Particle Physics

SECTION 4

SECTION OBJECTIVES

- **Define the four fundamental interactions of nature.**
- **Identify the elementary particles that make up matter.**
- **Describe the standard model of the universe.**

THE PARTICLE VIEW OF NATURE

Particle physics seeks to discover the ultimate structure of matter: *elementary particles.* Elementary particles, which are the fundamental units that compose matter, do not appear to be divisible and have neither size nor structure.

Many new particles have been produced in accelerators

Until 1932, scientists thought protons and electrons were elementary particles because these particles were stable. However, beginning in 1945, experiments at particle accelerators, such as the Stanford Linear Accelerator shown in **Figure 11,** have demonstrated that new particles are often formed in high-energy collisions between known particles. These new particles tend to be very unstable and have very short half-lives, ranging from 10^{-6}s to 10^{-23}s. So far, more than 300 new particles have been catalogued.

Figure 11
The Stanford Linear Accelerator, in California, creates high-energy particle collisions that provide evidence of new particles.

There are four fundamental interactions in nature

The key to understanding the properties of elementary particles is to be able to describe the interactions between them. All particles in nature are subject to four fundamental interactions: *strong, electromagnetic, weak,* and *gravitational.*

The strong interaction is responsible for the binding of neutrons and protons into nuclei, as we have seen. This interaction, which represents the "glue" that holds the nucleons together, is the strongest of all the fundamental interactions. It is very short-ranged and is negligible for separations greater than about 10^{-15} m (the approximate size of a nucleus).

The electromagnetic interaction, which is about 10^{-2} times the strength of the strong interaction at nuclear distances, is responsible for the attraction of unlike charges and the repulsion of like charges. This interaction is responsible for the binding of atoms and molecules. It is a long-range interaction that decreases in strength as the inverse square of the separation between interacting particles, as described in the chapter "Electric Forces and Fields."

The weak interaction is a short-range nuclear interaction that is involved in beta decay. Its strength is only about 10^{-13} times that of the strong interaction. However, because the strength of an interaction depends on the distance through which it acts, the relative strengths of two interactions differ depending on what separation distance is used. The strength of the weak interaction, for example, is sometimes cited to be as large as 10^{-6} times that of the strong interaction. Keep in mind that these relative strengths are merely estimates and they depend on the assumed separation distance.