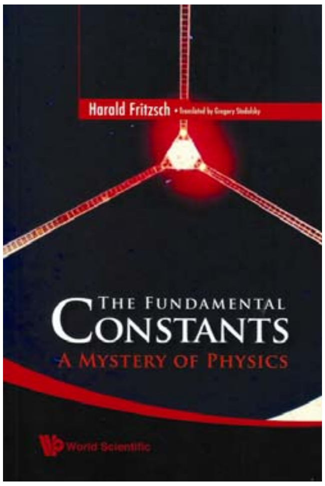

The Fundamental Constants – A Mystery of Physics. Harald Fritzsch. Translated by Gregory Stodolsky. World Scientific Publishing Co Pte Ltd, 5 Toh Tuck Link, Singapore 596224. 2009 (reprinted 2010). 195 pp. Price: £ 30.00/ US$ 38.00

The direct reductionist approach to the unravelling of the structure of matter is a little over a hundred years old. It may be said to have begun in earnest in 1897, with the discovery of the electron by J. J. Thomson. Much has happened between then and the announcement in 2012 of the detection of what is very likely a 'Higgs boson' at the Large Hadron Collider. In succession, the internal structures of molecules, atoms, nuclei and nucleons have been elucidated. A quick way of summarizing this progress is to express it in terms of the effective length scales that have been probed in this inward journey into the heart of matter: from the nanometre (10^{-9} m) to the attometre (10^{-18} m). Alternatively, one may measure it in terms of the characteristic energy associated with a particle in each domain: from the deca (10^1) electron volt regime of atomic physics to the tera (10^{12}) electron volt regime of 'high energy' particle physics. (The speed of a 7 TeV proton is 99 : 999999% the speed of light in a vacuum.) While there has been a steady ascent to better understanding on the whole, closer inspection shows that actual progress has come in identifiable spurts. The current picture of what matter is made up of was pieced together bit by bit, but most of the clinching experimental evidence was obtained in the 1960s and 1970s. This picture has come to be known as the Standard Model (of physics; to be distinguished from the 'Standard Model of cosmology', which has some overlap with the former).

Very briefly, the Standard Model says that matter is made up of quarks and leptons, all of which are (spin-$\frac{1}{2}$) fermions, while the electroweak and strong interactions between all these particles are mediated by so-called (spin-1) gauge bosons. Quarks come in three 'generations' of two quarks each. Besides, they possess a 'color' charge (or quantum number) that can take on three possible values. This makes for 18 distinct particles. Together with their anti-particles, we have 36 such particles. Leptons too come in three generations, each comprising a pair, of which one is a kind of neutrino. Leptons do not have any colour charge. This gives 6 leptons, or 12 leptons and anti-leptons. These 48 particles are the building blocks of all matter and anti-matter, as far as we know. In fact, the heavier particles in each category generally decay into the lightest ones. Thus, except for creation events in the early universe (and in particle accelerators), one is left with matter made up of the lightest quarks (labelled *u* and *d* for 'up' and 'down'), which make up protons and neutrons and hence all nuclei, and electrons. The three varieties of neutrinos are a class apart, with many weird and wonderful properties. They permeate the universe in copious numbers, interacting weakly with everything else, as they transmute back and forth into each other ('neutrino oscillations'). The gauge bosons comprise four particles (the photon and the particles $W^{\pm}$ and Z^0) that mediate electroweak interactions, and eight gluons that take care of the strong interactions between the quarks. This makes a total of 60 'elementary' particles. Perched in a vantage position over these is at least one variety of a special particle, the so-called Higgs boson, about whose definitely non-theological role in the acquisition of mass by the quarks and leptons much has been written (and more has been misunderstood) in the popular press. All in all, the Standard Model therefore has 61 particles, with at least 19 and as many as 27 'fundamental' constants, depending on how you count the number of parameters. This construct is, in principle, the basis of 'everything else' at higher levels of organization, except on very large scales when gravitation comes into its own, adding *G* as well to the count of fundamental constants.

It seems fairly evident that this cannot be the ultimate explanation (much less a 'theory of everything') even within the restricted ambit of the reductionist approach. Nor is it claimed to be one, notwithstanding occasional assertions to the effect that 'all else follows' from the Standard Model. Notably, it stops short of a 'grand unification' of the electroweak and strong interactions, representing what is presumably the broken symmetry phase of such a unified theory. Future progress in the understanding of the Higgs particle(s) will almost certainly enable us to reduce the number of independent parameters, as will further understanding of the elusive neutrinos. Moreover, a substantial number of deep and difficult questions exist, that go well beyond the Standard Model: gravitation, supersymmetry, the dimensionality and nature of spacetime, dark matter and dark energy, and so on, to mention just a few prominent ones. On the other hand, the Standard Model is indeed a triumph of the reductionist approach, albeit a very lofty intermediate peak rather than the highest one (if any). It is woven together most intricately, and has effectively passed all tests to check its internal consistency. Its more recent history is also the story of what one might term 'distributed science', in analogy with distributed computing: hundreds, indeed thousands, of scientists worldwide worked for decades to create the edifice. In the present era of dispersed talent and instantaneous dissemination of information, this might well turn out to be an early example of the future style of scientific research itself.

