The Trouble with Physics: The Rise of String Theory, the Fall of Science, and What Comes Next. Lee Smolin. Allen Lane, an imprint of Penguin Books, London. 2007. 392 pp. Price: £ 25.00/Rs 650.

In 1980 Stephen Hawking, on the occasion of occupying the chair of Lucasian Professor of Mathematics at Cambridge, one occupied once by Issac Newton, gave his inaugural lecture, 'Is the end of theoretical physics in sight?'. What was being envisioned was that we would soon be in possession of the basic equations describing all possible particles and their various interactions. One would then be left with only the task of working out their consequences for various physical phenomena. Calculations would continue but theoretical physics, at its most basic, would have ended. What could have led Hawking to discuss such a scenario at that point of time?

The first quarter of the 20th century had produced two great theories of physics. One of these was the theory of relativity which revolutionized our classical concepts of space, time and gravitation. The separate concepts of space and time were first fused into a single 'space–time' in the special theory of relativity. Later, in the general theory of relativity (GTR), the force of gravity was shown to be a manifestation of the curvature of space–time, which was produced by the masses present in it, and in turn, controlled their motion. As gravitation rules all the large-scale phenomena in the universe, we had a theory of the macroscopic world. For a description of the microscopic world of atoms, molecules and radiation, it was found necessary to replace classical physics by quantum mechanics, the second of these two great theories.

The theory of relativity, both special and general, was given by Einstein. The founders of the old quantum theory were Planck, Einstein and Bohr and its present mathematical formulation was given Heisenberg, Schrödinger and Dirac. The rigorous interplay between experimental work and theory played a vital role in the discovery of quantum mechanics. There were quite a few experiments on determining the earth's velocity in aether but it is not clear whether they played any role in Einstein's discovery of special theory. The GTR was a result of pure thought by Einstein.

During the next quarter century the progress came mainly from combining the insights of quantum mechanics with the special theory of relativity. Dirac discovered his relativistic wave equation for the electrons and laid the foundation of quantum electrodynamics, i.e. the quantum theory of interaction between electrically charged particles, such as the electrons, with the electromagnetic field. Dirac's equation also predicted the existence of anti-matter. The present form of quantum electrodynamics is due to Feynman, Schwinger and Tomonaga. A phenomenological theory of weak interactions, responsible for nuclear beta decay, was given by Fermi. Yukawa proposed his meson theory for strong nuclear forces. A number of new elementary particles, viz. neutron, muon and pion were discovered. Pauli postulated the existence of massless neutrinos to account for energy imbalance seen in nuclear beta decay.

Einstein, and others working in the GTR, tried then to reduce the only other known long-range force, i.e. electromagnetic forces, also to geometry. Some of these attempts, known as Kaluza–Klein theories, invoked increasing the dimension of space–time. These attempts at unification of gravitation and electromagnetism, however, had a long history of failures and brought an aversion to the whole unification programme.

In the quarter century after that physicists, through intense interplay between theory and accelerator experiments reminiscent of the way quantum mechanics was discovered, made great progress in understanding elementary particle interactions through the use of ideas of gauge theory and spontaneous symmetry breakdown. The electromagnetic and weak interactions were unified into 'electroweak interactions' by Salam and Weinberg. For strong interactions quantum chromodynamics, with exact colour symmetry, was seen as the correct theory. The two together constitute the 'standard model (SM) of elementary particle physics'. The periodic table of the elementary particles (and/or fields) at this stage consisted of leptons, quarks, gauge bosons and Higgs particle. Among these, only the Higgs particle has not been produced in accelerators yet. It has proved to be successful beyond any expectations and no experimental violation of it has been ever observed, despite enormous efforts. This period also saw great progress in astronomy and the establishment of the 'standard big bang model of the universe'.

With so much achieved by 1980, in the previous three-quarter centuries, and his own work on Hawking radiation from black holes, it is no wonder that Hawking expected the rapid progress to continue in order to wrap up all the loose ends in theoretical physics soon. His estimate was that the end of theoretical physics should come by the end of the 20th century.

