Celebrating physics at Princeton

Critical Problems in Physics. V. L. Fitch, D. R. Marlow, Margit A. E. Dementi (eds). Princeton University Press, 41, William Street, Princeton, New Jersey, USA. Price: $ 24.95. 308 pp.

This volume contains the proceedings of a physics conference held toward the end of 1996 at Princeton University as part of the 250th anniversary celebration of its founding. It contains 14 invited lectures on topics ranging from snowflakes (J. S. Langer) to string theory (E. Witten) and clearly, few readers will even attempt to absorb the whole. Granting this, one must say that many of the authors have made a conscious attempt to look beyond the confines of their specialization, communicate at least to fellow physicists, draw lessons from the past and hazard guesses about the future.

In the opening lecture, S. B. Treiman, goes over the record of the 200th anniversary meeting held 50 years earlier and warns us how rapidly such exercises can be rendered obsolete by new developments and perspectives (there was no hint in the 1946 meeting of the transistor, the laser, . . .). Interestingly, the participants in that meeting were deeply concerned with the effects of wartime secrecy and large scale projects dependent on governmental funding on the way physics would be done. One is not told explicitly if these apprehensions have been realized.

After this backward look, the next four presentations deal with the field which used to be called solid state physics but for which even the current catch-phrase 'condensed matter' is bursting at the seams. Langer's talk is a beautiful quantitative and detailed analysis of snowflakes but also a veiled warning against the prevailing tendency to try and capture the richness of complexity in nonequilibrium systems in a few 'universality classes'. This does not deter Hopfield from discussing 'Dynamics, computation, and neurobiology' from a physicist's perspective. But in this kind of field, experiment is far ahead of theory, as made clear by Swinney's talk on the emergence and evolution of patterns in driven dissipative systems. The behaviour of ball bearings in a sinusoidally shaken tray goes far beyond the wildest dreams of an *ab initio* theorist.

Perhaps the same could be said about high temperature superconductivity, though the theorists have struggled valiantly, both with the problem and with the scenario for a solution proposed by P. W. Anderson. His presence and anti-reductionist motto – 'More is different' – clearly loom over the discussions of this and other topics. Since the subject is one which generates high temperatures in its own right, Ramakrishnan begins with the disarming disclaimer of being an 'interested and occasional participant', and then goes on to plant his feet firmly on the ground of experiment, with only the briefest of remarks on the highly contentious and seductively fascinating theoretical issues. The bottom line is that we may be opening Schrieffer's 'second book of solid state physics' in a range of systems, many of them oxides, where the correlations between electrons are not just quantitatively but qualitatively important, and the single particle wisdom of decades is powerless. As a sidelight on globalization, Bangalore and Madras get to exchange views on superconductivity in New Jersey!

After Hillman's four page appetizer on medical imaging come the cosmological challenges for the next century, from P. J. Steinhardt – does the universe have enough energy density to make it spatially flat? if not why not, and if so what kind of matter makes up the shortfall? These questions lead inexorably to deeper ones about physics at the Planck scale of length and time (10^{-33} cm and 10^{-43} s). The only firm prediction is that these will continue to be discussed at Princeton's 350th birthday party!

In the same overall area comes the article by T. Damour on gravitation and experiment. While it reinforces the already widespread impression that Einstein's theory has proved hugely successful, the limitations of existing tests and the motivation for seeking deviations ('was Einstein 100 right?') are well brought out.

K. S. Thorne presents, with the clarity one expects, perhaps the greatest gamble that experimental physics is taking today. Ground-based laser interferometers are being constructed to detect the gravitational waves from compact binary stars in their death throes of spiralling in and coalescing, almost certainly to black holes. The word gamble is not meant to discount the years of meticulous study both of the detector concepts and the theory of the phenomenon itself. Another piece of globalization is the reference to the French/Indian/American consortium which is calculating the radiation reaction to the unprecedented accuracy which the success of the data analysis demands. The actual existence of these objects is not in doubt thanks to the discovery of the Hulse–Taylor binary pulsar which is a hundred million years from coalescence. Uncertainties about the numbers of such systems and the performance of the detectors in regimes of signal to noise yet unexplored still remain but the decade long, roughly half billion dollar projects are funded and going ahead.

The remaining part of the book is devoted mainly to high energy physics. Perkins covers the topic of oscillations in the shadowy world of neutrinos, a world made real by truly heroic experiments starting with Reines and Cowan on neutrinos from reactors, Davis from the Sun, and Kamiokonde (this is the name of the detector!) which picked up the neutrinos from the supernova in 1987. What is fascinating is that newer experiments will test the oscillation concept decisively, with strong repercussions for models of particle physics. In a somewhat different vein, A. Tollestrup recounts the building of the Tevatron at Fermilab near Chicago, still the biggest machine to hurl protons on fixed targets. One learns that it was both the first to use superconducting magnets, and the last in which the conception and construction were dominated by a single physicist, R. R. Wilson. There is a telling picture of the lab director winding a magnet, and the mechanical, magnet, vacuum, and cryogenic systems have truly mind-boggling specifications, especially when one realizes they were produced in bulk. This chapter is a must for anyone involved in a big project!

