We will not be able to say which particles are elementary until we have a final theory of force and matter.

not known. This turned out to be possible in certain circumstances in nonrelativistic quantum mechanics, where an elementary particle might be defined as one whose coordinates appear in the Hamiltonian of the system. For instance, a theorem due to the mathematician Norman Levinson shows how to count the numbers of stable nonelementary particles minus the number of unstable elementary particles in terms of changes in phase shifts as the kinetic energy rises from zero to infinity. The trouble with using this theorem is that it involves the phase shifts at infinite energy, where the approximation of nonrelativistic potential scattering clearly breaks down.

I worried about this a good deal in the 1960s, but all I could come up with was a demonstration that the deuteron is a bound state of a proton and neutron. This was not exactly a thrilling achievement—everyone had always assumed that the deuteron is a bound state—but the demonstration had the virtue of relying only on nonrelativistic quantum mechanics and low-energy neutron-proton scattering data, without any specific assumptions about the Hamiltonian or about what happens at high energy. There is a classic formula that gives the spin triplet *s*-wave neutron-proton scattering length in terms of the nucleon mass and the deuteron binding energy, but the derivation of this formula actually relies on the assumption that the deuteron is a bound state. If we assume instead that the free-particle part of the Hamiltonian contains an elementary deuteron state, then this formula for the scattering length becomes incorrect, and instead we get a formula for the scattering length in terms of the nucleon mass, the deuteron binding energy, and the fraction of the time that the deuteron spends as an elementary particle (that is, the absolute value squared of the matrix element between the physical deuteron state and the elementary free-deuteron state). Comparing this formula with experiment showed that the deuteron spends most of its time as a composite particle. Unfortunately, arguments of this sort cannot be extended to deeply bound states, such as those encountered in elementary particle physics.

The lack of any purely empirical way of distinguishing composite and elementary particles does not mean that this distinction is not useful. In the 1970s the distinction between elementary and composite particles seemed to become much clearer, with the general acceptance of a quantum field theory of elementary particles known as the Standard Model. It describes quark, lepton, and gauge fields, so these are the elementary particles: six varieties or "flavors" of quarks, each coming in three colors; six flavors of leptons, including the electron; and twelve gauge bosons, including the photon, eight gluons, and the W^+, W^-, and Z^0 particles. The proton and neutron and all of the hundreds of mesons and baryons discovered after World War II are not elementary after all; they are composites of quarks and gluons, not because we can knock quarks and gluons out of them, which is believed to be impossible, but because that is the way they appear in the theory.

The one uncertain aspect of the Standard Model is the mechanism that breaks the electroweak gauge symmetry and gives the W and Z particles their masses, thereby adding an extra helicity state to what would have been the two helicities of a massless W or Z particle of spin 1. Theories of electroweak symmetry breakdown fall into two categories, according to whether these extra helicity states are elementary, as in the original form of the Standard Model, or composite, as in so-called technicolor theories. In a sense, the prime task driving the design of both the Large Hadron Collider and the ill-fated SSC was to settle the question of whether the extra helicity states of the W and Z particles are elementary or composite particles.

THIS MIGHT have been the end of the story, but since the late 1970s our understanding of quantum field theory has taken another turn. We have come to understand that particles may be described at sufficiently low energies by fields appearing in so-called effective quantum field theories, whether or not these particles are truly elementary. For instance, even though nucleon and pion fields do not appear in the Standard Model, we can calculate the rates for processes involving low-energy pions and nucleons by using an effective quantum field theory that involves pion and nucleon fields rather than quark and