What were the loose ends? One was to understand whether the known elementary fields and interactions in the SM could be unified together. Further, can one explain the 20 or so constants of the model in terms of fewer quantities? These constitute problems 3 and 4 in a list of five great problems of theoretical physics at present, listed by Smolin.

Initially the idea of grand unified theories (GUTs) of interaction looked promising, and especially elegant in the SU(5) version, but it predicted proton instability which has not been observed, despite efforts. It was also realized that Higgs mass is unstable in any unified theory and tends to be of the order of the unification scale. Various solutions to this so called 'hierarchy problem' have been tried, including composite Higgs, technicolour, preons and so on. The most unexpected in this connection was the discovery of supersymmetric theories having symmetry under the exchange of Fermions and bosons.

We thus had a quantum theory of electromagnetic, weak and strong interactions given by the SM of elementary particles. The gravitational interactions, as given by the GTR, however continued to resist any attempt to produce a consistent theory of quantized gravity. For a while it appeared that the supergravity theories, which are supersymmetric versions of the GTR, would provide such a theory. Unfortunately this did not work. If we have to understand all the forces, then we cannot shirk the task of quantizing gravity. This heads Smolin's list of the great problems. The brilliant saga of discovering the SM is recalled by Smolin in the first part of the book. It serves as a background, as well as a contrast, to the period of the last quarter century dominated by string theory.

The string theory was proposed around 1970 by Nambu, Nielsen and Susskind in an attempt to understand Veneziano formula (1968) for some hadronic scattering processes. After encountering problems in applying it to hadron interaction, it was realized by 1974, that the string theory might really be a theory of elementary particles and their interactions, including gravity. The string theory, in the version in which it had fermions, turned out also to have supersymmetry. For consistency with special relativity it however required a ten-dimensional space–time instead of the usual four-dimensional space–time of the quantum field theory.

In 1984, the string theory suddenly caught the attention of the whole high-energy physics community, as offering the possibility of a solution to all the three great problems discussed so far. In the aftermath of a paper by Schwarz and Green written that year on anomaly cancellation, it became the most exciting area of research. John Schwarz getting catapulted from a mere senior research associate to a full professor at Caltech was another side effect. Our standard paradigm of regarding elementary particles as zero-dimensional point objects was being overthrown in favour of tiny one-dimensional strings, with all the elementary particles being now regarded as its different vibrational states. This solved the problem of unification of particles and forces neatly. It also appeared that the string theory had only one constant, i.e. string tension. So the 20 or so parameters of the SM would possibly be reduced to just this one constant. What was further emphasized, for example, by Witten and others, was that not only did string theory offer the possibility of a finite theory of quantizing gravity, it seemed to demand the gravity to exist for its consistency. With such high promise, string theory quickly became an extremely active area of research. It was promptly dubbed as 'Theory of everything' (TOE).

How has string theory developed since? The first item on the agenda was the problem of extra six space dimensions which the theory wanted to have, apart from usual three space dimensions which we encounter in physics. Clearly, we have to make these extra space dimensions directly unobservable by compatifying them into tiny spaces, as in the earlier Kaluza–Klein theories. Witten and collaborators showed that a compactification of these extra dimensions into Calabi–Yau type of space would maintain supersymmetry. Since there is a large number, at least a hundred thousand, of these spaces and as we do not know how to choose the right Calabi–Yau space, all pretention to have predictive power is lost at the level of phenomenology. Strominger's work on new ways to construct supersymmetric compactification makes the problem worse. Amusingly, while almost everybody among the string theoriests were hoping for some new insight to tell the 'right' solution, Smolin was the first person to take the plethora of solutions to string theory seriously and discussed them in his earlier book *Life of the Cosmos*, from an evolutionary point of view.

