programs is that they do not allow the theorist to take too much for granted; this constraint can liberate the imagination. The truth is that Bruner has no taste for this sort of theorizing, perhaps because he lacks the necessary background. Indeed, at one point, he refers to himself as a "non-scientist".

The danger of a dislocation between Bruner's scientific and humanistic tendencies reaches a maximum in his essay on consciousness. He distinguishes its evolutionary origin as a "tool" for solving problems from its "ornamental" role as a vehicle for "making visible the unseen, making possible the unimagined". He draws a parallel distinction between two modes of discourse — the formal scientific mode, and the narrative mode of the poet and myth-maker. The essay itself jumps from one mode to the other, its very form buckling under the pressure.

After the triumphs of the "New Look" and the study of thought, which were both to launch a thousand experiments into the literature, Bruner shifted his attention to schools, and to the reform of the curriculum. His best ideas were thwarted by politicians, but he nonetheless served to shape certain aspects of the educational system in the United States. Subsequently, he returned to the laboratory to investigate children's cognitive development. As he candidly admits, his work here was too close to Piaget's, and it was less well received. At the beginning of the 1970s after the Harvard Center had been disbanded, Bruner, always ready to move, came to England to the Watts professorship of psychology at Oxford. One of the most absorbing essays in the book describes his life in universities, and compares Harvard and Oxford to the latter's disadvantage. In retrospect, one can see that although the Oxford intellectual milieu suited him, the department of psychology did not. It lay entirely on the scientific side of the border, whereas he retained his scepticism. Ultimately, bored by "Bruner-bashing" seminars, he returned to the United States.

Although Bruner has written a number of widely praised books, this one is his best. Its success rests on two factors. One is Bruner's talent for being at the centre of the cognitive revolution. The other is his skill in re-creating on paper his own personality and cast of mind — a vivid, and very unEnglish mixture of passion, restlessness, gregariousness and intellectuality. He is indeed an intellectual first, a psychologist second and a scientist third. His book is bound to be widely read by psychologists; it should be read by anyone who wants to understand what has happened to American psychology in the past half century. □

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Through to another dimension

Thomas Banchoff

The Planiverse: Computer Contact with a Two-Dimensional World.

By A. K. Dewdney.

Poseidon, New York: 1984. Pp. 267.

Hbk \$16.95, pbk \$9.95. To be published in the UK on 11 May by Picador, hbk £7.95, pbk £2.95.

ONE hundred years ago *Nature* published a review of *Flatland: A Romance of Many Dimensions*, Edwin Abbott Abbott's classic tale of A Square, a two-dimensional creature who encounters a visitor from the third dimension. Now there appears a new book, *The Planiverse* by Alexander Keewatin Dewdney, hailed by the publishers as a worthy successor to *Flatland*. For those of us who received our first challenge to think about lower and higher dimensions from Abbott's little volume, this claim must be viewed with scepticism. Yet the claim is correct.

Dewdney's volume is a fable for our own time that will delight anyone who likes a good story and who enjoys a mind-stretching experience. Subtitled *Computer Contact with a Two-Dimensional World*, the book introduces us to "Yndrd" (Yendred), a creature we meet only on the

video screen of a professor of computer science, Dewdney himself, and his team of students. The progressive encounters which intermesh the world of the observers and the world of the observed lead to an amazingly rich description of Arde, a two-dimensional planet, complete with a well-developed technological society, worked out in fascinating detail. But this is no video game and still less a dry treatise on two-dimensional science. It is simultaneously a fine tale of adventure, as we accompany Yendred on his trek in search of higher meaning for existence, and the story of Dewdney and his students as they become caught up in the experience and are themselves educated through their contact with Arde.

The original reviewer of *Flatland* found some parts of the book tedious, as A Square went on at length about the physiology and psychology of perception, or described his society's blinkered view of women's education (an effective satirical device by Abbott, a distinguished schoolmaster well known for his liberal leadership in the cause of education for women). Similarly some readers of *The Planiverse* will find parts of it slow going, even though the author has relegated many technical asides to special boxes or to an appendix. Yet the pace of the book gives assurance that each new chapter will present something quite different, as the author strives to include material of interest to a wide range of readers — biology, astronomy,

Yendred and his father go fishing

"When the mast had been put up and all the gear and tackle made ready, we realized that the boat had no bow or stern as such. Being completely symmetrical about its mast, bow and stern could be determined only by which direction the boat was moving. This ceased to puzzle us when we realized that a two-dimensional boat could not 'turn around'."

"The mast of the boat has two sections, a stout lower section inserted in a well-braced framework, and a graceful upper section resting on this and held in place by two wedges or pegs. Two long ropes dangled from the top of the mast. There were lockers for food, tackle, and line, as well as two holds for the catch. At either end of the boat were oars. One of these was soon being pumped by Yendred's father; the other was folded up to be used by Yendred on their return. Ingeniously designed, the blades of the oars were hinged so that when the rower pulled down on the handle and the blades stroked toward the rear, they formed a rigid paddle. When the rower pushed up on the handle, the blades moved forward, folding out of the way so as not to counteract the boat's forward motion." (From *The Planiverse*.)

sociology, physics, art, engineering, religion, on and on.

Indeed, when earlier work on a plane world was reported by Martin Gardner in *Scientific American* in 1980, Dewdney received over one thousand letters so there is no lack of enthusiasm for the subject. What is exceptional about the present book is that it brings all of us in to share the excitement of discovery of this new land.

