

dable argument in favor of his alternative view.

Penrose's critiques of string theory and other popular ideas are carefully and respectfully presented. He is a lover of beautiful mathematics, and he writes very sympathetically about the aesthetic attractions of string theory. Nevertheless, his criticisms are formidable. For example, he invokes a singularity theorem that he was the first to prove, and he uses it to argue (convincingly to me) that all higher-dimensional theories suffer instabilities that will lead them to collapse quickly to singularities. To my knowledge, his critique has not been answered. If he is right, the idea of unification of gravity with other forces through higher dimensions is doomed. Penrose also explains why he finds supersymmetry disappointing; he correctly points out that it does not unify any known particle with any other known particle but that it does lead to a huge expansion in the number of free parameters.

Other approaches to unification receive equally balanced treatment. Penrose is uniquely honest in mentioning the weak points and gaps in his own favored ideas. He reminds us of an earlier era before physicists learned to aggressively hype their ideas, an era in which the prevailing ethic called for honestly explaining the pros and cons and letting the ideas and results speak for themselves.

At the core of Penrose's thinking are arguments that lead him to believe that quantum mechanics must be modified to be unified with gravity. This idea leads him to reject both string theory and such competing approaches as loop-quantum gravity. More than that, he rejects a governing assumption of almost all post-standard model theorizing, which is that such foundational challenges as the measurement problem and quantum gravity can be ignored while physicists work on the problem of unification. Although Penrose's proposal for modifying quantum theory may or may not succeed, it has a feature string theory so far lacks: a doable experiment to test it.

Penrose's case for his ideas is sufficiently strong that it raises the question of why more physicists do not follow him in investigating the possibility that gravity limits the applicability of standard quantum theory. My guess is that most physicists are trained to be problem solvers rather than visionaries, and it is easier for them to work on research programs that offer well-defined problems to solve. To follow Penrose is to engage in a much more risky and challenging activity: a search

for a new theoretical framework. But the longer time goes on without clear evidence for the success of other approaches, the more pressing will be the need to take Penrose seriously.

At the very least during this moment of crisis for string theory, a thoughtful critique by someone who has himself achieved so much is something that no working physicist should ignore. Unless the crisis is quickly resolved, physicists will see in the next few years a more public argument between the radicals who argue that science must be modified to allow belief in a theory that may never make a falsifiable prediction and conservatives who say that the mainstream took a wrong turn somewhere after the standard model. The conservatives will argue, as Penrose convincingly does in *The Road to Reality*, that the reason theoretical physics lost touch with experiment after the standard model was that physicists had by then gone as far as they could go without solving such deep foundational problems as quantum gravity and the interpretation of quantum mechanics.

It is ironic that one of the most radical and independently minded thinkers we have in modern physics, Roger Penrose, will be a leading inspiration for the conservatives who will try to bring physicists back to a physics based on sticking closely to the phenomena experiments observe. Physicists who care about the future of our science should read his book and consider what this careful and creative man has to say.

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