this radiation is perhaps the strongest evidence that the Universe did begin in this way, rather than as in Fred Hoyle's theory of continuous creation. The reader who doesn't know Bell Labs may well wonder what this has to do with an industrial laboratory, but after the War it was natural for a communications laboratory to hire a radioastronomer, and the consequence was the discovery of the background radiation by Arno Penzias and Robert Wilson. The management allows that sort of thing, and was rewarded when these two won the Nobel prize, shared with Peter Kapitza in 1978. As I remember from 1977, a Bell Nobel prize can be used as a song of triumph.

The last chapter is about Penzias himself. His father, born and resident in Germany, was a Polish Jew. In 1938 the Germans started deporting to Poland those who did not have German passports. Penzias and his parents got to the Polish frontier, but the Poles would not take any more people. After a brief period of imprisonment the family was sent back to Munich and told to get out in six months or else go to Dachau. Fortunately they succeeded in emigrating, and came to America. Education in New York's elementary schools for a boy who started with no English was tough, but Brooklyn Technical High School, New York City College and Columbia University under C.H. Townes led to Bell Labs, radioastronomy and the Nobel prize. Penzias is now vice-president in charge of research, an advance which he regards as "nothing short of miraculous".

This chapter on Penzias tells most about how Bell Labs is run and about fears for the future. On management he says:

> We have to understand, and I think our owners do, that it can take years and years before someone may be able to make something useful out of a piece of pure research. That we understand this is one of the unique strengths of this place. The few competitors we have, who hire people as good as we do, do not do as well as we do because they *manage* them too closely.

The italics are mine, and it expresses the secret of Bell Labs' success. May it continue! Penzias's last words are: "I am a high pressure guy, and I didn't take this job to conduct a going-out-of-business sale". □

Sir Nevill Mott is Emeritus Professor of Physics in the University of Cambridge. In 1977 he shared the Nobel Prize for Physics with J.H. Van Vleck and Philip W. Anderson, whose work is described in this book.

Optics applied

Springer-Verlag have issued a second edition of Matt Young's *Optics and Lasers: Including Fibers and Integrated Optics*, a revision of the original work of 1977.

The book is an introduction to the engineering and applied aspects of optics, and has been updated to take account of advances in optical communications and the development of integrated optics. Price in paperback is DM 64, $22.

Life, the Universe . . . everything

C.J.S. Clarke

The 4th Dimension: Toward A Geometry of Higher Reality.
By Rudy Rucker.
Houghton Mifflin: 1984. Pp.228. $17.95. To be published in Britain in April 1985 by Hutchinson.

CAN the picture of the world developed by modern physics really affect the way people act and think? Clearly Rudy Rucker believes that it can, and to this end he sets out to teach the reader to think four-dimensionally. He achieves his aims mainly through a careful dimensional expansion of E. A. Abbott's romance about the two-dimensional inhabitants of Flatland, published one hundred years ago, which he vivaciously continues in sections on "The Further Adventures of A Square". Initially Rucker develops the idea of our space (in the common, three-dimensional sense) being embedded in a four-dimensional hyperspace, which allows for the possibility of space being curved, the whole exercise being carried out in a light-hearted style with copious cartoons. When he passes to space-time he can then build on the reader's understanding of four-dimensional geometry to describe the relativistic picture of the Universe as a four-dimensional manifold. In addition he can combine the pictures of space-plus-time and of space-in-hyperspace to move on to the idea of space-time as a whole being embedded in a five-dimensional hyperspace. Finally, with the inclusion of ideas derived from quantum mechanics, he presents a picture of the world as infinite-dimensional, composed of the coordination of every inhabitant's separate perceptions of reality.

One great achievement of the book is that it should help to overcome the feeling of bemused awe by which non-mathematicians are often overwhelmed when multi-dimensional space is mentioned. On the one hand, the author succeeds in explaining clearly the way in which it can be useful to expand the mathematical description of space in terms of three parameters when further degrees of freedom are involved; on the other, he shows by discussing hyper-cubes and hyperspheres how the additional parameters can be built into a complete geometry.

But to convert the reader's heart and mind an author must do more: he must show that the higher spaces being built up are genuine geometrical wholes and not just arbitrary mathematical toys. In the case of special relativity Rucker conveys this well, showing that in the space-time of fast-moving particles the decomposition into space and time depends on what particle is used as the basis for a reference frame and so is not intrinsic to the space-time itself: it is a true unity in which space and time have no absolute individual existence.

