# Part IV

# Gauge Theory of Strong Interactions

In this part we shall discuss the possibility of applying gauge fields to describe the *strong interactions* of particles.

The theory of strong interactions is one of the most complicated problems of elementary particle physics. Following the discovery of the $\pi$-mesons, there were attempts to construct a theory of strong interactions based on the perturbation theory within the Lagrangian formalism (patterned upon quantum electrodynamics). These attempts were based on the assumption that strong interactions are mediated by $\pi$-mesons. It soon became clear, however, that such a treatment cannot even lead to qualitative agreement between theoretical and experimental results. Therefore, other theoretical approaches were put forward which do not make use of perturbation theory but rather are based on general principles of analyticity and unitarity (e.g., dispersion-relation methods, etc.).

However, recently our understanding of the structure of hadrons and of their interactions has changed substantially. It has been established in deep-inelastic lepton-hadron scattering experiments that at high momentum transfers, or at short distances, hadrons behave like systems consisting of weakly interacting particles – quarks and gluons – which, in the first approximation, may be considered free. The same result follows from the theory in which all interactions between the quarks are mediated by gauge fields: at small distances the coupling constant is quite small. Such theories are said to be *asymptotically free*. These theories predict, on the other hand, that the interaction between particles increases with increasing distance.

Thus, we arrive at the following qualitative picture: hadrons have a complicated structure, the interaction of the constituent particles tending to zero at small distances (much smaller than the hadron size). At large distances (of the order of the hadron size) the interaction becomes strong and the particles cannot escape the hadron; one speaks of quark and gluon *confinement*. This picture underlies the model of strong interactions referred to as *quantum chromodynamics*. In quantum chromodynamics, hadrons are considered as bound-states of quarks, while the strong interaction between the hadrons is reduced to the interaction of their constituent quarks mediated by the gauge fields of the *colour group* $SU_3$. These latter fields are called the *gluon fields*.

Since strong, electromagnetic, and weak interactions are all mediated by gauge fields, there appears a possibility of unifying all these types of interactions into a single one. This is called the *grand unification*.

In this part we shall discuss the asymptotically free theories, the dynamical structure of hadrons following from the deep-inelastic lepton-hadron scattering experiments, chromodynamics, and the grand unification.