The particle connection

C. H. Llewellyn Smith

Dreams of a Final Theory. By Steven Weinberg. *Pantheon/Hutchinson: 1993. Pp. 260. $25, £16.99.*

THIS important book will stimulate, provoke and possibly outrage, but never bore, its readers. Steven Weinberg's intention is "to lay out the issues raised by the idea of a final theory as part of the intellectual history of our times, for readers with no prior knowledge of physics or higher mathematics". This suggests that the book is simply a popularization for nonscientists. In fact, it is an exceptionally clear and profound exposition of the views of a leading scientist on issues that are by no means uncontroversial, such as reductionism, the role of beauty and mathematics in the formulation of physical laws, the nature of scientific explanation, the status of 'emergent' phenomena, the (lack of) utility of philosophies of science, positivism, the possibility of discovering the handiwork of God in nature, and the possible existence and nature of a final theory, which Weinberg thinks exists and may not be far from our reach.

Many working scientists will be delighted to read Weinberg's carefully marshalled arguments supporting points of view that many of us hold but have never been forced to articulate. His explanation of the interplay of theoretical reasoning and experiment, which he illustrates with the discoveries of relativity, quantum electrodynamics and the 'standard model' of elementary particles, is outstanding and will strike a chord in anyone who has been engaged in fundamental research. More controversially, Weinberg argues — convincingly in my opinion — that "The reason we give the impression that we think that elementary particle physics is more fundamental than other branches of physics is because it is", although he is careful to say that this "does not mean that it is more mathematically profound or more needed for progress in other fields or anything else but that it is closer to the point of convergence of all our arrows of explanation". The reader who disagrees should read the book, as should those who believe that complex (chaotic) systems exhibit new kinds of fundamental laws, a view that Weinberg convincingly demolishes. Less controversially, among scientists at least, he also does a wonderful demolition job on the view that scientific knowledge is largely subjective.

The one point of physics on which I am unable to follow Weinberg is his espousal of Everett's many-worlds interpretation of quantum mechanics, which seems to me not only extravagant but ill defined, and his belief that "The one part of today's physics that seems likely to survive unchanged in a final theory is quantum mechanics", not only because it works so well but because "no-one has been able to think of any way to change quantum mechanics in any way that would preserve its successes without leading to logical absurdities". I remember hearing another Nobel prizewinner use the same argument to 'prove' that a 'renormalizable' theory of weak interactions could not exist, at about the time that Weinberg constructed one, for which he won his Nobel prize! Weinberg may be right, but I would not be surprised if our understanding of quantum mechanics changes radically in the future, and (like Newton's laws) it may turn out to be only approximate; in either case, the construction of a final theory would presumably be impossible until this occurs.

Weinberg states that this "is not a book about the [Superconducting] Super Collider [SSC]," although the debate over the project forced him "to try to explain what we are trying to accomplish in our studies of elementary particles". But the case for the SSC runs through the book and provides the climax. This is a pity, because it reads like special pleading, and is likely to prove more ephemeral than the rest of the book.

Weinberg begins the book by stating that "The century now coming to a close has seen in physics a dazzling expansion of the frontiers of scientific knowledge.... But now we are stuck" and that the SSC was planned "in order to break out of this impasse". Fair enough, and later he explains brilliantly the frustration produced by the incredible success of the standard model of quarks and leptons governed by electroweak and strong forces, which currently describes all data with ever improving accuracy while becoming more and more obviously incomplete. However, I consider that Weinberg overplays his hand in asserting the absolute necessity, and in implying the possible sufficiency, of the SSC in the search for a final theory.

Progress to a better theory "beyond the Standard Model" is blocked in particular by ignorance of the mechanism that breaks the symmetry between electromagnetic and weak forces. Weinberg states that "The only sure way to settle this question is to do experiments in which a trillion volts is made available for the creation either of Higgs particles or of massive particles held together by extra-strong forces. For this purpose it turns out to be necessary to give a pair of colliding protons a total energy of about 40 trillion volts [the energy of the SSC]". It is certainly true that the SSC will explore an energy range in which it is almost certain that new phenomena associated with electroweak symmetry breaking will appear. But the elusive Higgs particle may well be discovered in experiments at the Large Electron–Positron Collider (LEP) at CERN, the European Laboratory of Particle Physics, long before the SSC is built. On the other hand, if there is in nature an underlying 'super symmetry' (connecting particles obeying Fermi and Bose statistics), as Weinberg believes, it may not be possible to detect Higgs particles produced by the SSC (although there would be additional 'super particles' awaiting discovery by LEP and the SSC).

Furthermore, if the question of electroweak symmetry breaking can be settled by the SSC, it can almost certainly also be settled by the European version — the Large Hadron Collider (LHC) — proposed at CERN. Dismissing the LHC in one paragraph, Weinberg states that it "would cost much less than the Super Collider" but its energy "would be limited to less than half of the Super Collider". This is somewhat misleading, because the physics potential does not increase linearly with the energy and also depends on the luminosity, which is maximized in the design of the LHC (but not in the current SSC design), thereby giving the LHC the same potential to produce heavy particles as the SSC, although the experiments will be harder. (Furthermore, the LHC can be used to collide nuclei and also collide electrons with protons at unprecedented energies.)

Although Weinberg is careful to say that beyond the questions that he expects to be answered by the SSC "there is a level of deeper questions ... that cannot be directly addressed by any accelerator now conceivable", he nevertheless raises the prospect in readers' minds that the final theory may be discovered in their own lifetimes; and the statement, with which the final paragraph begins, that "No-one can say whether any one accelerator will let us make the last step to a final theory", certainly seems to imply that the SSC might do the job. Although I find this line of promotion disturbing, Weinberg makes an excellent case for the SSC (and also by implication for the much less costly LHC) and I have dwelt on his arguments only because this part of the book has attracted considerable attention. The case he makes for a realist, reductionist approach to physics is even better and is likely to be read for many years to come. □

C. H. Llewellyn Smith is in the Department of Physics, University of Oxford, OX1 3NP, UK.