By 1995, it had been realized that there are five different string theories in ten space–time dimensions, each having millions of different versions depending on how unwanted dimensions were compactified. Using the emergence of some evidence for dualities between these string theories, Witten proposed a unification idea, 'All these string theories are versions of a unified string theory', and named it as *M*-theory. What *M* stood for in *M*-theory was not specified, as the theory was not yet known. It could be *M* for matrix/magic/mysterty/mother or something else. This is the second string theory revolution of 1995, which again energized the field. Polchinski soon showed that a consistent string theory also requires not only one-dimensional objects, but also higher dimensional objects moving in the background space. These are now known as branes. Branes were good for much progress. They made it possible to relate lower-dimensional gauge theories to the higher-dimensional string theory. They also showed how to describe 'extremal' black holes in string theory. It was possible to understand the concept of black hole entropy within string theory. In 1997, Maldacena conjectured that a gauge theory could be dual to a string theory, which was another advance. All the same, the exact formulation of *M*-theory has remained a dream even today.

One may emphasize that these developments in the two string theories did not owe anything to any physical experimental or observational input. Begining in 1998, however, astronomers made a startling discovery as a result of supernova observations, i.e. the expansion of the universe is actually accelerating. Nobody, till that time, had entertained such a possibility. This calls for a positive cosmological constant. These new developments in cosmology have shown that the universe is not entirely made of our kind of matter and radiations, even if we include 'dark matter'. It seems about 70% of the universe consists of 'dark energy'. This was totally unsuspected and a progress towards the understanding of the 'dark energy' is Smolin's fundamental great problem number five. The phenomenology of 'dark matter' also is a part of this problem. No string theory was known, despite millions of them, to have such a value of cosmological constant. Even Witten expressed a sense of being troubled by this development. In 2003, Kallosh *et al.* at last succeeded in demonstrating the possibility of solving this problem in a toy model. Their trick opens up a possibility of some 10^{500} or so such string theory models with positive cosmological constants.

Until this point the string theorists hoped for a right model, but now string theorists are getting reconciled to the scenario that may be all these string theories, defining a landscape, are equally significant. Maybe we have to appeal to something like 'anthropic solution', to say in which part of the landscape we are. Susskind, one of the originators of the string theory, favours this approach. The string theory seems to have brought us no closer to solving any of the fundamental problems that we faced a quarter century ago. This is the message of the second part of the book, where Smolin summarizes the developments in string theory.

Smolin then turns in the third part of the book to look at the possibilities for making progress using nonstringy approaches. Are there any indications from nature? Could it be that Newton's law of gravitation is not valid for small accelerations of the order of C^2/R, where C is the velocity of light and R is the distance scale, about 10 billion light years, over which the universe curves, as suggested by Milgrom in 1983 in his modified Newtonian dynamics (MOND) theory. The MOND theory accounts quite well for the same motions of stars within spiral galaxies, which indicated the existence of dark matter. However, dark matter theory does better for scales larger than the galactic scale. Is there evidence for a possible failure of the special theory of relativity for very large energies (or very small distances)? Greisen, Zatsepin and Kuzmin had shown that beyond a cut-off energy, about a billionth of the Planck energy, no protons should be seen in cosmic rays due to the presence of microwave background radiation. The AGASA events, where one has seen protons with energy higher than this cut-off, could be an indication of the failure of the special theory of relativity, as suggested by Coleman and Glashow. In any case, if any of these possibilities is realized we would have evidence of physics which would be beyond the string theory.

The special theory of relativity reduces to Galilean relativity when velocities involved are much smaller than the velocity of light. Is it possible to extend the special theory of relativity further so that the extended version, now named double-special-relativity (DSR), is consistent with the concept of a maximum energy (or a minimum length of the order of Planck length). A surprising discovery is the existence of DSR, which has been found in two versions. Effectively, it amounts to a faster speed of light for the early universe. This was first suggested by Magueijo as a possible explanation for supernova observations, which are normally understood in terms of mysterious dark energy.

One of strongest attractions of the string theory is its claim to provide a finite theory of quantum gravity. The proof of finiteness by Mandelstam is incomplete, but is believed to be fixable by the string community. Those outside the committed group, like Smolin, are not convinced. Is there any other promising approach to quantizing gravity? The only serious contender for this is the loop quantum gravity approach of Ashtekar and others.

