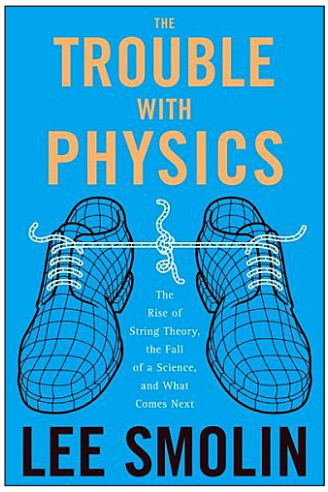

The Trouble with Physics: The Rise of String Theory, the Fall of a Science, and What Comes Next

Reviewed by Brent Deschamp

The Trouble with Physics: The Rise of String Theory, the Fall of a Science, and What Comes Next
Lee Smolin
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The Trouble with Physics: The Rise of String Theory, the Fall of a Science, and What Comes Next is a book about the history of physics from Copernicus forward. It is also a book that discusses the current state of physics research, particularly the dominion that string theory holds over the field. The author covers many diverse topics, and, while the title singles out string theory, this is a book about much more.

Smolin starts with the five great unanswered problems in physics today. I replicate them here as they appear in Chapter 1:

> Problem 1: Combine general relativity and quantum theory into a single theory that can claim to be the complete theory of nature (known as quantum gravity).
>
> Problem 2: Resolve the problems in the foundations of quantum mechanics, either by making sense of the theory as it stands or by inventing a new theory that does make sense.
>
> Problem 3: Determine whether or not the various particles and forces can be unified in a theory that explains them all as the manifestation of a single, fundamental entity.
>
> Problem 4: Explain how the values of the free constants in the standard model of particle physics take on the values they do in nature.
>
> Problem 5: Explain dark matter and dark energy, or if they don't exist, determine how and why gravity is modified on large scales.

Smolin goes into some detail about each problem, and with this background he walks the reader through the amazing advances in physics since Copernicus. His tour is guided by the idea that physicists seek to unify both theories and objects in an attempt to come to a better, and one hopes simpler, understanding of the universe. Along the way Smolin spends almost as much time on the ideas that failed as on those that have survived. His reasons become clear later on, but at this point in the book this emphasis shows the path great minds with great ideas have traveled to bring us to modern physics.

He begins with two failures. The first is that sound and light are instances of the same phenomenon, which led to the invention of aether,

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the substance through which sound and light were supposedly transmitted. He moves on to planetary motion and the theory of circles circling circles, or epicycles, and he even spends time talking about Kepler's theory that the orbits of the five known planets were related to the five Platonic solids. With each theory he shows how it was disproved as experiment and evidence began to show otherwise.

He then shows some of the great unifications: Newton's unification of motion and rest; Bruno's unification that the sun and stars are the same thing; Faraday and the understanding that forces and fields are the same; Maxwell's unification of electricity and magnetism; and Einstein's double unifications, of space and time in special relativity, and acceleration and gravity in general relativity. The presentation of these concepts is intended for a general audience. Still, it is done in a manner so that for those of us who understand the concepts these descriptions are not boring.

Among the interesting side notes Smolin presents during this discussion is a hypothesis that arose after the unification of electricity and magnetism: it suggested magnetic lines might be knotted in various ways and that each knot might be associated with a particular atom. Knowing if one knot was the same as another was suddenly of great interest. The theory was wrong, but it led to the establishment of knot theory as a branch of mathematics. The book is filled with such intriguing side notes, and it is clear Smolin knows a great deal about the history of physics.

Throughout these discussions Smolin points out that each unification not only led to a better understanding but also raised new questions—questions no one could have foreseen before the unification. Each of these led to testable hypotheses, and in that way the validity and usefulness of each theory was measured.

Smolin ends the first section of the book by describing the state of physics at the dawn of string theory. This includes a nice discussion of basic quantum theory, symmetry and spontaneous symmetry breaking, along with the gauge principle and the current search for the Higgs boson. He again delves into incorrect theories such as SU(5) and the unsuccessful search for proton decay. His point is that experiments in physics show the correctness/incorrectness of theories. He also spends several chapters discussing supersymmetry, cosmology, supergravity, and quantum gravity theories.

Smolin now turns to string theory. He describes how it began as an ignored idea and slowly expanded into the theory that has dominated particle physics for the last twenty years. He does a good job of explaining the idea that everything is composed of small vibrating strings and that strings propagate through time according to the simple restriction that they minimize the surface area of the tubes they sweep out over time.

String theory unifies all particles and all forces, it connects to symmetry though the existence of gauge fields, it unifies the quantum and relativity, and it reduces twenty basic free variables in the standard model to one variable in string theory. So from the beginning it had great potential in that it helped deal with two of the great problems in physics (1 and 3).

String theory, unfortunately, first existed as hundreds of versions of the same theory, though it was eventually whittled down to only five. At this point a revolution took place in the theory when Edward Witten gave a talk unifying all five theories into a coherent theory, which he called M-Theory.

To listen to string theorists talk to the public it appears as if M-Theory is a solid, existent theory, but Smolin points out that what Witten did is not create a new theory but to point out some of the features such a theory would have to have. This explanation was, to me personally, a great shock since I had always believed M-Theory was a complete theory. Smolin points out other aspects of string theory where public perception does not match reality.

