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BOOK REVIEWS

Science in the Looking Glass: What Do Scientists *Really* Know? by **E.** Brian Davies. Oxford University Press, 2003. 295 + x pp. $29.95 (cloth). ISBN 0-1985-2543-5.

Consciousness, dualism, and similarly deep and fascinating issues are treated in this book with exceptional lucidity and fine examples. So much ground is covered, with admirable concision, that every reader will surely find many points of interest and much that is novel.

The book's contents might have been better described by the title, "Mathematics, Science, and Knowledge", or perhaps "What We Can Know and How We Can Know It". Its range and appeal are not adequately described even by the chapter headings: Perception and Language; Theories of the Mind; Arithmetic; How Hard Can Problems Get?; Pure Mathematics; Mechanics and Astronomy; Probability and Quantum Theory; Is Evolution a Theory?; Against Reductionism; Some Final Thoughts.

Those headings sound so dry and abstract, yet the book is anything but that. It is written in first-person prose, and reading it is very much like having a conversation with an erudite companion keen to share his insights without forcing them down your throat. Dry wit is deployed throughout; for example, David Chalmers states "that the existence of subjective consciousness is not capable of serious doubt—even though he admits that Daniel Dennett and others do doubt it" (p. 248). I would begin a section with a little mental groan because I didn't really want to read a "chapter ... largely devoted to discussions of the beliefs of Plato and Descartes", but then I'd be immediately hooked by this reference to Roger Penrose and Kurt Gödel: "I do not agree with anything they say (about this subject)"; and then I'd be delighted by what I read and learned. Davies has a clear point of view and discusses the substantive issues. He cites Plato et alia but does not subject readers to any extended exposition of their views. He does, however, correct some simplistic thought-bites that I have harbored about Platonism, Gödel's proof of the incompleteness of mathematics, and much else.

An intensely thought-provoking work, this book cannot be called light reading. Yet I found it easy, or at any rate enjoyable reading, for it is written with great clarity and with analogies that are fresh and well founded. It is likely to offer new insights to most readers; certainly I gained an enormous amount from it, for instance, about the nature of mathematics and what mathematicians do and how they think about it. Again, I have read quite a lot over the years about sense perception and its relation to scientific knowing, yet it took Davies's take on it to bring home the full import of the fact that the path from physiological perception to consciousness depends entirely on unconscious processes. The figure Davies uses to illustrate this is not one of the three or four hackneyed ones; it is an optical illusion that is nowise ameliorated by understanding it intellectually. "To the extent that we have a correct or true view of reality, it is *a result of the use of our intellects"* and not of our senses (p. 17; emphasis in the original). The importance of education could hardly be put more cogently. The larger lesson Davies draws is that "What seems straightforward and obvious is . . . highly species-dependent" (p. 12).

Davies's approach is insistently, almost dogmatically empirical and pragmatic. He is splendidly caustic about arguments that something is possible "in principle". His application of this attitude to mathematics will surely seem original and highly enlightening to many other non-mathematicians besides me. In the same vein, Davies makes a compelling case that those scientific theories that are least quantitative, that can be expressed in common-sense terms—evolution, plate tectonics, the existence of atoms—have a longer useful life than highly mathematical theories, no matter that the latter can make very accurate predictions; "history has shown that theories which can only be expressed in mathematical form are liable to radical change with the passage of time" (p. 230).

A key point, stressed throughout, is the difference between mathematical models and physical reality: "The quantum world is really and objectively there, but . . . we may never be able to construct an intuitive model of it" (p. 13). What we can know or understand is a function of what we are and the tools and concepts we develop. We can be very sure about well confirmed theories based on extensive experience when they are applied within the domain in which they were developed, but we should be clear that extrapolation beyond that domain is unjustified. That theories work does not mean they are true.

In a few (too many?) places there are typos and the like that copyediting should have caught: for instance, a reference to Davies (2002), while the bibliography lists only 2001 and 2003 references. In a few more places a symbol or a footnote will be opaque to most non-mathematicians, and occasionally some background scientific knowledge is presupposed. But none of these instances is any barrier to understanding what Davies is getting at.

To whet the appetite of potential readers, I will mention just some of the points I found most provocative:

- It would have no deep implications if an alien civilization were to be found to use numbers as we do (p. 30).
  A dualistic view is held implicitly by many people, but rejected by most of those who have thought about it explicitly. **A** post-Cartesian view is sorely needed.
- Discussions of "consciousness" need to distinguish between first-person and third-person consciousness, between the nature of one's own subjective experience and what can be inferred from the behavior of others about their subjective experience. I suppose this is the distinction sociologists sometimes make between empathetic "Verstehen" (understanding) and objective "Erklaren" (explanation). At any rate, Davies uses the distinction to good effect in considering whether computers could be conscious.

