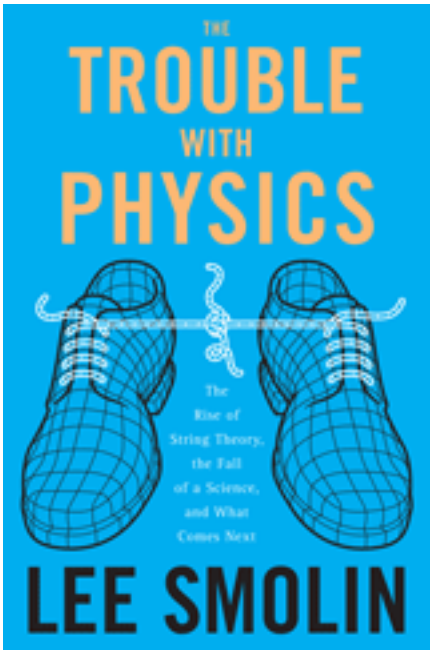

The Trouble with Physics

by Lee Smolin

An exposé by a leading theoretical physicist of how string theory is hurting science — and what can be done about it

About the Book

"My job is to finish the revolution that Einstein started," claims Lee Smolin. One of the golden boys of physics and once touted by *Discover* magazine as "the new Einstein," Smolin knows that the most cherished goal and biggest thrill in physics, as in bad romance novels, is unification — bringing together two things previously understood as different and recognizing them as aspects of a single entity. To do this, for the past twenty years physicists have used string theory, an ambitious attempt to formulate a "theory of everything" that explains all the forces and particles of nature and how the universe came to be. But in string theory, just as in a bad romance novel, scientists must use complications to make the plot work in ways that it can't in the real world. In *The Trouble with Physics* Smolin, a former string theorist, argues that the failure of these grand unified theories has given rise to a crisis in science that has stagnated scientific progress — and lead us toward an alarming future.

String theory, with its exotic new particles and parallel universes, has captured the public's imagination and seduced many physicists. But as Smolin reveals, there is a deep flaw in the theory: *no part of it has been proven, and no one knows how to prove it.*

Science is a process within a community of people looking for the truth; string theory is just faith-based science. The ideas are beautiful, but the theory has been a failure. And for twenty years it has soaked up most of the funding, attracted some of the best scientific minds, and penalized young physicists for pursuing other avenues.

Other revelations in *The Trouble with Physics*:

• **The failure of string theory:** A veritable cottage industry has sprung up around string theory (*The Elegant Universe*, the *NOVA* miniseries), driven largely by its charismatic, evangelical leaders. This is the first book to proclaim that the emperor has no clothes. In some ways it is the sequel to *The Elegant Universe* that Brian Greene could never have written. In the coming months a heated debate raging on the Internet and at physics conferences is poised to break wide open, and *The Trouble with Physics* will serve as a rallying cry.

• **The problem of groupthink:** Smolin explains how the progress of science is slowed by the tendency of string theorists to form a closed circle of adherents, who see every development in the light of the fixed belief that string theory must be correct. This leads them to ignore critics and alternative directions.

• **What comes next:** Smolin doesn't just describe the crisis; he tells us how to get out of it. In addition to pointing out promising new theories and theorists, he reveals the soap opera at the core of theoretical physics today and offers novel solutions for searching out and nurturing the best new talent — giving us a chance, at long last, of finding the next Einstein.

About the Author

Lee Smolin is a pioneer in the field of quantum gravity and cosmology. He earned his Ph. D. in physics at Harvard, then went on to teach at Yale, Cambridge, and Oxford before helping to found the innovative Perimeter Institute in Ontario, modeled after Princeton's Institute for Advanced Study. He is the author of *The Life of the Cosmos* and *Three Roads to Quantum Gravity.* When he's not theorizing about physics, he enjoys art, philosophy, political theory, playing jazz guitar, and sailing small boats. He will be on tour this fall and available for interviews.

