between the particle masses is "broken" by some kind of mechanism, while the underlying equations remain symmetric.

An everyday example of broken symmetry is a bar magnet. Maxwell's equations, which describe the magnetic field permeating the magnet, favor no particular direction. But the bar magnet itself *has* a special direction; like every magnet, it has a north and south pole. This polarization occurs because the iron atoms in the bar are themselves tiny magnets whose preference is to line up with one another—reinforcing each other's magnetism. So although the underlying equations are symmetric, their physical manifestation is not.

Broken symmetries, however, had a highly undesirable feature. In 1961 Yoichiro Nambu of the University of Chicago and Jeffrey Goldstone of Cambridge University showed that they required the existence of massless spin-0 particles, later called *Nambu-Goldstone bosons*. As no such particles had ever been observed, the ideas of broken symmetry seemed to have little relevance to particle physics.

Then in 1964 a number of physicists solved this problem. They discovered a mechanism whereby these unwanted bosons would automatically disappear from the theory while the spin-1 vector bosons in a theory could have masses. Most noteworthy was the work of Edinburgh University theorist Peter Higgs, who showed that in *gauge* theories the troublesome spin-0 bosons might go away when the symmetry is broken. Several other theorists then demonstrated how the force carriers in gauge theory could possess mass—as though they had somehow "gobbled up" the Nambu-Goldstone bosons.

In 1967 Steven Weinberg, a Berkeley physicist on leave at MIT, first realized that this "Higgs mechanism" might provide a way to unify the weak and electromagnetic forces. By incorporating the mechanism in a Yang-Mills gauge theory, he could allow the W and Z particles to acquire their masses "naturally." He published his ideas in a short paper titled "A Model of the Leptons." In 1968 the same idea occurred independently to Abdus Salam of the Imperial College in London. But neither physicist could prove that the resulting *electroweak* theory was in fact calculable—that it did not have the same infinities that always seemed to crop up when masses were introduced.

The proof that the electroweak theory could lead to calculable results, that it was indeed *renormalizable* in physicists' language, was finally made in 1970 by two Dutch theorists. Martinus Veltman of Utrecht had developed a number of calculation techniques that his graduate student, Gerard't Hooft, applied to Yang-Mills gauge theory. If the masses of the vector bosons in this theory were generated by the Higgs mechanism, they showed, then the physical quantities of the theory—particle masses and other properties—were indeed calculable. Only then did the infinities that had plagued gauge theories for years go away.

Armed with this electroweak theory, physicists began making testable predictions. A leader of these efforts was Weinberg, who showed how to extend his "model of the leptons" to include the weak interactions of the hadrons. The clearest evidence for the new theory would be a proof that the Z particle indeed existed. But with a mass thought to exceed 40 GeV, this boson was impossible to produce at accelerators of the day. Its *indirect* effects, however, could still turn up in weak interactions.

Experimenters began to look for indirect effects of the Z in neutrino collisions with matter. Because neutrinos interact only through the weak force, this was an ideal place to search for such subtle effects, which would have been overwhelmed if neutrinos had strong or electromagnetic interactions. In particular, physicists were searching for events in which a neutrino glanced off an atomic electron or nucleus and remained a neutrino afterwards. Such *neutral current* events could occur if the weak force between the neutrino and the atom had actually been carried by a neutral boson like the Z instead of charged bosons like the W^+ and W^-. It was a crucial test of the electroweak theory.

Neutrino scattering experiments were among the first to be planned for the big proton synchrotron then under construction at the new Fermi National Accelerator Laboratory (Fermilab) just west of Chicago. Built under the leadership of Robert Wilson and with $250 million in AEC funding, this 4 mile ring was the largest particle accelerator in the world when it began operations early in 1972. At the time it could boost protons to energies of 200 GeV, setting a new world record. Its performance has steadily improved over the years until today it supplies them at almost 1,000 GeV, or 1 TeV—still the world's highest energy particles.

In 1972 a collaboration of physicists from Harvard, Pennsylvania, and Wisconsin began to use the Fermilab accelerator to search for evidence of