imagination, I think his preference is to place his foot on the brake rather than the accelerator. Perhaps it is related to the fact that a scientist is rarely happier than when he is demonstrating folk beliefs to be badly mistaken.

It would not be important if this were not a book intended for impressionable minds. Kierkegaard talked about the two broad categories of despair. The first, the despair of possibility, arises from the lack of any necessities, a deficiency in vitamin N, let us say. The second sorrow, the despair of necessity, arises from the lack of possibilities. Adler's book is a wonderful cure for the first ailment, a deficiency in vitamin N. But if one is suffering from a lack of possibilities, the cure is not to be found in Adler's book.

I do not wish to imply the book depressed me. It did not. I admired the precision of the prose, the clarity of Adler's examples, his sense of humour and the ever-fascinating ability of physics to cut through to the heart of the problem. Reading this book reminded me why I loved physics as a teenager. Adler mentions in a couple of places how an early exposure to a couple of Poul Anderson's essays on the science in science fiction led him to a career in physics and this present work. In fact, the book is dedicated to Anderson. It is a fitting tribute. The best recommendation I can give this book is that it will help ensure that other bright teenagers will also find a lifelong interest in science.

1. Aristotle, *Prior Analytics*, Book II, chapter 27, Jenkinson, A. J. (translator).
2. Even Bayesian probability in all its many subjectivist incarnations is indifferent as to who holds a particular belief or their opinions on Bayes' update rule.
3. McConnell, F., In *Hard Science Fiction* (eds Slusser, G. E. and Rabkin, E. S.), Southern Illinois University Press, IL, USA, 1986, pp. 14–23.

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Annual Review of Nuclear and Particle Science, 2013. Barry R. Holstein, Wick C. Haxton and Abolhassan Jawahery (eds). Annual Reviews, 4139 El Camino Way, P.O. Box 10139, Palo Alto, CA 94306, USA. Vol. 63. 556 pp. Price: US$ 92.00.

This volume is a collection of 20 delightful articles at the forefront of research in particle physics and nuclear physics and cosmology. As is often the case in this series, an eminent scientist is honoured by a detailed discussion of his/her life's work. The first article in the book by Luth is entitled 'Wolfgang K. H. Panofsky: Scientist and arms-control expert', which is a self-explanatory title. This eminent scientist was born in Germany in 1919 and emigrated with his parents to USA and later went on to become the founder and first Director of the Stanford Linear Accelerator Centre. He made immense contributions to the field of accelerator physics and also devoted his time to issues of policy and science planning and was an advisor to several Governments. Indeed, as a person of conscience, 'Pief' as he was known to friends, also devoted his mind and attention to the important issue of arms control and international security, thereby transcending the boundaries of a traditional scientist's range of activities. While many of these issues may have been important in the by-gone days of Cold War, in the coming years and decades such issues of engagement of scientists to problems of nations and society would take on a different complexion, and the lives of persons such as Panofsky are well worth the time of scholars and young persons.

This book being a part of the *Annual Review of Nuclear and Particle Science* series, it is therefore fitting that there should be an article on nuclear physics and particle physics. In the modern era, the laws of the Universe on the largest scales (cosmology) and more conventional large scales (astrophysics) go hand in hand with those at the smallest scales, as the laws of microscopic physics bear their imprint on the cosmos.

If one were to start looking at this admirable collection of articles, one may wish to look at the article 'Search for superheavy nuclei' by Hamilton *et al.*, which reports the discovery of several superheavy nuclei. One learns in school that the heaviest naturally occurring nucleus is an isotope of uranium, which has 92 protons, and a significantly larger number of neutrons are required to supply the binding force to fight off the Coulomb repulsion between the protons. Indeed, in the atomic number–neutron number plane, there is only a small range of allowed values, and any deviation from this stability region leads to the spontaneous emission of either protons or neutrons or fission of nuclei. Over the course of the 20th century, the alchemists' dream of producing new elements was realized and this article captures the excitement of experimental effort and discusses the development of new facilities.

