BOOK REVIEWS

Elementary particle theory

R.H. Dalitz

An Introduction to Quarks and Partons. By F.E. Close. Pp.481. (Academic: London, New York and San Francisco, 1979.) £26.40; $54.50.

EVEN a decade ago, it was apparent that the proton and neutron, previously regarded as elementary constituents of the atomic nuclei, were actually composite. Very many excited states were known for them and many also for the hyperons and the mesons. The quantum numbers of these excited hadronic states formed definite patterns, recognised to correspond to a 'molecular model' for the hadrons, each baryon consisting of three of the quarks hypothesised by Gell-Mann and Zweig some years before, each meson consisting of a quark and an antiquark. Each pattern corresponded to a definite excitation of their internal spin and orbital motions. Independently, the data on deep-inelastic electron–nucleon scattering had shown rather directly that nucleons contained point-like particles, which Feynman termed 'partons'. With later experiments on deep-inelastic $\nu \rightarrow \mu^-$ and $\bar{\nu} \rightarrow \mu^+$ reactions on nucleons, these data showed that partons and quarks appeared to be identical, having the same spin, baryon number and charge values ($\frac{2}{3}$ and $-\frac{1}{3}$ times the proton charge). This quark–parton picture of the hadrons is now generally accepted.

The quarks are 'point-like' for distances down to 10^{-16} cm, at least, so that they are our present-day candidates for the title 'elementary particles'. However, quarks come in a number of kinds, with differing attributes, known as 'flavours'. There are $N=5$ flavours established today, the corresponding quarks being labelled u,d,s,c and b, in order of mass, and the discovery of further flavours is expected. The experiments also showed that nucleons contain neutral objects; these are now believed to be the quanta of a 'gluon field' which binds the quarks and antiquarks into the hadron. Finally, in order to give the patterns observed, the Pauli principle required that each quark have three possible states, each now labelled by a colour, and each indistinguishable through the hadronic, electromagnetic and weak interactions we know. This corresponds to an exact 'colour symmetry' and we now believe that the gluon field may be the gauge field for 'colour', just as the photon field is the gauge field for charge. This gauge theory is now known as quantum chromodynamics (QCD). It is a tightly constrained theory, almost unique in form, and it is the theory at the centre of attention today.

Following QCD, elementary particle theory is now undergoing rapid changes and our views today differ greatly from those when this book was finalised. Nevertheless, the book will be much welcomed, especially by students, for it is the only recent introduction available at book length. It does not proceed to expound the subject deductively, from basic principles, but is better described as a discursive review surveying the state of the art in this field of physics in mid-1978. It tends to give results without derivation, although then analysing the result to give some intuitive understanding of its origin and meaning, a procedure having great value for any isolated reader.

Following a brief introduction to set the scene, the book consists of three parts. The first part begins with SU(N) symmetries for N quark flavours, initially for $N=2$ and then for $N=3$. This SU(3) symmetry is then extended to an SU(6) symmetry in the space $SU(3) \times SU(2)_\delta$, where δ denotes Pauli spin. In this framework the quark model classifies hadrons according to the product group $SU(6) \times O(3)$. Since Pauli spin is non-relativistic, this classification cannot refer to a fundamental symmetry; its use today is motivated only by the quark model and is for convenience, allowing the systematic procedures of group theory to be used for economic calculation and tabulation. In general, the observed hadrons correspond to mixed representations of $SU(6) \times O(3)$. The matrix-elements, for the most important transitions, are shown to correspond to the group $SU(6)_W$, so its algebra is discussed in considerable detail, making the usual distinction between SU(6) for currents and SU(6) for hadron constituents and leading to the general Melosh expression for electromagnetic transition amplitudes. Various selection rules are noted, compared with the data and analysed to show how they work. For hadronic decay processes, the transition 'Vacuum $\rightarrow {}^3P_0(\bar{q}q)$' is introduced, and the resulting amplitudes are related with $SU(6)_W$. Some review is given of attempts to include relativistic effects in quark-model calculations.