Many books have been written over the years to present the Standard Model and related topics at a semi-popular level. The short but very readable book under review is a translation (by G. Stodolsky)

Helium forming after the Big Bang.

of the original version in German authored by Harald Fritzsch, published in 2005. The author is well qualified to narrate the exciting story of how we have arrived at where we are now. The discovery of the color quantum number was a crucial step in the acceptance of the reality of quarks themselves, and in establishing quantum chromodynamics as the correct field theory of strong interactions. The idea of a color quantum number evolved over a period of time, beginning with independent suggestions by B. Struminsky and O. W. Greenberg in the early 1960s. Other notable contributors include N. Bogoliubov, A. N. Tavkhelidze, M.-Y. Han, Y. Nambu, W. Bardeen, H. Fritzsch and M. Gell-Mann. A seminal 1973 paper by Bardeen, Fritzsch and Gell-Mann put the concept of colour charge on a firm footing. Taking a cue from the famous dialogue form favoured by Plato in *Timaeus* and by Galileo in *Dialogo* as well as *Discorsi*, Fritzsch has presented his account of the Standard Model and related matters in the form of an extended imaginary conversation, set in balmy California, between three well-chosen characters: Isaac Newton, Albert Einstein and 'a modern-day physicist named Adrian Haller, who comes from the University of Bern and is serving as a guest professor at Caltech in Pasadena'. The latter is the counterpart of Galileo's Salviati, and (understandably) does most of the explaining, bringing his elite fellow-conversationalists up to date on what has happened since their day, step by step. Newton and Einstein are of course very different from Galileo's Simplicio and Sagredo. The dialogue format permits them to make perceptive remarks and pose pertinent questions at appropriate junctures, so that Haller (as the alter ego of Fritzsch!) can carry the explanation forward without becoming monotonous.

The topics discussed range from the beginnings of modern ideas regarding the constants of nature and the fundamental interactions of nature, up to brief remarks on the early universe and some of the physics that may be expected beyond the Standard Model. The flow of ideas is coherent, and the pace is just right for a book at this level. The story roves back and forth between various acts in the drama of particle physics as it has unfolded in the second half of the 20th century. The dialogue form keeps the narration from flagging, and the interjections of Haller's alert audience raise (as intended) precisely the questions that arise in the reader's mind. As the narrative proceeds, Newton's share in the conversation falls distinctly below that of Einstein, showing how far we have come from the beginning of modern physics. Haller believes (as of 2005) that the mechanism of mass creation is different from the Higgs mechanism, and he has doubts about the chances of the Higgs particle being found in the LHC experiments. As we know, events have already overtaken him. I found a couple of minor inaccuracies, such as the statement (in the fictitious Einstein's share of the conversation, as it happens) that the group $SU(4)$ is isomorphic to $SO(6)$, and the group $SU(2) \times SU(2)$ is isomorphic to $SO(4)$. In each case the relationship is a 2-to-1 homomorphism, of course. On the whole, however, the book makes for a really good read, for students as well as professional physicists, especially for those in other areas who wish to get a quick bird's-eye view of what has been happening in particle physics. Haller succeeds in holding the attention of the reader throughout, and not just in the very brief, almost casual aside in which he recounts the dramatic escape of Fritzsch and a friend of his from East Germany in 1968, via Bulgaria to Turkey across the Black Sea in a folding canoe – an adventure that seems to have aroused the interest of the CIA, presumably because that agency was intrigued by the possibility of such a feat under the very nose of the Soviet Navy. Apart from realizing his goal of escaping a totalitarian regime, Fritzsch's daring led to another happy outcome. According to the author, it caught Gell-Mann's attention, and brought them together for their notable collaboration on an important part of the Standard Model.

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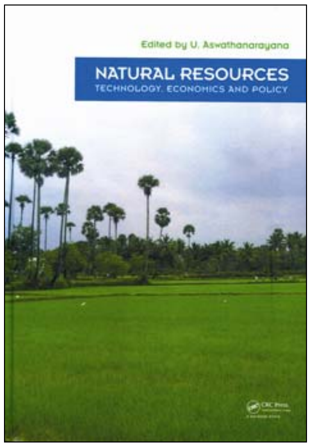

Natural Resources: Technology, Economics and Policy. U. Aswathanarayana (ed.). CRC Press/Balkema, P.O. Box 447, 2300 AK Leiden, The Netherlands. 2012. xxxv + 474 pp. Price: US$ 94.22.

Perceptions of water and energy management in India are sharply polarized in two diametrically opposite viewpoints. The paradigm which is practised all over India and elsewhere in the world too, is based on modern technology-based initiatives like dams, barrages, canals, irrigation systems, deep tube wells, agrochemicals, HYV seeds, may be even GM seeds, hydro/thermal/nuclear power, etc. Stacked against this is what can be called, for want of a better name, 'traditional wisdom' paradigm which argues that water and other natural resources management and agriculture practices reached their pinnacle in some unspecified past; all change thereafter has been only for the worse, and rejects all modern technology-based interventions.

The environment and rights-based opposition to large river-valley projects that started around 1985, has forced the practitioners of technology paradigm to get sensitized to the deficiencies in their practice of technology. This has resulted in significant, though not yet sufficient, improvements in the practice of technology. For example, a detailed EIA, public consultations, an elaborate R&R plan instead of a lump-sum monetary compensation, compensatory afforestation and watershed management, are now an integral part of the formulation process of large projects.

However, the reverse sensitization has not taken place. The advocates of 'traditional wisdom' paradigm do not seem to have improved their understanding of what are different technology interven-