It may also be recalled that many nuclei are (beta-) unstable because of the presence of the weak interactions, which operate at the quark level. Since neutrons and protons are made up of quarks, it would lead to the decay of one of these, which in turn would lead to the decay of either a neutron or a proton, which in turn would lead to the decay of the nucleus, to a lighter and more stable nucleus. There is the exotic possibility of 'double beta decay' when a nucleus would decay through the emission of two electrons and two anti-neutrinos (or two protons and two neutrinos) (in contrast to an even more exotic, so-called beyond the standard model process of the decay with no (anti-) neutrinos). This process was proposed by Maria Goeppert-Mayer, one of the two women physics Nobel laureates in the 114 year history of the Prize. Only in the last couple of decades, this has been seen in the laboratory, in various fascinating experimental situations and has been indirectly inferred from the study of radioactive rock-bearing samples. This has been reviewed in the article 'Two-neutrino double-beta decay' by Ruben Saakyan.

The properties of the elusive neutrinos themselves continue to fascinate particle physicists, and indeed the last couple of decades have proved to be fruitful ones, with the notoriously difficult neutrino experiments turning into precision experiments. In 'The LSND and mini-BooNE oscillation searches at high Δm^2', Conrad *et al.* discuss in great detail the design and analysis of the Liquid Scintillation Neutrino Detector (LSND) and the (Mini)Booster neutrino experiment, where the latter was designed to check the results of the former, which are best explained in terms of the existence of a 'sterile' neutrino. In the article 'Status

and new ideas regarding liquid argon detectors' Marchionni describes the fascinating possibility of designing and commissioning 100 kilo-tonne liquid argon detectors as precision telescopes for neutrino astrophysics and also for proton decay experiments, where it may be recalled that many 'grand unified theories' predict that the proton itself is unstable with very long lifetimes, but at the edge of observability in ongoing and future experiments. These could be handy in establishing the mass hierarchy patterns of neutrinos and also explore the possibility that in the neutrino sector, there is the phenomenon of violation of 'CP' the property that states that laws of physics are invariant under particle and anti-particle interchange (C = charge conjugation) and reflection (P = parity or mirror symmetry). Krizan and Korpar in 'Photodetectors in particle physics experiments' review in great detail how photons are detected using vacuum photodetectors, semiconductor and hybrid detectors and gaseous photon detectors, and inform the reader of the ongoing and planned directions in this important field.

While on the subject of weak interactions, an important advance that came with the construction of the 'standard model' was the realization in the Nobel Prize-winning work of Sheldon Glashow, Steven Weinberg and Abdus Salam, that the weak interactions are required to be described in unision with the familiar electromagnetic interactions. These two proto-interactions 'mix' among themselves to yield each of them. Thus, an important task is to determine in as many ways as possible the 'weak mixing angle' reviewed in the article by Kumar *et al.* is entitled 'Low-energy measurements of the weak mixing angle', where precision atomic experiments also play a role. These determinations test the consistency with determinations coming from higher-energy cleaner experiments. Forte and Watt report on the 'Progress in determination of the partonic structure of the proton', which is in the strong interaction sector of the standard model, The 'parton distribution functions' which describe the structure of the proton are of great importance also for the precision experiments at the Large Hadron Collider (LHC). While it may appear that the proton is one of the most familiar particles of all, a mystery is lurking in something as straightforward as the radius of the proton: Pohl *et al.* in 'Muonic hydrogen and the proton radius puzzle' review the recent experiments from the Paul Scherrer Institute in Switzerland that uses a muon (a heavier cousin of the electron) to yield muonic-hydrogen and from there infer that the proton radius is significantly smaller when measured in such experiments compared to those from more conventional methods.

