decision-making process a physician uses to diagnose a case of appendicitis—where failing to act has grave consequences" (p. 203).

The potential threat of endocrine disrupters is a critical issue for our time. By the manner in which we as scientists participate in the public discourse on this issue, we can help to ensure reasoned, careful deliberation of a most important question. As the authors point out, "Deciding on a wise course involves a host of considerations, and, most of all, value judgments" (p. 246). Scientists must decide whether we should contribute to the ongoing debate solely by providing data or whether we should also recognize and accept the responsibility to participate in the equally important component of policy-making that involves the rendering of value judgments. If we avoid this responsibility, then we leave it to others to decide what information is needed and how this information is to be interpreted.

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Quantum Gravitationists

The Nature of Space and Time. STEPHEN HAWKING and ROGER PENROSE. Princeton University Press, Princeton, NJ, 1996. x, 141 pp., illus. $24.95 or £16.95. Isaac Newton Institute Series of Lectures.

The theory of general relativity was formulated in a mathematically complete form 80 years ago, and the basic principles of quantum theory were laid out about 70 years ago. Nevertheless, only within the past few decades have major efforts been under way to merge these theories into a mathematically consistent and complete quantum theory of gravitation. Despite these efforts, research in quantum gravity remains highly speculative, with very few solidly established results and with wide disagreements among researchers not only about the best approach to take but even about what unresolved issues deserve the most attention.

Stephen Hawking and Roger Penrose are, without question, the leading developers of our modern view of the structure of space and time. In particular, their singularity theorems and their contributions to the theory of black holes have provided us with major new insights. Both Hawking and Penrose have given considerable thought to the relationship between quantum theory and gravitation. In view of the situation noted in the paragraph above, it is not surprising that they differ widely in their views.

"It is normally assumed that a system in a pure quantum state evolves in a unitary way through a succession of [such] states. But if there is loss of information through the appearance and disappearance of black holes, there can't be a unitary evolution. Instead, the . . . final state after the black holes have disappeared will be what is called a *mixed quantum state.* This can be regarded as an ensemble of different pure quantum states, each with its own probability. But because it is not with certainty in any one state, one cannot reduce the probability of the final state to zero by interfering with any quantum state. This means that gravity introduces a new level of unpredictability into physics. . . . It seems God still has a few tricks up his sleeve." [From chapter 3 of *The Nature of Space and Time*]

This book is based on a series of public lectures by Hawking and Penrose and is described as a debate between them. This characterization is accurate only if one understands the term "debate" in the sense used in American Presidential campaigns. Both Hawking and Penrose do an excellent job of expounding their own views and perspectives on fundamental issues related to space-time structure and quantum theory. Although they make some criticisms of each other's views as well as some criticisms of other alternative approaches (including some "one-line zingers" on string theory), most of the criticisms and responses are of a "sound bite" nature; there is relatively little direct engagement at a deep level between them in the book.

The first two chapters (one each by Hawking and Penrose) discuss some key concepts and results in modern general relativity. Almost all of these results are solidly grounded, and there is little or no disagreement between Hawking and Penrose here. Chapter 3, by Hawking, describes his work on particle creation by black holes and some related (somewhat more speculative) ideas in Euclidean quantum gravity. Chapter 4, by Penrose, primarily introduces his concerns about quantum measurement theory. Chapter 5, by Hawking, presents his (much more speculative) views on quantum cosmology, while chapter 6, by Penrose, contains a very brief discussion of twistor theory and his views on how it may be related to quantum gravity. The final chapter, entitled "debate," contains some direct engagement between Hawking and Penrose on issues such as "Schrödinger's cat," Euclidean methods in quantum gravity, and the equivalence or inequivalence of black holes and white holes. All of the main ideas in the book have appeared in previous scientific writings by the authors (and, indeed, their views do not seem to have evolved significantly in the past decade or so), but the discussion here is much more lively and informal than can be found elsewhere.

Most of the details of the arguments given in the book are far too technical for a layperson to follow—or even a physicist not specializing in general relativity or related areas. Nevertheless, even readers without much technical background should be able to enjoy the flavor of much of the discussion. This is an interesting book to read now, but it promises to become an even more interesting book for future generations of physicists, after it becomes more clear which present-day ideas lie on the path toward the development of a quantum theory of gravity.

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