 1979), Davies concludes that the Universe is so "fine-tuned" to its present condition by the values of fundamental constants that even a very small alteration would produce a world vastly different from ours and almost certainly unable to support life physically constituted as we know it. This leads him into a discussion of the anthropic principle, which in its weak form asserts: "What we can expect to observe must be restricted by the conditions necessary for our presence as observers", and in its strong form asserts: "The Universe must be such as to admit the creation of observers within it at some stage".

This sudden emergence into cosmology of the idea that the physical structure of the Universe is very special and related to its cognizability is rather strange. It seems to be connected in a curious way with the current preoccupation in applied mathematics with the concepts of genericity and structural stability as especially emphasized by René Thom. Much effort is being expended to determine the nature of the generic (that is, typical, or non-special) solutions of the equations representing physical laws, in the belief that these, being stable against perturbation, can represent persistent structures (condensed matter or life, for example). But the equations themselves are highly non-generic; Maxwell's laws of electromagnetism, for example, are a very special set of linear relations which strongly constrain two vector fields, and any modification would lead to wrong "laws". In this picture of generic solutions of non-generic equations it is difficult to see how the fundamental constants fit in: are they "random initial conditions" or are their ratios determined by laws we do not yet know?

The consequences of physical laws have been explored much more extensively employing the actual ratios of fundamental constants than with hypothetical modified values. It might be that evolution towards structural complexity is virtually irresistible, would survive such modification and still lead to intelligence (albeit with a physical basis quite different from ours — Olaf Stapledon's novel *Star Maker* comes to mind, with intelligence developing via organized fluid motion in the wisps of galaxies and, later, inside stars). If this is correct — that is, if in the space of fundamental constants it could be shown to be generic for universes to have intelligence as an "attractor" of physical laws — the strong anthropic principle would follow as a marvellous consequence, and this aspect of the "coincidences" would lose its mystery.

Paul Davies does not devote much space to such speculations but quite properly concentrates on explaining the physics underlying them. He does this with the lucidity and authority we have come to expect from him. The book should be accessible to anyone with an undergraduate acquaintance with physics, and I warmly recommend it as an excellent introduction to this new and important idea. □

Michael Berry is a Professor in the H.H. Wills Physics Laboratory, University of Bristol.

Common ground in a changing climate

Hubert Lamb

The Earth's Climate: Past and Future. By M.I. Budyko. Pp.307. ISBN 0-12-139460-3. (Academic: 1982.) $39.50, £26.20.

THIS important book by the Soviet Union's outstanding climatologist, Professor M.I. Budyko, is a landmark in the development of climatology as a branch of physical science. At the same time, because climate itself touches more or less every aspect of life on Earth, and because of the way the author draws on the varied works of his long and active career, the book ends by being a statement of Budyko's life philosophy and perhaps of the broadest view of the world as seen from the Soviet Union. As such, it is not only an important work (and one written with notable lucidity) but of wide interest.

Since about 1960 Budyko has been actively involved in concern over man's impact on the environment and with the possibility that the overall effect of the accelerating increase of carbon dioxide in the atmosphere might so disturb the balance of in- and out-going radiation as to lead to an unacceptable warming of the Earth. He was also among the first to discuss the feasibility of counter-measures, such as introducing an aerosol veil into the stratosphere to reduce the warming.

The Earth's climate is some 40°C warmer than would be expected at this distance from the Sun thanks to the extent to which out-radiation is intercepted by the carbon dioxide, water vapour and so on in the atmosphere. Among the most interesting features of Budyko's book is the way in which he traces the changes of climate through the geological past in terms of the carbon dioxide and water supplied by volcanic activity. Decline set in as the volcanism eased off and as vegetation appeared and increased, removing carbon dioxide and converting it to oxygen. This decline was accompanied by a lowering of temperature and the appearance of polar ice. Other shorter-term temperature drops have been associated with periods of specially active volcanism and frequent loading of the atmosphere with veils of dust and aerosol.

However, not all geologists agree that the record of carbon dioxide in the atmosphere fits so well with the known history of prevailing temperatures. Nor can the temperature history of the past century or more be explained by carbon dioxide alone. I am concerned that not only Budyko's book but prevailing opinion among leading meteorologists and climatologists may seriously over-emphasize the importance of carbon dioxide *vis-à-vis* other causes of climatic change. In this book it turns out that in 101 pages carbon dioxide is considered as a major cause of climatic changes, compared with 21 pages for volcanism, and 25 pages for the capacity of polar ice variations and other albedo variations to amplify the overall effect on world temperature. Possible variations of the solar constant get two pages, variations of cloudiness five pages, and continental drift/polar wandering and the Earth's orbital variations about four pages each. The last named variables are surely under-stressed.

The frequent forecasts nowadays, in this book and elsewhere, of a coming drastic change of climate due to man's production of carbon dioxide (and other effluents) are in general a good deal too confident. Despite its basis in the laws of physics, so well expounded in this book, climate is the product of a complex of influences that defies precise modelling. There is no clearly definable limit to the range or the rate of natural climatic variability, particularly the coolings associated with waves of volcanism and (perhaps) other causes. Once within the past 300 years, between 1690 and 1750, there was an oscillation which changed the ten-year average temperatures in England by nearly 2°C, probably the local expression of a global phenomenon. Carbon dioxide changes can be presumed to have played no part in this. The prevailing confidence in the carbon dioxide forecasts is based on their grounding in straightforward physics, but our experience of the difficulties of short-range meteorological forecasts is not entirely irrelevant to this problem.

That said, the possibility of a drastic