

## Elementary Particles and the Forces of Nature

### *A Brief History of Time* by Stephen W. Hawking

Up to about thirty years ago, it was thought that protons and neutrons were “elementary” particles, but experiments in which protons were collided with other protons or electrons and high speeds indicated that they were in fact made up of smaller particles. These particles were named quarks by the Caltech physicist Murray Gell-Mann, who won the Nobel Prize in 1969 for his work on them. The origin of the name is an enigmatic quotation from James Joyce: “Three quarks for Muster Mark!” The word *quark* is supposed to be pronounced like *quart*, but with a *k* at the end instead of a *t*, but is usually pronounced to rhyme with *lark*.

There are a number of different varieties of quarks: there are six “flavors,” which we call up, down, strange, charmed, bottom, and top. The first three flavors had been known since the 1960s but the charmed quark was discovered only in 1974, the bottom in 1977, and the top in 1995. Each flavor comes in three “colors,” red, green, and blue. (It should be emphasized that these terms are just labels: quarks are much smaller than the wavelength of visible light and so do not have any color in the normal sense. It is just that modern physicists seem to have more imaginative ways of naming new particles and phenomena - they no longer restrict themselves to Greek!) A Proton or neutron is made up of three quarks, one of each color. A proton contains two up quarks and one down quark; a neutron contains two down and one up. We can create particles made up of the other quarks (strange, charmed, bottom, and top), but these all have a much greater mass and decay very rapidly into protons and neutrons.