Palmer and Gallardo look into the future of the concept of colliding beam machines, including variants which might have sounded exotic only a few years ago, such as muons on muons and photons on photons. Driving all this activity is the widespread success of, only matched by widespread dissatisfaction with, the standard model of particle physics. Everyone agrees that something new has to come up, be it relating to the Higg's particle already present in the existing model, or to the supersymmetric partners which are required by the most popular extensions of the present model. Perhaps the greatest gamble by *theoretical* physicists is adherence to and indeed energetic pursuit of a model whose main merit, as the wags put it, is that exactly half of the predicted particles have been discovered.

One needs to study the last two contributions to realize why this idea of supersymmetry is so compelling to theorists. Witten's overview is centred around the inner consistency and beauty of the ideas known collectively as string theory. One of the first lessons we learn is that strings – one dimensional objects in the place of the points of field theory – are just the motivation and the route to higher (and higher dimensional!) things. It is staggering to realize that old fashioned, i.e. pre-1995 string theory, regarded by many as too high in energy by 15 orders of magnitude to be of relevance to the highest energy accelerators, is regarded by the new breed of theorists as the low energy limit of the REAL theory. But let us remember that Einstein's theory of gravitation, which too started out as a quest for consistency and beauty, must have aroused similar feelings in its time, but is today an essential ingredient of something as mundane as global timekeeping! After this dizzying perspective, the book closes with F. Wilczek's more down to earth views on the future of particle physics as a natural science. There have been many accounts of this material – the successes of the standard model, its unnatural features, attempts to cure these and their possible tests, implications for cosmology, etc. This account is at a level and length which may be just right for a readership outside the particle physics community. An interesting underlying theme is the strong influence of the condensed matter theorists' experience with symmetries, phase transitions, collective excitations, effective theories incorporating what is relevant at a given scale, etc. Wilczek promises elaboration in a series of Reference Frame articles in *Physics Today* which has indeed now just begun.

The organizers of this meeting, and the authors of this book whom they invited, have taken on the increasingly difficult task of looking at all or at least much of physics as it stands today, with the courage to be selective and steer a course between superficiality and incomprehensibility. The fact that they have done their best still does not guarantee easy reading, but the book will have something for most physicists. It will have very many things for those cursed with curiosity but not blessed with infinite time, patience, and insight. Surely a good buy for any library which is used by serious students of contemporary physics.

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Darwin in 90 Minutes. John Gribbin and Mary Gribbin. Universities Press, 3-5-819 Hyderguda, Hyderabad 500 029, India. 1997. Price Rs 45.00. Pbk. 80 pp.

Mendel in 90 Minutes. John Gribbin and Mary Gribbin. Universities Press, 3-5-819 Hyderguda, Hyderabad 500 029, India. 1997. Price Rs 45.00 Pbk. 78 pp.MM

In this new innovative series of books, two of which are reviewed here, John and Mary Gribbin narrate the lives and accomplishments of a number of eminent scientists from both the physical and the biological sciences. All these books follow a similar format. They begin with a brief chapter that very succinctly describes the academic environment in which these scientists began their career, and the influence that the leading thinkers of that time may have had on their work. An introductory chapter of this kind is important since these books would appeal not only to non-scientists, but also to specialists who may not remember what came before as well as they remember what came after! This is followed by the main chapter which thoroughly examines the life and work of the chosen protagonist. What is most remarkable about this section is the careful attention that the authors give to the smallest details of the scientists' personal lives. Knowledge of such details invariably provides insight into the motivations that must have contributed to their research as well. And all of this in about 60 pages of large easy-to-read script. Let me assure you this is no mean accomplishment.

An afterword, as short as the introduction, brings the account to a close. This section offers, in each case, a historical perspective of the academic aftermath that invariably followed such revolutionary thinking. A notable exception is that of Mendel, whose achievements in plant genetics were 'rediscovered' almost a quarter of a century after he finished his work. Finally, a table, common to all the books, provides a chronological 'history of science' from the construction of the famous observatory of Stonehenge in ca. 2000 BC to the tentative discovery of microscopic life in a Martian meteorite in 1996. Given the remarkable enthusiasm of the Gribbins, historians of our science, they obviously have a lot of work ahead of them!

To turn to the two texts in hand, there is much that I learnt about the two arguably greatest biologists of our times. Small details like how Darwin almost became a clergyman so that he could lead a comfortable life and how Mendel almost did not become one. How Mendel's actual fame as a meteorologist and astronomer may have prematurely terminated the recognition of the fundamental importance of his genetic experiments in his lifetime. How Darwin and Mendel came tantalizingly close to each other (different towns in England at the same time) but managed to never meet. How Darwin and Mendel did read of each other's work but how their implications for each other's theories completely escaped them both. It is amazing to rediscover how, like the phenomena of genetic recombination or evolution by natural selection, chance affects great scientific discoveries as profoundly as well.

The books also contain a wealth of personal detail. One thus learns of Darwin's realization that the person who would be most affected by his theory was his conventionally religious wife, Emma. Or, that Mendel was so wonderful and kind-hearted a teacher that he always passed his scores of students – his