Praise for Lee Smolin

"Lee [Smolin] is a brilliant, original thinker." — Roger Penrose, quoted in the *New York Times Magazine*

"[Smolin] argues lucidly and effectively." — *New York Times Book Review*

"It would be hard to imagine a better guide to this difficult subject." — *Scientific American*

Five Basic Problems in Theoretical Physics

For the past thirty years, physicists have been stumped on five basic questions. In *The Trouble with Physics*, Lee Smolin describes the various ideas and theories that have tried and so far failed, to answer the questions. They include string theory, higher dimensions, braneworlds, supersymmetry, loop quantum gravity, twistor theory, causal set theory, spin foam models, causal dynamical triangulations, Technicolor, and preons. Smolin

proposes an explanation for the failure of all these attempts and tells us about new ideas that may finally succeed.

Problem 1: Find the quantum theory of gravity. We have two basic theories of nature: general relativity, which deals with gravity, space, and time, and quantum theory, which describes everything else. We seek to replace these by a single comprehensive theory.

Problem 2: Make sense of quantum mechanics. Quantum mechanics works very well to predict the results of experiments, but many great physicists, beginning with Einstein, have been unable to accept it as a final theory of nature because it gives such a counterintuitive picture of nature and our relationship to it. The problem is to either make sense of the theory as it stands or to invent a new theory that does make sense.

Problem 3: Unify the different particles and forces. Physicists seek to determine whether the various particles and forces can be unified in a theory that explains them all as manifestations of a single, fundamental entity.

Problem 4: Explain all the constants of nature. Our current laws of nature have more than twenty constants, whose values we can measure but do not understand. These include the masses of the electron, quarks, and neutrinos and the strengths of the different forces. We would like to understand how the values of these constants are chosen in nature.

Problem 5: What is the dark matter? What is the dark energy? Cosmological and astronomical observations tell us that only 4 percent of the universe is ordinary matter. The rest gives off no light, and we see its effects only through gravity. A complete theory of the universe should explain what dark energy and dark matter are and why they dominate the universe.

Talking points for *The Trouble with Physics*

• It's been thirty-five years since many exciting speculations in theoretical physics have been proposed, such as higher dimensions, imaginary time, and string theory. Yet none of them has ever been confirmed by experiment.

• After years of research by hundreds of physicists and mathematicians, the essence of string theory remains a mystery. We do not know the principles of the theory or its main equations. We do not even know if there is a genuine theory. And no experiment with doable technology has been proposed that can even test string theory.

• One reason for the crisis in physics is that one hundred years after Einstein's radical discoveries in 1905, the most original, critical, and daring young theorists are ignored in favor of less creatively independent scientists who are happy to work on academically established but unsuccessful theories.

• Still, a small group of highly original and courageous theorists have been pioneering a path to the post–string era of physics. They have come up with new ideas and theories implying dramatic predictions that could be tested by experiment. This new generation of physicists confronts, rather than ignores, the deep puzzles concerning the meaning of

quantum theory. Their efforts have led recently to efforts to make a quantum computer.

• Another recent discovery is a proposal called doubly special relativity, in which the basic principles of Einstein's special theory of relativity are modified in ways that could be verified in upcoming experiments. One such effect, which may be observed in the next few years, is that the speed of light becomes slightly dependent on energy.

• Weird anomalies having to do with gravity, if confirmed, point to the need for a revolution in physics, taking it in very different directions from those that most theorists have been studying.

• Another alternative approach, loop quantum gravity, has led to a new picture of spacetime as a network of discrete processes. This has led to an understanding of how quantum effects remove the big bang singularity, meaning that there was time before the big bang. The apparent consequences of this approach may be tested in upcoming experiments.

• Smolin argues that the progress of science may be slowed by an academic system that is too hierarchical and gives too much authority to older scientists and not enough freedom to younger, intellectually bold and independent scientists. By telling the stories of how a few courageous and highly independent theorists have managed to forge ahead, he shows how a more democratic and open-minded spirit may help theoretical physics to escape from its current crisis.

Hot Young Physicists

In *The Trouble with Physics* Lee Smolin charts the rise and fall of string theory and takes a fascinating look at what will replace it. A number of young theorists have begun to devise new and exciting theories that, unlike string theory, are actually testable. Smolin tells us who and what to watch for in the coming years.

