the answer to this question was *no*. Of the trillions of neutrinos passing through their detector, less than 50 interacted, but all of these interactions gave off a muon and none produced an electron.

This key experiment, for which Lederman, Schwartz, and Steinberger shared the 1988 Nobel prize, proved that there are at least two completely different kinds of neutrinos. The one that emerges in tandem with an electron or positron in radioactive nuclear decays is known as the *electron neutrino*. The one that surfaces together with a muon when a pion decays is called the *muon neutrino*. After 1962, therefore, we knew about four fundamental leptons: the electron, the muon, and their respective neutrinos (plus their antiparticles, of course).

While the number of leptons remained small and manageable, the list of hadrons continued expanding during the 1950's and on into the 1960's. A further division of the hadron kingdom became necessary. *Baryons,* from the Greek word for heavy, are matter particles like the proton, neutron, lambda, and sigmas. All baryons have at least as much mass as a proton. The *mesons,* from the Greek for middle, are carriers of the strong force like pions and kaons. These lightest mesons weighed in between the electron and proton, but much heavier mesons eventually turned up, too.

Other types of particles, discovered in the early 1950's, were initially thought to be baryon-meson combinations. Enrico Fermi found the first such *resonance* at a mass of 1,236 MeV at the University of Chicago. It survived about a trillionth of a trillionth of a second, far too brief to leave tracks in particle detectors. For awhile these resonances were not classified on the same level with other hadrons. But as their ranks began to swell without bound in the 1960's, they began to appear in tables of baryons and mesons.

A defining characteristic that separates baryons from mesons is *intrinsic spin,* the amount of rotation a particle has about an internal axis. Like charge, intrinsic spin is an inherent property of a particle; as long as it exists, its spin does not change. According to quantum mechanics, the spin of a particle must be an integer (0, 1, 2, . . .) or half-integer (1/2, 3/2, 5/2, . . .) times a fixed value (equal to Planck's constant h divided by 6.29). Physicists say that a particle is "spin-0" or "spin-1/2" or "spin-1" (the commonest values) if it has 0 or 1/2 or 1 units of spin, respectively.

Baryons have half-integer spin and mesons have integer spin. The lightest baryons, like the proton and neutron, have spin-1/2, while the lightest mesons, like the pion and kaon, have spin-0. Resonances generally possess higher spins and are classified as baryons or mesons according to whether they have half-integer or whole number values. The resonance that Fermi discovered at 1,236 MeV, for example, is a baryon with spin-3/2.

All other subatomic particles have a definite spin and are classified accordingly. Leptons have spin-1/2 like the light baryons; they too are matter particles. With spin-1, the photon was in a class by itself—at least during the 1950's. It has whole-number spin like the mesons; all are force-carrying particles that glue matter together. But unlike mesons, the photon has zero mass, which means it can carry the electromagnetic force over very large distances. Mesons can transport their forces only over very short distances.

Another property of subatomic particles was recognized in 1953, called *strangeness* by Murray Gell-Mann, a theoretical physicist at the California Institute of Technology. Unlike spin or electric charge, it has no parallel in everyday life. Baryons and mesons have varying degrees of strangeness, ranging from -3 to +3 units, depending roughly on how heavy they are and how much they resemble the nucleon and pion, which both have strangeness 0. For example, kaons, the next lightest mesons after the pion, have strangeness -1 or $+1$. The lambda particle has strangeness -1 while its antiparticle has $+1$.

More than mere numbers, these properties of subatomic particles— charge, spin, and strangeness—determine how they behave in the many possible encounters with one another. As the particle list began to swell in the early 1960's, some physicists continued to maintain order in the kingdom by classifying the new particles according to these properties. Dissatisfied with this taxonomic approach, however, others had already begun the search for a deeper explanation.