Though he is convincing on relativity, what are we to make of Rucker's higher space where the parameters being combined are as different in kind as (to take one of his examples) the raw–cooked and the sweet–salty axes for food? Surely here, whenever it is possible to define points in the space, it is also possible to decompose the space uniquely into the direct sum of the two constituent spaces. Before one can truly speak of a many-dimensional geometry, as opposed to the mere juxtaposition of lower-dimensional geometries, there must be some internal isotropy or symmetry between the dimensions.

This need for a symmetry between the dimensions becomes a crucial problem when it comes to the idea that our space-time is embedded in a hyperspace. One of the main growth areas in theoretical physics is the study of Kaluza–Klein theories where just this happens. But the symmetry relating spatial directions with directions into the hyperspace is a super-symmetry that does not preserve the normal fabric of matter, and the size of the Universe in the other dimensions is generally taken to be minute. When Rucker talks of the world floating around in a hyperspace, attractive though the idea is, one must doubt whether there is any real connection between his speculations and those of the theoreticians. The weakness of Rucker's argument, at a macroscopic level, is that there is no parameter that could be used to define the additional dimension.

Another difference between the author's approach and that of modern theory concerns curved space. Rucker stresses the picture of the curvature of space-time being thought of as the curvature of a hypersurface in a hyperspace. By implication that hyperspace is flat (otherwise one would pass to a hyper-hyperspace to explain its curvature), whereas the hyperspace of modern theories remains curved. Sadly, no formal advantage has been derived from embedding space-time in some hyperspace, and it is not even known what is the minimum number of dimensions that such a hyperspace would have to possess in order to accommodate a general space-time: the best so far achieved is to show that it is less than 84 dimensions (see, for example, my paper in *Proc. R. Soc. Lond.* A **314**, 417–428; 1970).

But I am in danger of imitating the reviewer in the *Times Literary Supplement* who criticized *Wind in the Willows* as making a "negligible contribution" to natural history. Rucker aims not to write a monograph, nor indeed to present merely an amusing curiosity, but to make his ideas fire the reader's imagination and so make a difference to the way he thinks. To return to the question I posed at the outset, I believe that there is an interaction between scientific ideas and the ideas that form the basic motivations for our thoughts and actions, including religious ideas, but it is easy to make the connection seem more inevitable than it really is.

To take one of the most salient examples from the book: does the relativistic view of time as simply one dimension of a four-dimensional Universe have any bearing on our attitude to our own death? For many the fear of death is the fear of non-existence, as expressed by Unamuno when he wrote:

> For myself I can say that as a youth and even as a child I remained unmoved when shown the most moving pictures of hell, for even then nothing appeared quite so horrible to me as nothingness ["Del Sentimento Tragico de la Vida", quoted by R. Sorabji in *Time, Creation and the Continuum* (Duckworth, 1983)].

As argued by Sorabji in that book, this fear depends on a particular view of time in which there is some absolute distinction between past and future; for we were just as non-existent before we were born as we shall be when we are dead, and yet there are a great many who are indifferent to or intrigued by the former but appalled by the latter. In relativity, according to the most usual metaphysical gloss on the subject, not only is there symmetry between the future and the past of any event (so that a horror evoked exclusively by future non-existence is shown to be irrational) but it is not even possible to say that "at time *t* I was/will be non-existent", because there is no absolute meaning to "time *t*": the statement that I shall not exist (anywhere) in the year 2060 is metaphysically equivalent to the statement that I did not/shall not exist (anytime) in Mongolia, except for the first being more certain to be true. Every part of the space-time universe is equally tenselessly existent.

Rudy Rucker writes in this book that

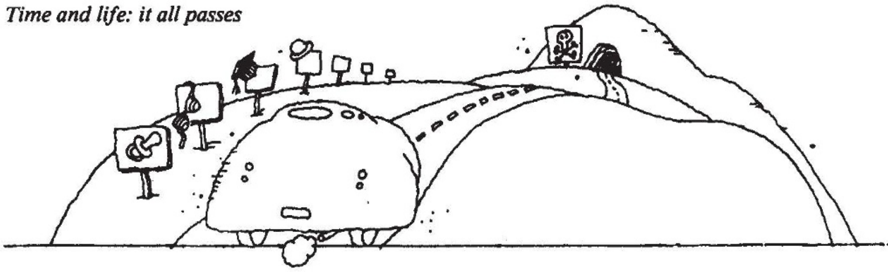
> Instead of thinking of myself as a decaying bag of meat, I can think of myself as a part of eternal spacetime. This is a way to cheat death. Instead of identifying myself with my specific body pattern, I identify myself with the block universe as a whole [p.147]

and because of the impossibility of defining a "now", a "time *t*", in which to localize existence

> The idea of the block universe is, thus, more than an attractive metaphysical theory. It is a well-established scientific fact . . . Spacetime is a single unified whole, and the passage of time is just an illusion [pp. 149, 155].

