the mass of its constituents. The composite nature of such a particle would be far from obvious.

How could one tell which of these particles is elementary and which composite? As soon as this question was asked, it was clear that the old answer—that particles are elementary if you can't knock anything out of them—was inadequate. Mesons come out when protons collide with each other, and protons and antiprotons come out when mesons collide with each other, so which is a composite of which? Geoffrey Chew and others in the 1950s turned this dilemma into a point of principle, known as "nuclear democracy," which held that every particle may be considered to be a bound state of any other particles that have the appropriate quantum numbers. This view was reflected decades later in a 1975 talk to the German Physical Society by Werner Heisenberg, who reminisced that:

> In the experiments of the fifties and sixties . . . many new particles were discovered with long and short lives, and no unambiguous answer could be given any longer to the question about what these particles consisted of, since this question no longer has a rational meaning. A proton, for example, could be made up of neutron and pion, or Lambda-hyperon and kaon, or out of two nucleons and an antinucleon; it would be simplest of all to say that a proton just consists of continuous matter, and all these statements are equally correct or equally false. The difference between elementary and composite particles has thus basically disappeared. And that is no doubt the most important experimental discovery of the last fifty years.

P. Ehrenfest, Jr.

Werner Heisenberg, left, talking with Neils Bohr at the Copenhagen Conference, Bohr Institute, 1934.
(Courtesy AIP Emilio Segrè Visual Archives)

LONG BEFORE Heisenberg reached this rather exaggerated conclusion, a different sort of definition of elementary particle had become widespread. From the perspective of quantum field theory, as developed by Heisenberg, Pauli, and others in the period 1926–34, the basic ingredients of Nature are not particles but fields; particles such as the electron and photon are bundles of energy of the electron and the electromagnetic fields. It is natural to define an elementary particle as one whose field appears in the fundamental field equations—or, as theorists usually formulate these theories, in the Lagrangian of the theory. It doesn't matter if the particle is heavy or light, stable or unstable—if its field appears in the Lagrangian, it is elementary; if not, not.

This is a fine definition if one knows the field equations or the Lagrangian, but for a long while physicists didn't. A fair amount of theoretical work in the 1950s and 1960s went into trying to find some objective way of telling whether a given particle type is elementary or composite when the underlying theory is