The conventional-magnet Main Ring synchrotron (top) and the Tevatron (bottom) within their 6.3-km enclosure. During the initial stages of Tevatron operation, the Main Ring served as an injector into the Tevatron and as the source of protons for antiproton production. Later in the Tevatron era, this role was assumed by the Main Injector, and the Main Ring was decommissioned.

One of the sectors that has been well studied in the recent past is that which involves the so-called b-quarks. At electron–positron colliders, it is possible to produce b-quarks and their anti-particles in copious quantities, and in bound states known as bottomonium (a play on the word 'positronium' which is an electron–positron bound state). These states are sufficiently long-lived for us to study their excitation spectrum in great detail and to test their properties in theory using quantum mechanics. Patrignani *et al.* review these studies in 'Recent results in bottomonium'. Davier painstakingly describes in 'Low-energy e^+e^- hadronic annihilation cross sections', the challenges in this field since these are of paramount importance for evaluating the contributions from vacuum processes to the anomalous magnetic moment of the muon, a quantity that occupies pride of place in the comparison of experiments versus theory as a test of the standard model.

b-quarks can form 'mesons' by bonding with anti-quarks of various flavours, for instance with s-quarks to give rise to what are called B_s mesons. Borissov *et al.* in 'Rare decays and CP violation in the B_s system' review the status of this field, especially in view of recent data coming from the LHC.

In the past, the primary source of information on systems such as these were the Tevatron experiments at Fermilab, USA, which dominated the particle physics landscape with the discovery of several particle states as well as the famous top-quark. Holmes and Shiltsev describe the accelerator achievements in 'The legacy of the Tevatron in the area of accelerator science', whereas Grannis and Shochet in 'The Tevatron collider physics legacy', eponymously describe the physics legacy.

Above and beyond the realm of the standard model in the microscopic world, the repurcussions of such known physics are immense and cataclysmic: Kasen and Nugent in 'The supernova in the pinwheel galaxy' describe with great gusto the features of this astrophysical explosion, while Kawasaki and Nakayama describe in 'Axions: theory and cosmological role', the properties of this postulated particle that arises in an esoteric sector of the strong interactions.

Not directly related to these issues by theoretical developments born in nuclear physics are reviewed by Bulgac in 'Time-dependent density functional theory and real-time dynamics of Fermi superfluids', and the physics of collisions at very high densities and energies leading to important developments such as the detection of the 'quark–gluon plasma' are reviewed by Heinz and Snellings in 'Collective flow and viscosity in relativistic heavy-ion collisions'.

While the standard model fares well, it has grave deficiencies. It has too many free parameters and essentially serves as only an engineering model. Why are there particles of half-integral spin (electrons, protons, neutrons, ...) and those of integral spin (photons, force carries of the weak and strong interactions, Higgs particle) (spin in units of Planck's constant divided by (2π)), and why do they respect Fermi–Dirac and Bose–Einstein statistics respectively? How about extensions of these? So-called supersymmetric theories unify particles of different statistics and also offer a solution to the so-called naturalness problem, which asks why there should be disparate scales in nature (the weak scale of about 100 GeV and the Planck scale where gravity must become quantum mechanical at energies that are 17 orders of magnitude larger).

Feng presents an accessible introduction to these issues in 'Naturalness and the status of supersymmetry'. Interactions that go beyond the standard model may lead to particles such as electrons and muons transmuting into one another: Mihara *et al.* review these issues and experiments searching for such signals in 'Charge lepton flavor–violation experiments'.

In summary, this fascinating collection of articles is entertaining as well as illuminating and an excellent addition to any library.

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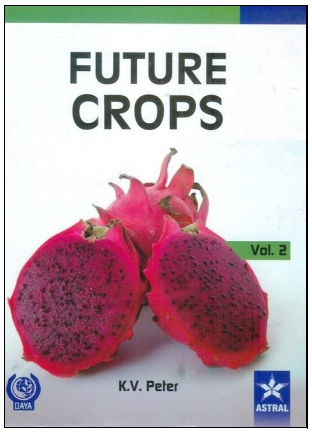

Future Crops. K. V. Peter (ed.). Daya Publishing House, a Division of Astral International Pvt Ltd, 81 Darya Ganj, Delhi Medical Association Road, New Delhi 110 002. 2014. Vol. 2. xix + 361 pp. Price: Rs 2995.

