INTRODUCTION AND SURVEY

K. Bleuler (Bonn)

During the past years we took part in a most important and successful development of particle physics: It was realized that all fundamental interactions have to be derived from a local gauge principle. In particular, this viewpoint represents the basis of the Salam-Weinberg theory of electro-weak interactions which led recently to these wonderful verifications. In very much the same way quantum chromodynamics (QCD) was successfully checked in the realm of high-energy particle physics. It is, however, of decisive importance that QCD serves as a basis for all strong interactions, i.e., for nuclear physics in general. In fact, the underlying SU(3)-color gauge principle yields a well-defined interaction scheme between the gauge (or gluon) field and the Dirac wave function which describes the quarks, i.e., the fundamental constituents of all hadrons. Within this framework, this interaction appears to be the new and fundamental starting point for research in nuclear theory. This means that - in principle - the various, partly phenomenological parameters of the conventional theory (i.e., the masses and interaction properties of the relevant hadrons, so far expressed by coupling constants and form factors) should be derived from one single constant (i.e., the Λ-parameter within the expression for the "running" coupling constant) appearing in the gauge-invariant coupling scheme. This amounts, of course, to an enormous and far-reaching program which, as will be immediately realized, can be reached only through various intermediate steps and, for the time being, a large number of simplifying assumptions. The main scope of this symposium is to give an account of present day research within this general frame.

The various contributions may be ordered - according to rather different, and so far feasible, ways of approach - into three groups:

(i) Calculations based directly on the fundamental laws of QCD (Chaps.1 and 2); for the time being these attempts lead to the determination of the masses and - in a very restricted sense - to the inner structure of the relevant light hadrons, i.e., nucleons and bosons.

(ii) Special models representing these bound quark-gluon systems in simplified (parametrized) form (Chaps.3 and 4). The corresponding, partly phenomenological approaches (mainly so-called bags) are - in view of the enormous extension of the QCD-calculations - of greatest practical importance.

(iii) Special applications leading to corrections (or improvements) with respect to the conventional theory (Chaps.5 and 6). In view of the relatively large diameters of the various hadrons, these investigations are mostly concerned with the short-range part of nuclear interactions.

The first chapter is thus entirely devoted to the fundamental question of a determination of the masses of the relevant hadrons from first principles, with the help of the so-called lattice gauge theory (lectures by M. Bander, G. Schierholz, J. Engels, and F. Palumbo). Although this mathematical approximation scheme is far from being ideal, the results appear to be most promising and represent, in fact, a decisive step in our understanding of heavy particles in general. Apart from reducing the empirical masses of the relevant light hadrons to one single strong coupling constant, one obtains, at the same time, an idea of the inner structure of the building stones of nuclear matter. Different approximation schemes with very much the same scope were discussed in the second chapter. It was of decisive importance to see that dispersion theoretical methods yield similar results and can also be used for dealing with the problem of the interaction between hadrons (lectures by J. Namyslowski and, in a somewhat different sense, by G. Miller). A most important part of the general theory represents the fundamental relation between the principle of symmetry breaking of the QCD-vacuum state and the characteristic properties of the pion (lecture by W. Weise and R. Brockmann). In this respect it was of the greatest interest to realize that this "ground state" may be treated with the help of methods which had been developed within the framework of a general theory of nuclear matter (D. Schütte).

It is clear that the most complicated lattice-theoretical calculations cannot, at present, be extended to the determination of nuclear structure as a whole and not even to a detailed interpretation of the nucleonic properties (magnetic moments, charge distribution, etc.). For this reason, it is of decisive importance to represent the structure of the light hadrons with the help of simplifying models, i.e., the well-known bags, which, so to speak, represent an overall parametrization of the detailed quark-gluon structure of hadrons (Chap.3 with lectures by G. Miller, J. Wambach, and A. Szymacha; L. Wilets proposes an interesting "dynamical" enlargement by replacing the walls of the bags by the action of a "soliton field"). In view of the fact that these viewpoints by no means lead to a unique prescription, it appeared interesting to compare the different models proposed so far. In this context it was appealing to discuss a special model which yields nuclear structure as a whole (Chap.4). As it turns out that the bag diameters are, in fact, not small with respect to characteristic nuclear dimensions, and that the internal excitation energy is comparable to nuclear binding energies, it is clear that nuclear structure as a whole might differ in an essential way from the conventional N-nucleon picture. It was thus proposed (lecture by H.R. Petry) that the bag concept be extended (i.e., by introducing a so-called "overall" bag) in order to represent spherical nuclei as a whole. It was very encouraging to realize that, in this way, characteristic nuclear properties were reproduced in a rather natural and relatively simple way. (In this context a field-theoretical viewpoint was taken by E. Hilf.) Under these circumstances it was, of course, of greatest importance that the quark distribution in finite nuclei had been measured experimentally, and that it was shown to differ in an essential way from the distribution expected from unchanged inner structures of the individual nucleons (lecture on the EMC-effect by K. Rith). An interesting generalization of nuclear structure stems from inserting strange quarks into the system in order to represent empirical results obtained through embedding hyperons into nuclear matter (J. Pirner).

The last part of the conference dealt with the problem of nuclear forces in the light of QCD and with a comparison with the conventional theory (Chaps.5 and 6). The lectures of A. Fässler, M. Harvey, and P. Sauer thus contained quark-theoretical interpretations of the short-range part of nuclear forces as well as natural extensions to larger distances. In this connection it is of special interest to study and to analyze the forces between heavy quarks within the framework of the empirical results on the Y/J-particle (lecture by A. Martin). In order to have a basis for a general comparison, R. Machleidt represented a detailed and, to some extent, complete analysis of boson exchange in the conventional sense. Taking internal excitation of the nucleons as well as the finite extension of the sources into account, it was shown that all empirical NN-scattering phases could be reproduced in a satisfactory way. Within this frame, it turned out that the numerical values of the source extensions (replacing approximately the effect of an inner quark structure) played a decisive role. It was, therefore, of interest to see that gluon exchange yields to some extent similar results for the inner part (K. Holinde). Eventually, boson exchange was discussed from a more general standpoint by M. Bolsterli, whereas A. de Swart discussed the fundamental nucleon-antinucleon problem, both from the bosonic and from the quark-theoretical viewpoint.

A short, tentative survey of these contributions yields, in fact, various promising attempts toward a deeper understanding of nuclear structure with the help of quark-theoretical viewpoints. It became clear, however, that only a long and difficult way might lead to the final goal of full quantum chromodynamical interpretation. In particular, it was realized that there still exists a large gap between the direct lattice and dispersion theoretical determination of hadronic properties and the (phenomenological) description through various bag models. A more detailed analysis should lead to an interpretation of the important empirical results on the inner quark-gluon structure and - hopefully - to an understanding of the (fundamental but unsolved) confinement problem. A similar situation occurs in the determination of the structure of finite nuclei. Again, we have two extreme viewpoints, i.e., a conventional system of nucleons bound by boson exchange (enlarged by quark-theoretical interpretations of the short-range part) and an overall quark structure based on a natural extension of the bag concept. The gap should, again, be filled by a much more detailed description which should, among other things, describe the (unknown) behavior of the inner structure of individual nucleons within matter and - if possible - clarify the confinement problem (maybe in connection with the EMC-effect). The lectures thus suggested new directions for further (urgently needed) research which might also lead to a deeper insight into the underlying field theoretical concepts.

This meeting was held for the third time, in commemoration of the untimely death of Klaus Erkelenz 10 years ago; it was, again, supported by the "Volkswagenstiftung" in a most generous way.

Konrad Bleuler
Bonn, January 1984