True, it is a valuable insight that one's life has worth as a whole, and as part of a greater whole; that "I am, as it were, an eye that the cosmos uses to look at itself" (p. 147). This insight seems to fit naturally with relativity. But we should be conscious of the presupposed philosophical realism that seems to underlie this particular argument. Is the space-time, the para-compact Hausdorff manifold, that parametrizes the motion of fast particles actually the same thing as the space and time in which we develop our lives? Or is the manifold more "real" than the time of our experience just because it relates best to physics? I plead guilty to being a confirmed realist myself; but the times when I have been most aware of reality bursting through delusion have been in human, rather than mathematical, experience. □

Time and life: it all passes



From *The 4th Dimension.*

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Law, and prophecy

David R. Rosseinsky

The Second Law. By P.W. Atkins.
Scientific American Library: 1984. Pp.230. $21.95, £16.50. (Members of the Library only.)

A PRECEPT for both admirers and critics of Atkins's book could well be "Thou shalt not make unto thee any graven image". *The Second Law* encompasses, in essentially non-mathematical form, the rigorous to the reflective, but Atkins firmly imputes mechanism to every process. C.P. Snow's contemporary Renaissance Man would know both Shakespeare and the Second Law, and even a popular entertainment by Flanders and Swan some time ago properly enunciated the Lex Secunda, before mangling it in the chant, "Heat is work and work is heat". Correctly, work may all be simply converted into heat, but heat cannot all be simply converted into work. The complexity of fuel plus machine necessary to have work done contrasts with the ready processes available for squandering energy as mere heat.

In explanations of great clarity, Atkins relates spontaneous macro processes to particulate systems where energy becomes dispersed over localized sites (which, in Atkins's exposition, have only a ground and an excited state — that is, OFF and ON, except that ON may be both organized and unorganized). The simplicity ensuing from contemplation of only two states is notable, extensions to greater complexity being straightforward. For me, such analysis resolved apparent conflicts between savants as to whether or not crystallization from supersaturated solution establishes a correspondence between entropy and randomness (you must specify your knowledge of the system); at less subtle levels, the book will lift the hex on entropy traditionally suffered by tyros.

Here, engines of various nomination are unexceptionably cycled in commendably clear applications of the model of energy dispersion. Chemistry is shown to be controlled by free energy (though whether Gibbs's or Helmholtz's is relegated to the thermodynamics appendix). The emergence of complex biological systems (Life itself?) as a result of greater chaos elsewhere, is cogently argued. The so-called "Life Game" is outlined and there are several computer programs appended to play this and other exercises masquerading as games, a nice didactic ploy (also available, note, on discs).

Purists, however, will find much to baulk at in the philosophical implications thus laid before them. For example the validity of contemplating the entropy of the Universe is severely questioned in current correspondence in *Chemistry in Britain*, and indeed has been over the years by many cognoscenti. Atkins's equating of entropy with randomness or chaos is justified by his meticulously numerical definition of randomness, but his use, as synonyms for energy dissipation, of such emotive terms as corruption, chaos and decay — perhaps in a striving to soften the austerity of traditional scientific prose — is questionable. And introducing "Jack" and "Jill" as engine operators mistakes the mental age of the reader, who must distinguish Atkins's "universe" (a large enough region encompassing observable change) from his "Universe", the Whole Thing; unluckily the illustrator has got the capitals wrong in the accompanying diagram (and elsewhere has colour-coded the fluctuations diagram incorrectly).

But this is still a lovely book, beautifully illustrated and presented, and clearly commensurate with its companion volumes in the Scientific American Library. It should engender affection as a sophisticated latterday Hogben, complete with the social allusions implicit in the call to conserve, not energy, but entropy, and to use the virtuous entropy-conserving heat pump rather than crude and profligate combustion. If, for the purist, the net is cast too wide, it may nevertheless capture minds otherwise intent on escaping the chill waters of pure thermodynamics. □

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