James Chadwick who discovered the neutron in 1932. (Courtesy AIP Meggers Gallery of Nobel Laureates)

FOR THE FIRST FEW decades of this century there did not seem to be any trouble in saying what is meant by an elementary particle. J. J. Thomson could use the electric field in a cathode-ray tube to pull electrons out of atoms, so atoms were not elementary. Nothing could be pulled or knocked out of electrons, so it seemed that electrons were elementary. When atomic nuclei were discovered in Ernest Rutherford's laboratory in 1911, it was assumed that they were not elementary, partly because it was known that some radioactive nuclei emit electrons and other particles, and also because nuclear charges and masses could be explained by assuming that nuclei are composed of two types of elementary particles: light, negatively charged electrons and heavy, positively charged protons.

Even without a definite idea of what is meant by an elementary particle, the idea that all matter consists of just two types of elementary particle was pervasive and resilient in a way that is difficult to understand today. For instance, when neutrons were discovered by James Chadwick in 1932, it was generally assumed that they were bound states of protons and electrons. In his paper announcing the discovery, Chadwick offered the opinion: "It is, of course, possible to suppose that the neutron is an elementary particle. This view has little to recommend it at present, except the possibility of explaining the statistics of such nuclei as N^{14}." (One might have thought this was a pretty good reason: molecular spectra had revealed that the N^{14} nucleus is a boson, which is not possible if it is a bound state of protons and electrons.) It was the 1936 discovery of the charge independence of nuclear forces by Merle Tuve et al. that showed clearly that neutrons and protons have to be treated in the same way; if protons are elementary, then neutrons must be elementary too. Today, in speaking of protons and neutrons, we often lump them together as *nucleons*.

This was just the beginning of a great increase in the roster of so-called elementary particles. Muons were added to the list in 1937 (though their nature was not understood until later), and pions and strange particles in the 1940s. Neutrinos had been proposed by Wolfgang Pauli in 1930, and made part of beta-decay theory by Enrico Fermi in 1933, but were not detected until the Reines-Cowan experiment of 1955. Then in the late 1950s the use of particle accelerators and bubble chambers revealed a great number of new particles, including mesons of spin higher than 0 and baryons of spin higher than 1/2, with various values for charge and strangeness.

On the principle that—even if there are more than two types of elementary particles—there really should not be a great number of types, theorists speculated that most of these particles are composites of a few types of elementary particles. But such bound states would have to be bound very deeply, quite unlike atoms or atomic nuclei. For instance, pions are much lighter than nucleons and antinucleons, so if the pion were a bound state of a nucleon and an antinucleon, as proposed by Fermi and Chen-Ning Yang, then its binding energy would have to be large enough to cancel almost all of