- There are four types of numbers: small (up to 10,000, say); medium (from about 10,000 [10^4] to about a trillion [10^{12}]); large (about 10^{12} to about 10^{100}); and huge—much bigger than large. According to Davies's practical, pragmatic, empirical approach, there are *quite fundamental* differences between these, and he illustrates beautifully how careful one must be in dealing with numbers.

  This is one place where Davies waxes indignant about mathematicians who claim to see no problems "in principle". As to such differences in belief, "what different people do or do not find incredible is of less significance than what we discover when we look at the evidence" (pp. 85–86). I would say, perhaps of less *intellectual* significance.

  As to the influence of computers on mathematics: Computers may demonstrate whether or not a theorem is true, but that cannot really satisfy mathematicians, who want an intuitive understanding of why it is true, in other words, how it connects with the rest of mathematics. Computation also "marks another step in the transformation of mathematics into an empirical science".
- Chapter 5, "Pure Mathematics", has the goal "to demolish the myth that mathematics is uniquely free of controversy, and therefore a guarantee of objective and eternal knowledge" (p. 99).

  No part of the universe can be effectively isolated from the rest. "Chaos" is much more significant a concept—or fact!—than the "picturesque but quite wrong" shibboleth that the flap of a butterfly's wings in Brazil may set off a tornado in Texas (p. 163). I had not known before reading this book that Newton's equations do not entail deterministic behavior; certain systems, for example a five-body phenomenon, show "chaotic" behavior under Newton's laws of motion (pp. 163–164).

  Don't sneer at Ptolemy's recourse to epicycles. Our recourse to Fourier series amounts to much the same thing (p. 166).

  "Probability is a very strange subject. The Encyclopedia Britannica has two separate articles on it, one mathematical and the other philosophical. The first gives the impression that the theory is completely straightforward while the second states that the proper interpretation is a matter of serious controversy" (p. 171).

  The subsequent discussion should interest and be clear to everyone. Davies also makes plain how real-world situations often make a mockery of naïve *a priori* notions of randomness, for instance through what Marks and Kammann (1980) called "population stereotypes"—ask people to choose a number between 1 and 10, and the distribution of choices will be vastly different from 10% for each number.

  Probabilistic proofs are also discussed here, and I was led to do some "fairly painful" algebraic computation because I found it so hard to believe that if a formula is correct for $x = 0, 1, 2, 3$, and 4, it might not be correct for other numbers (p. 178). Coincidences are also mentioned here, and the consequence of stopping trials once an unexpected result is obtained: "It is responsible for the so-called Torah codes and for claims about ESP" (p. 179). As to ESP, this is perhaps the only substantive point in the book where I would beg to differ and to suggest that Davies has lapsed from his determination to be empirical and pragmatic. Still, it is wise advice indeed, "that if you do not know where some 'random' numbers come from then you should spend your time thinking about what is likely to be their distribution, rather than betting in ignorance" (p. 181); "until one knows the mechanism by which... choices are made, it is meaningless to talk about probabilities" (p. 182).

- Quantum phenomena show that "Probabilities are embedded in the nature of the physical laws of the universe, and cannot be explained in terms of our ignorance of the necessary facts, *even in principle"* (p. 190, italics in original). "Entanglement is an intrinsically quantum phenomenon with no classical analogue" (p. 192). "The moral is that the less an experiment invokes measurement theory the better, as far as physics is concerned" (p. 193). Davies's discussion of the EPR paradox and of Schrodinger's cat is exceptionally enlightening.

Chapter 8, "Is evolution a theory?", shows Davies's empiricism at its best, as he differentiates the fact that evolution has occurred from the question of how, let alone why. An unfortunate lapse is his apparent endorsement of the conclusion "that human beings have indeed evolved from apes" (p. 204), when it is more correct and less inflammatory to say that we share a common ancestor with the apes. Chapter 9 demolishes naïve reductionism with ample illustrations of emergent properties that have no counterpart or grounding in the supposedly more fundamental laws, and reminds us that Newtonian mechanics "contains the proof of its own limitations" (p. 238). Davies concludes that "Chalmers' attempt to develop a science of SC [subjective consciousness] is bound to fail because ultimately it is only based on plausibility arguments" (p. 250); I find that somewhat hard to reconcile with Davies's determined empiricism, which acknowledges that probabilities are embedded in the universe. Can we ever do more than deal in plausibilities? Chapter 10 not only summarizes what came earlier but touches on some even deeper issues, including anthropic principles.

I recommend this book unreservedly as a rich intellectual adventure. The issues Davies addresses may have been grappled with innumerable times in innumerable ways, but I doubt they have ever been put more concisely, clearly, and sanely.

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