Stephon Alexander, an exciting young cosmologist working on the frontier between cosmology and quantum gravity, has been responsible for several of the most original and bold ideas of recent years connecting cosmology, quantum gravity, and particle physics. Born in Trinidad and raised in the Bronx, Stephon received his Ph.D. from Brown in 2000. He has just joined the faculty of Penn State University after postdoctoral positions at Imperial College, London, and Stanford University.

Martin Bojowald, when still a Ph.D. student, initiated a new direction in research by applying recent developments in quantum gravity to the nature of the big bang. He showed that the singularity, or first moment of time, is removed in quantum theories of gravity, showing that there was time before the big bang. This discovery led to the first predictions for effects of quantum gravity that could be observable in the cosmic microwave background. Recently he and his collaborators have shown that the singularities in black holes are also removed by quantum gravity. Martin has recently joined the faculty of Penn State University.

Etera Livine is a young star of quantum gravity who has already made many important contributions to the field. Just twenty-five, he recently was judged first in a competition among 150 young theorists for a lifetime research position in France. Originally from

Paris, he has degrees from the École Normale in Lyon and Marseille and is at Perimeter Institute.

Fotini Markopoulou is one of the most imaginative thinkers working in quantum gravity and foundational physics. Highly original and independent, she has taken a new approach to unifying quantum theory and cosmology and has recently pioneered the idea of modeling quantum spacetime as a quantum computer. Born in Athens, she received a Ph. D. from Imperial College, London, in 1998 and has been a long-term researcher at Perimeter Institute for Theoretical Physics since 2001. In 2002 she was the cowinner of an award from the Templeton Foundation for the best young researcher working on foundational problems in physics.

Giovanni Amelino Camelia is a charismatic Italian theorist who has catalyzed the birth of a whole new field: the use of astrophysical experiments to study the structure of spacetime at the smallest possible scale. He is also one of the discoverers of the recent modifications of Einstein's special theory of relativity, called doubly special relativity. He is now at the University of Rome La Sapienza.

Olaf Dreyer is a bold, deep, and extremely independent thinker who has made new proposals for solving the key foundational issues, including the measurement problem in quantum mechanics, the nature of black hole entropy, and the problem of the cosmological constant. Olaf got his Ph.D. at Penn State University in 2001, and after a period at Perimeter Institute is now a Marie Curie Fellow at Imperial College, London.

Laurent Freidel has quickly become one of the most influential physicists working on an approach to quantum gravity called spin foam models. He has a permanent research position in Lyon and is visiting Perimeter Institute.

Renate Loll is the coinventor of a new and so far very successful approach to quantum gravity called causal dynamical triangulations. Her work shows for the first time how the geometry of space and time can emerge from a pure quantum theory. She is now a professor in Utrecht.

Joao Magueijo is known for, among other things, his bold proposal for a cosmology based on the idea that the speed of light changes in time. That was the subject of his popular book *Faster Than the Speed of Light.* He continues to be a driving force in conventional cosmology and has made provocative proposals about the foundations of physics. Portuguese, he has a Ph.D. from Cambridge and is now a reader at Imperial College, London.

Antony Valentini is perhaps the most imaginative and influential young person working on the foundational problems in quantum mechanics. He is known for his proposals to experimentally search for evidence of physics beyond quantum mechanics. Of English and Italian background, he was educated at Cambridge and SISSA in Trieste. He is currently a visitor at Perimeter Institute.

Listen to a lecture by Lee Smolin

The American Museum of Natural History, in cooperation with *Seed* Magazine and Houghton Mifflin bring you "The Trouble with Physics" a lecture by renowned theoretical physicist Lee Smolin, author of *The Trouble with Physics: The Rise of String Theory, the Fall of a Science, and What Comes Next.* This lecture was hosted and moderated by the Frederick P. Rose Director of the Hayden Planetarium, Neil Tyson, and was recorded live in the Hayden Planetarium on September 25, 2006.

The Trouble with Physics Lecture (MP3; 1 hour, 31 minutes; 20.9 MB)