When *Flatland* first appeared, some readers were disappointed that the author did not consider in more detail the physical laws which govern such a two-dimensional world. A contemporary of Abbott, Charles Howard Hinton, published *A Plane World* in 1884 and later his own *An Episode of Flatland* in 1907, trying in each to work out the scientific and technological implications of planar existence. Dewdney's book is more a successor to Hinton's work than Abbott's, although some of the basic issues concerning artificial intelligence, and the interaction of the observer and the observed, parallel a number of the key questions in *Flatland*. *The Planiverse*, too, lacks explanation at crucial points. The mechanism by which the original contact is established and maintained is certainly mysterious; the technique of "eavesdropping", though effective in moving the story along, seems far fetched; and the description of perspective and ambiguity seems to ignore the fact that Ardeans are functionally binocular, at least when they turn their heads. It seems certain that the author will receive a great many more letters from readers who become intrigued by this enterprise.

Names can also be a distraction. In *Flatland* Abbott used "A Square" and "The Chief Circle" while Hinton's all-too-human protagonists were "Laura Cartwright" and "Harold Wall". Dewdney's creatures have unpronounceably exotic names — Tba Kryd, Kewbt and so on — and they speak with a syntax reminiscent of that of Yoda in *The Empire Strikes Back*. It is difficult, apparently, to find a middle ground.

But these points will not distract a reader who becomes gripped by the tale. The ending leaves us wanting more, and not fully understanding what we have experienced. At the conclusion of *Flatland*, the hapless narrator, A Square, in the cell where he has been imprisoned for his unorthodox higher-dimensional views, wonders if it has all been but the fabric of a dream. Dewdney and his students at least have one another, but they too have to face the insubstantial fading away of their contact with Arde as the image of Yendred disappears from their screen.

Flatland is more alive than ever after one hundred years. *The Planiverse* will take its place alongside that book as a worthy companion, treating us all to the challenge of other dimensions. □

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Among the shifting sands: science in its place

David Bohm

Critique of Scientific Reason.

By Kurt Hübner. Translated by Paul R.

Dixon Jr and Hollis M. Dixon.

University of Chicago Press: 1983.

Pp.283. \$27.50, £22.

FOR several hundred years, scientific modes of reasoning have generally been taken as the proper forms for the expression of knowledge, not only in science but in most other areas of study. In this book, Professor Hübner makes an important contribution to the growing questioning of science as a unique road to truth. By showing how science is a special case within the larger sphere of human cognition, he not only brings out the limitations of scientific thinking but at the same time clarifies the basis on which such thinking is able to take place.

Hübner begins by criticizing Kant's notion that *a priori* categories, such as causality and reciprocity, present us with the necessary framework within which any experience at all is possible. He illustrates his point with quantum mechanics as a case study. In doing this, he cites the Bohr-Heisenberg approach, in which the quantum theory permits only transformations from statements concerning observables to other such statements without giving any notion as to how these transformations came about and as to what were their causes. This approach is then contrasted with my own proposals, made in 1951, of an alternative interpretation of the theory, in which the transformations could in principle be followed in detail and explained causally. From the possibility of having these two different interpretations in the same theoretical domain, it follows that neither the notion of causal principle nor that of an acausal principle is actually inherent in what is. To assert either causality or acausality as a principle of *unlimited* validity is therefore not justifiable. Rather, each of these positions is a methodological postulate, and considerations beyond those of scientific fact and theory are what actually make possible a decision between these alternatives, at any particular stage in the development of a science.

I would like to remark in passing that I think that Hübner is right on this point. (Indeed, I did put my own views rather dogmatically, but only at the beginning. Since then I have suggested that we use *both* interpretations to obtain a greater insight into the meaning of the quantum theory than is possible with one of them alone — see D. Bohm and B.J. Hiley *Foundations of Physics* 12, 1001; 1982).

Professor Hübner then goes on to

generalize these conclusions. He criticizes the notion of *facts* that stand by themselves and shows that they all depend crucially on what he calls systems-ensembles. Such systems-ensembles are characterized by certain kinds of presuppositions, which he terms precepts. These are contained not only as tacit assumptions of the theories under consideration, but also as a wide range of additional theoretical precepts, such as those having to do with the functioning of measuring apparatus and the allowable procedures for collecting and admitting data. Even more important are the axiomatic principles (e.g. Euclidean geometry), judicative precepts (i.e. rules for accepting or rejecting theories) and normative precepts (such as causality or non-causality). These all have a certain *a priori* character, and yet they differ from Kant's notion of a fixed and universal *a priori*, in that it is the *historical* context that determines them. As knowledge develops these precepts are therefore constantly changing. At first, this change merely *explicitates* what is implicit in the overall structure of ideas. But from time to time, the entire system-ensemble undergoes a radical *mutation* (corresponding to what Kuhn calls a scientific revolution). In this process, there is no fixed and final truth that is being approached. After a long time, the systems-ensemble changes so much that what was recognized as a fact in an earlier system often has no place in the later system. Thus, mediaeval alchemical facts, based on the accepted precepts of the time, have, for the most part, no place in physics and chemistry. We may expect that, in a century or two, precepts may have changed so much that many of our own present-day facts will also have little or no place in the thinking of that time.

Clearly, Hübner is here criticizing Karl Popper, who, he asserts, is leaving out the whole body of historically grounded precepts which Popper tacitly takes for granted in his attacks on historicism. Hübner further points out that, indeed, no theory can be falsified (or verified) except within such a system of historically based precepts.

Hübner is not denying the role of the actual experimental results and the creative insights of scientists, as they try to deal with contradictions, within the particular systems-ensemble in which they are working. Rather, he emphasizes that even these experimental results and creative insights have to work in a context that is determined by the total set of historically developed precepts that are part of the general background of scientific thought of a given time.

He then extends these notions to historical science and shows that, at bottom, it is also based on sets of facts and insights growing in a context of historically developed precepts. This argument leads in to a comparison of the modern scientific and technological systems — ensembles of precepts, and those prevailing at a much