INTRODUCTION

The phenomenological description of hadrons in terms of quarks continues to be successful; the most recent advance was the description of the new particles as built from charmed quarks. Meanwhile theoretical advances have led to the formulation of a specific field theory of quarks, namely "quantum chromodynamics." In quantum chromodynamics, the standard quarks of the quark model are each xeroxed twice to make three different "colors" of quarks, say red, yellow and blue quarks. The three colors form the basis for an SU(3) group (this group is a second SU(3) group, in addition to the Gell-Mann-Ne'eman SU(3).) The quarks interact with an octet of colored vector mesons called gluons. The theory is renormalizable and in some ways is similar to quantum electrodynamics. There is one very crucial difference however: in quantum chromodynamics the gluons interact with themselves. A consequence of this interaction is "asymptotic freedom." Asymptotic freedom arises as follows. The fundamental interactions of quarks and gluons are modified by "radiative" corrections of higher order in the quark-gluon coupling constant. These radiative corrections depend on the quark and gluon momenta. A careful analysis shows that the cumulative effect of radiative corrections to all orders can be characterized by a momentum-dependent effective coupling constant. The effective coupling is found to vanish in the limit of large momenta (to be precise, large momentum transfers between the quarks and gluons). This is called asymptotic freedom. As a result of asymptotic freedom the quarks can behave as nearly free particles at short distances; this is required to explain the high energy electron scattering experiments. Meanwhile the interactions of quarks at
long distances can be strong enough to bind the quarks into the observed bound states; protons, mesons, etc.

Unfortunately, it is not known yet whether the quarks in quantum chromodynamics actually form the required bound states. To establish whether these bound states exist one must solve a strong coupling problem and present methods for solving field theories don't work for strong coupling. The only way known at present to solve quantum chromodynamics is to use renormalized field theory, and at low momenta one gets infrared divergent logarithms to each order in perturbation theory; the sum to all orders of these logarithms is not known$^4$.

In order to make available a wider range of methods for solving the quark theory, it has been formulated on a discrete space-time lattice$^5$. The ultimate aim is to let the lattice spacing go to zero. The lattice is to be understood as an aid to solving the theory much as a discrete mesh is used when a partial differential equation is solved numerically. The continuum limit of the lattice theory should give back the continuum asymptotically free theory.

One of the methods which is available to solve lattice theories but not continuum theories is the block spin method borrowed from statistical mechanics$^6$. I am currently trying to carry out a block spin calculation for the lattice version of quantum chromodynamics: I have no results yet.

The lattice gauge theory has already been discussed in the Erice Lecture notes$^7$. In addition, various versions of the lattice theory are being investigated by Kogut and Susskind$^8$ et al. Bardeen et al.$^9$, and others.

In these lectures three specific topics will be discussed. First, the detailed definition of the space-time lattice theory will be given including the arguments showing that the theory has a Hermitian Hamiltonian in a Hilbert space with positive metric$^{10}$. Secondly, a qualitative discussion of quark confinement will be given. The emphasis will be on how quark confinement might arise due to specific properties of the gauge theory, including asymptotic freedom. Finally, the block spin method will be formulated and the reasons for pursuing this method explained.

An important feature of the lattice theory is that gauge invariance is an exact symmetry of the lattice action. This means the lattice action is invariant to separate SU(3) color groups at each space-time lattice point. The role of this symmetry in quark confinement is explained in the Erice lecture notes$^7$ and will not be reviewed here.