The first volume of *Future Crops* covered more than a dozen species and the book under review, the second volume, covers a score more. Although each chapter covers one species, both volumes feature a few chapters that are broader in scope, because they cover specific habitats such as the arid zone and the aquatic environment, or Indian states such as Mizoram and Kashmir. The organization of the book is not obvious: even if we assume that each of the two volumes aims at a representative collection (instead of devoting one volume to annuals and the other to perennials, for example, or one to fruits and the other to vegetables and so on), the sequence of chapters within each volume appears random (although it is actually alphabetical, an odd choice since the listing is a mix of common names and botanical names). The information is exhaustive and detailed, but variably so; for instance, there is a figure that shows the results of thin-layer chromatography of the bark of true asoka (*Saraca asoca*) and a photomicrograph of a transverse section of the bark, but the chapter contains no photographs of the tree or of its inflorescence.

I pondered over the title of the book. What exactly are future crops? The adjective normally excludes the present: you do not expect current leaders to feature in a volume titled 'Future leaders', for instance, nor commonly used materials in a volume on future materials. The Land Institute[1] can be said to focus truly on future crops such as perennial forms of rice and maize, whereas Crops for the Future[2] in Malaysia, works mostly on underutilized crops and prefers the term 'neglected and underutilized species'. The contents of the present volume fall in that category, as do those of several other publications on the topic, including, perhaps, the report[3] published nearly 40 years ago that spurred interest in the topic and introduced 36 plants, chosen from 400 nominated by plant scientists the world over. More broadly, future crops do not even have to be new crops; they can be old crops bred for new environments (city farming, vertical farming, and so on) or for new requirements (extra rich in some vitamins or minerals, higher glycaemic index, and so on). A more practical approach is that taken by the African Orphan Crops Consortium, which, for its Plant Breeding Academy, selected the crops 'based on surveys of anthropologists, sociologists and scientists working in Africa, who were asked to identify the crops most important to people's diets'[4]. The consensus is that species should have most or all of the following attributes irrespective of whether they are collectively labelled as promising, orphan, minor or traditional[5].

- Unrealized potential for contributing to human welfare, particularly through income generation, food security and improved nutrition.
- Strong cultural links.
- Inadequate information and poor documentation despite a long history of mainly local production or collection from the wild.
- Adaptation to specific agro-ecological niches.
- Non-existent or inadequate sources of seed or other plating material.
- Wide intra-specific diversity (landraces).
- Traditional and multiple uses and processing methods that vary locally.
- Little or no external inputs, or collected from the wild.
- Neglected by mainstream research, extension services, farmers, policy-makers, donors, technology providers and bulk consumers.
- Little-known or under-appreciated nutritional, culinary, medicinal or other properties.

Whether all the crops covered in the series share most or all of the above attributes is a moot question. Perhaps readers can judge for themselves from the list appended to this review. This raises another question: Who are the target readers? It is hard to discern a clear category from the contents or from the depth of treatment. The blurb tells us that 'fifty working scientists from research institutes of ICAR and CSIR have contributed to the present volume' and offers a brief resume of the editor, but is silent on the readership. The preliminary pages add little except for a line towards the end of the preface, which expresses the conviction that the publication 'will immensely benefit teachers, students, researchers and all engaged in enriching the fruit basket of India.' However, a curious disclaimer caught my eye: 'No responsibility for loss or damage occasioned to any person acting, or refraining from action, as a result of the material in this publication can be accepted by the editor, the publisher or the author.' This probably eliminates practitioners and also to some extent researchers because they would certainly expect to act on the information provided by the fifty experts and edited by another with decades of experience behind him, both as a scientist and as an editor of many volumes.