The second problem in Smolin's list are the difficulties with foundations of quantum theory. There is lot of activity here, but no definitive progress. Maybe one needs a modification of the present-day formalism of quantum mechanics. It could be that all the problems will fall in line together with this modification only.

The last part of the book is devoted to sociological and other comments on the theoretical physics community. Smolin is quite disturbed that so much of talent and support has been invested in string theory. He would like to see a different scenario in which young physicists pursue other approaches seriously, especially in view of the lack of success in the string theory approach. He feels that at present because of career reasons and other sociological reasons it is not so; and this is rather troubling for the discipline of theoretical physics. There is some truth in what Smolin has emphasized here. Of course, brilliant young physicists should and will decide the direction of their research, depending on which approach they think would lead to success in solving the fundamental problems in theoretical physics. So far, most of them have opted for string theory. Maybe now after reading the reasoned advocacy of other approaches by him, Smolin can hope that some of them will follow the newer alternative approaches.

Smolin has written an account of developments in fundamental theoretical physics, which I found to be full of wonderful insights and also a balanced one. That it is written well is a bonus. He also gives string theory its due. The whole tone of the discussion is rather reasonable and not unduly polemical. I recommend the book to all those who would like to have a critical assessment of present-day fundamental physics.

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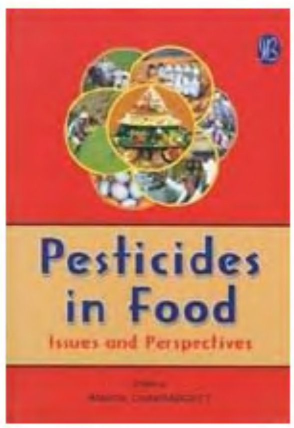

Pesticides in Food: Issues and Perspectives. Amrita Chakraborty (ed.). The Icfai University Press, 52 Nagarjuna Hills, Punjagatta, Hyderabad 500 082. 2007. 250 pp. Price: US$ 18.

The book has three sections with eight chapters along with an overview and an index. It basically looks at the issues and perspectives regarding pesticides in food, with a focus on lesser pesticide usage, analysis and reacting awareness. It also deals with the long-term inputs that the policy makers and farmers/growers have to put in, such that the use of pesticide decreases and ecological methods can be applied for better farming practices.

In general, the book begins with elaborating the use of pesticides being more profuse thus contaminating the system and demands for the use of non-chemical vis-à-vis chemical methods to combat pests in foods, especially in the food-grains. The book contains certain acronyms such as GPU (good pesticide use). If the agenda is that of no pesticides, where is the question of GPU? I think what is most important is good agricultural practices.

The use of pesticides, herbicides and fungicides in several countries in South East Asia and in other countries is not crop-wise but pest-wise. However, a generic use of it which is contaminating the whole water system and an excess use of these chemicals is the question. In today's situation, the classification of pesticides requires a chemical approach, rather than just classification into fumigants, herbicides, etc.

It is important that good standards be used for the analysis of pesticides. This is not brought out clearly in the book in terms of validation, cross-validation, accreditation, ISO 9001, ISO 14001 and other GLPs (good laboratory practices) that need to be a part of the entire validation system of analysis across the globe as one single method. Otherwise, under the WTO regime, we will be subjected to several rejections and acceptances, which can create safety problems.

The limit set for pesticides as indicated by the author is one that already exists, but it has a background which many may not be aware. The EU has set 0.1 ppb of contamination of pesticides as surrogate to zero! It is not that in every analytical method we can determine this limit, because it is dependent upon the matrix, the mix of pesticides, the interfering materials and the stability of the pesticide in a particular food ingredient. However, it is best that there are no pesticides in food and we must work towards that rather than looking only at the precision of analysis. Good agricultural practices and good food chain practices make a difference in reducing the level, as highlighted in the book. Chapters 5 and 6 address food safety and also crops with a focus on organic farming, which is mentioned from the point of view of the global situation.

Chapters 7 and 8 look at future action and farming practices. The database men-