

1 Hors d'œuvre

Nicht allein in Rechnungssachen
Soll der Mensch sich Mühe machen;
Sondern auch der Weisheit Lehren
Muß man mit Vergnügen hören.

Wilhelm Busch
Max und Moritz (4. Streich)

1.1 Fundamental Constituents of Matter

In their search for the fundamental building blocks of matter, physicists have found smaller and smaller constituents which in their turn have proven to themselves be composite systems. By the end of the 19th century, it was known that all matter is composed of atoms. However, the existence of close to 100 elements showing periodically recurring properties was a clear indication that atoms themselves have an internal structure, and are not indivisible.

The modern concept of the atom emerged at the beginning of the 20th century, in particular as a result of Rutherford's experiments. An atom is composed of a dense nucleus surrounded by an electron cloud. The nucleus itself can be decomposed into smaller particles. After the discovery of the neutron in 1932, there was no longer any doubt that the building blocks of nuclei are protons and neutrons (collectively called nucleons). The electron, neutron and proton were later joined by a fourth particle, the neutrino, which was postulated in 1930 in order to reconcile the description of β -decay with the fundamental laws of conservation of energy, momentum and angular momentum.

Thus, by the mid-thirties, these four particles could describe all the then known phenomena of atomic and nuclear physics. Today, these particles are still considered to be the main constituents of matter. But this simple, closed picture turned out in fact to be incapable of describing other phenomena.

Experiments at particle accelerators in the fifties and sixties showed that protons and neutrons are merely representatives of a large family of particles now called *hadrons*. More than 100 hadrons, sometimes called the "hadronic zoo", have thus far been detected. These hadrons, like atoms, can be classified in groups with similar properties. It was therefore assumed that they cannot be understood as fundamental constituents of matter. In the late sixties, the quark model established order in the hadronic zoo. All known hadrons could be described as combinations of two or three quarks.

Figure 1.1 shows different scales in the hierarchy of the structure of matter. As we probe the atom with increasing magnification, smaller and smaller structures become visible: the nucleus, the nucleons, and finally the quarks.