The second part is devoted to partons and their phenomenology. The notion of levels of scaling is introduced, and traced (for inelastic electron scattering) from the nuclear to the quark–parton level. The parton distributions in nucleons are deduced from the various leptonic deep-inelastic reaction data and discussed in considerable detail, bringing out their connection with simple field theories. There are brief discussions of scale invariance in electron–positron annihilation at high energies, of neutral currents appropriate to the unified electromagnetic-weak interaction, and of the observed scaling violations, now believed to reflect asymptotic freedom for the underlying field theory. The parton model is extended by introducing quark fragmentation functions, used to analyse and predict hadron spectra and their angular dependence in various high-energy reactions. This leads on to a discussion of large momentum-transfer phenomena in hadron–hadron collisions and to quark counting rules for their asymptotic forms. Specific models such as 'Drell-Yan' and 'constituent-interchange', are introduced and compared with the data.

The third part first sketches briefly the electromagnetic-weak and QCD gauge theories, analysing the qualitative features of the one-gluon-exchange potential between quarks. The major topic is the charmed quark c and its role in the 'new particles', such as the ψ/J and ψ' mesons discovered in 1974, and the D and F mesons established subsequently. Quite a detailed discussion is given of the bound states of Charmonium (c-$\bar{c}$), the 'hydrogen atom' of the 'new particle' physics; all of its properties are well accounted for by QCD, assuming that this can be shown to imply confinement. The heaviness of the c quark (about 1.5 proton masses) justifies a non-relativistic Schrodinger treatment and the hyperfine structure of the spectrum arises from the one-gluon-exchange potential. Electric dipole γ-transitions occur between its S and P states with rates in accord with these Schrodinger calculations. The long lifetimes of the ψ/J and ψ' states are due to the asymptotic freedom of QCD. The one-gluon-exchange potential and the quark masses are then used to account for all of the mass splittings between and within the various charge multiplets observed within particular $SU(6) \times O(3)$ mesonic and baryonic supermultiplets. There are also chapters dealing with the 'bag model' for hadrons and the possibility of bound multiquark systems. The former is entitled "Quarks confined to a sphere"; despite its very general formulation, the bag model program has been implemented to date only for the case with a rigid spherical bag. The book closes with gauge theories for 'grand unification', where quarks and leptons are assigned to common multiplets and the lepto-quark gauge fields are

extraordinarily heavy, with masses of the order of 10^{-10}g. These theories mostly imply that the proton should decay spontaneously (for example, to $e^+ + \pi^0$) and have led to a number of experimental proposals to push up the present limit ($\gtrsim 10^{30}$ years) on the proton lifetime.

This is a book for the quark-model practitioner. It gives all the prescriptions and rules; they are analysed thoroughly but are not always derived (nor even necessarily all consistent). It says something about every idea current today, although some in much more detail than others. The book is somewhat uneven in its treatment, being strongest and most detailed in the areas where the author's own contributions lie (photo-excitation of excited baryons and polarised lepton–hadron interactions). It also has a somewhat dated air, since our picture of elementary particle physics has been changing rapidly. It is now a general belief that the quarks (u,d) are almost massless, whereas most hadron spectroscopy still assumes non-relativistic motion for the quarks in hadrons. The SU(N) symmetries discussed here are now considered accidental, the true symmetry being the flavour independence of quark–gluon interactions, violated only by the quark mass values. Little is said about 'confinement', the central unresolved question for QCD; indeed, the book says rather little about QCD, beyond implications of the one-gluon-exchange potentials. The book has come too soon to include the recent developments in baryon spectroscopy due to Isgur and Karl, which have brought much order concerning Λ^* and Σ^* states. It would have greater value for students today if it had more about the fundamentals and applications of gauge theories, especially for QCD, since the book would then have appeared forward-looking; its present emphasis is on theoretical aspects from the past, which may be expected to change in the near future. But this is perhaps the fate of any book in this field of physics, where exploration is moving fast; it is easy and unfair to make this judgement in retrospect. There is no doubt that every physics library should possess this book, for there is much to be found on its pages which it is not easy to find elsewhere. □

R.H. Dalitz is Royal Society Research Professor in the Department of Theoretical Physics at the University of Oxford, UK.