The author also stumbles at this point in his usual careful descriptions for the general public. He talks a great deal about "higher-order terms" while never defining them. My assumption, given his vague description of the mathematics, is that he is trying to talk about convergence of series solutions. Given my own confusion, I can only wonder at what a general audience might make of the following: He states that for string theory to work the higher-order terms need to be finite and that their sum needs to be finite, too. It has been shown that the first two terms in the sum are finite, and many in string theory assumed the rest had been shown to be finite as well. Smolin digs into the past papers on the subject and reveals this has not actually been done in general, but in only one special case. Everyone, including Smolin, had assumed it had been done in general, so a key foundation of string theory seems to be incomplete.

Smolin's other great complaint with string theory is that it is background-dependent, in other words, to begin with a theory of strings one first fixes the background space in which the strings live. Relativity, which string theory supposedly unifies with the quantum, rests on the theory that space is not fixed, and so any theory that fixes space would not be consistent with other, accepted, theories.

Further chapters look into the extra dimensions that seem to come with string theory, the advent of branes, string theory and black holes, cosmological constants, dark energy, the anthropic principle, and the relationship between supersymmetry and

string theory. The final score is that string theory has potential for resolving Problem 3, it has made progress on Problem 1, but it has failed when it comes to the other problems.

For this reason Smolin concludes string theory, as the next great theory in physics, has failed. He also continuously reminds the reader that string theory has never produced results that are experimentally verifiable or falsifiable. The theory stands outside the realm of experiment, and so as a theory of the universe it lacks testability and cannot be seriously considered as a theory for physics.

The next section is a tour of competing theories, with all their strengths and weaknesses—my favorite being: what if special relativity is wrong? Smolin also spends some time talking about his own pet theory, quantum-loop gravity, but it is given the same amount of space as the other theories. With these competing theories Smolin is careful to point out why they are testable—a reason they should be investigated considering the deficiencies of string theory.

These three sections have taken nearly three-quarters of the book, and it's been good reading, but now things get interesting.

It's been difficult to gauge how Smolin feels about string theory up until this last section. He talks about great ideas and the beauty of string theory, but he also is quick to tear it apart. Is this book for or against string theory? I would have guessed it was against it, and the next few chapters would have confirmed this theory.

The first chapter in this last section describes working in physics under the reign of string theory. It describes a world in which some people whole-heartedly believe in string theory and some people study string theory only because it is, as the oft-repeated expression holds, "the only game in town". Smolin points out, "In the last fifteen years, there have been a total of three assistant professors appointed to American research universities who work on quantum gravity other than string theory, and these appointments were all to a single research group." String theory has a stranglehold on the field, and Smolin believes this is wrong.

This chapter also reveals a strange crack in the scientific veneer of the book. For a few pages Smolin whines, much like a kid in high school who doesn't understand why the "cool" kids won't let him sit at their table in the cafeteria, and he also describes a bizarre world that feels almost like *Invasion of the Body Snatchers*—a world in which the vast majority of the field has been strangely brainwashed and a lone few run, chased and persecuted, holding onto the truth.

As strange as these pages were, and as out of place as they felt, I'm slightly glad Smolin let down his guard, dropped the dispassionate scientific mantra, and let us know how he really feels about his field. But again, this doesn't mean he dislikes string theory.

How then, does Smolin really feel?

His point is this: he likes string theory, he's worked in string theory, it's come up with some good ideas, but it simply cannot be "the only game in town". The theory has its limitations, and he feels the physics community is deluding itself by thinking string theory by itself is going to answer the big questions.

Smolin sees the problem two-fold:

(1) Research in string theory is done differently from the research that produced the great theories that came before. Einstein and other visionaries were just that: they dared to see a world that had never before been imagined. While string theory started as a visionary idea, the last twenty years have been spent in refining that idea, and technical proficiency in computation has been valued more than original thinking that might disagree with the party line.

(2) The current tenure system in the United States has only exacerbated this problem. In order to get tenure a physicist needs to have results within five years. This means they cannot be spending those five years thinking outside of the box. They could be, but what if they don't produce anything by then? It's a safer road to work in string theory.

Smolin documents numerous conversations with people who feel this way, and he also points out that even once they have tenure the people who may like to leave string theory really have nowhere to go. Grants go to string theorists, there's a cultural pressure to continue in string theory, and time has already been invested in string-theoretic lines of thought.

Smolin would like to see more balance in his field. He would like to see more than a vast sea of technically proficient physicists (he calls them craftspeople) working on refining one theory; he would like to see visionaries (he calls them seers) who are allowed to dream big and are given the space and time and resources to do so without the usual five-year deadline.

What's fascinating about this dream is that Smolin actually identifies the people in the field, who are, in his estimation, the seers physics needs. The list includes Antony Valentini, Gerard 't Hooft, Julian Barbour, and Roger Penrose. Some of them have shunned academia in order to find the time and freedom to follow their own ideas (Barbour). Of these some have actually had their work accepted by the community and now find themselves with jobs (Valentini), others continue to remain on the fringe and still others have jobs but are taking risks with their careers for the future of their science ('t Hooft and Penrose).

Smolin points out that the seers have always been few in number, but he shows why his field

needs them. He doesn't promote redefining the tenure system, but he does suggest finding room for these people within the system and encouraging them to follow their ideas. He offers a novel criterion for evaluating such candidates: some people in the field should believe the candidate has great potential, and some people should think the candidate's ideas are nonsense. In this way no one group can control who is given a position of this sort.

By the final page I realized Smolin likes string theory; he thinks that it has as much potential as any other theory to generate new ideas that will promote our understanding of the universe, but as a final theory he feels it has failed. For this reason he feels that it should not dominate the field and that other theories should be given just as much consideration and the room in which to explore. Smolin's book leaves the reader thinking long after finishing the last page. And in my estimation, that is what a good book does.