Chondrocytes and their matrix

F.N. Ghadially

Biology of Cartilage Cells. By R.A. Stockwell. Pp.329. (Cambridge University Press: London, New York and Melbourne, 1979.) £25.

THIS book is a welcome addition to the literature on cartilage. It is not a book about the chondrocyte only, as the title might lead one to believe; quite detailed accounts of the morphology and chemistry of various components of the matrix are included as well as other topics such as the nutrition and permeability of cartilage and the nature of the articular surface. All this is successfully accomplished in what the author modestly refers to as a "short book", but the concise style of writing has permitted the inclusion of a volume of factual data which one usually associates with much larger works. The well selected references and a carefully prepared index enhance the value of this work.

It is difficult to fault the text in any major respect. The photomicrographs are rather small in size but of good quality; the same, however, cannot be said of the electron micrographs, which are of a variable quality. In contrast to this the line drawings are superb, and the graphs and tables are well planned and informative.

The book begins (chapter 1) with a brief description of the morphological and chemical differences between various types of cartilage. Chapter 2 gives an adequate account of the ultrastructural morphology of the chondrocyte, the effect of hormones on the chondrocyte and the antigenicity of chondrocytes. Chapter 3 deals with the morphology and chemistry of the matrix components. In this excellent chapter we are treated to quite a detailed account of collagen structure and synthesis, elastic fibres and elastogenesis, and the structure of proteoglycans. However, the morphology of proteoglycans (that is, matrix particles) is barely discernible in the electron micrographs presented. Chapters 4 and 5 deal with the metabolism and nutrition of chondrocytes. Chapters 6 and 7 deal with chrondrocyte differentiation and proliferation. The book ends (chapter 8) with a discourse on degenerative changes, age — associated changes, and a section on calcification in which an up-to-date account of matrix vesicles and their role in cartilage calcification is presented.

In summary, this book provides a brief review of existing knowledge about the chondrocyte and surrounding matrix. It is up to date, well written and packed with factual data. In my opinion this book should be of value not only to research workers as suggested by the author, but also to rheumatologists, orthopaedic surgeons and postgraduate students (residents) interested in cartilage.

F.N. Ghadially is Professor and Joint-Head of Pathology at the University of Saskatchewan, Saskatoon, Saskatchewan.

Primary energy resources

D.O. Hall

Biological Energy Resources. By M. Slesser and C. Lewis. Pp.192. (E. & F. N.Spon: London, 1979.) £8.50.

TODAY about one-seventh (or possibly more) of the world's primary energy is derived from biomass — this is equivalent to 19 million barrels of oil a day (which is twice the Saudi Arabian oil production and equal to the US daily oil use). However, because most of this biomass energy use occurs in the developing countries (and there predominantly in rural areas) and because it seldom enters the official statistics, it has, until recently, been virtually ignored by planners, politicians and aid agencies alike. A combination of the "energy crisis" and desertification problems has focussed the attention of both developing and developed countries on the importance and potential of 'biological energy resources'.

This aptly titled book is a must for anyone interested in the basics of bioenergy and its conversion, and more especially in the energetics and economics of biomass systems. The concepts of energy ratios, net energy yield, net utilisable energy production, and gross energy requirement are well presented, and a number of case studies are thoroughly discussed. It is clearly pointed out that intensification of natural ecosystems for biomass energy requires both capital inputs and better management — but local industry, skills and energy self-reliance can be built up. Such energy systems are applicable to varying extents in diverse conditions around the world and must be tailored to suit local conditions.

The chapter on economics of biomass systems touches on net present value, energy payback times, and economic costings. It considers some specific examples like ethanol production and biogas generation, and compares costs with other energy sources. These costs are changing so rapidly it seems imperative to update one's analyses and comparisons annually to take account of accelerating costs.

It is a good book and very timely. But please could authors and/or publishers try to list references that can be traced — conference proceedings references are useless unless the accurate source is given and organizations who publish booklets, and so on, have their addresses given. In such a rapidly developing field with wide sources of interest it is important to be able to trace the information. □

D.O. Hall is Professor of Biology at King's College, University of London, UK.