Leptons are thought to be elementary particles

Electrons and neutrinos are both leptons. Like all leptons, they have no measurable size or internal structure and do not seem to break down into smaller units. Because of this, *leptons appear to be truly elementary.*

The number of known leptons is small. Currently, scientists believe there are only six leptons: the electron, the muon, the tau, and a neutrino associated with each. Each of these six leptons also has an antiparticle.

Hadrons include mesons and baryons

Hadrons, the strongly interacting particles, can be further divided into two classes: *mesons* and *baryons.* Originally, mesons and baryons were classified according to their masses. Baryons were heavier than mesons, and both were heavier than leptons. However, this distinction no longer holds. Today, mesons and baryons are distinguished by their internal structure.

All mesons are unstable. Because of this, they are not constituents of normal, everyday matter. Baryons have masses equal to or greater than the proton mass. The most common examples of baryons are protons and neutrons, which are constituents of normal, everyday matter. A summary of this classification of particles is given in **Figure 13.**

Hadrons are thought to be made of quarks

Particle-collision experiments involving hadrons seem to involve many short-lived particles, implying that hadrons are made up of more-fundamental particles. Furthermore, there are numerous hadrons, and many of them are known to decay into other hadrons. These facts strongly suggest that hadrons, unlike leptons, cannot be truly elementary.

In 1963, Murray Gell-Mann and George Zweig independently proposed that hadrons have a more elementary substructure. According to their model, all hadrons are composed of two or three fundamental particles, which came to be called *quarks.* In the original model, there were three types of quarks, designated by the symbols *u, d,* and *s.* These were given the arbitrary names *up, down,* and *sideways* (now more commonly referred to as *strange*). Associated with each quark is an antiquark of opposite charge.

The difference between mesons and baryons is due to the number of quarks that compose them. The compositions of all hadrons known when Gell-Mann and Zweig presented their models could be completely specified by three simple rules, which are summarized in **Table 7.**

Later evidence from collision experiments encouraged theorists to propose the existence of three more quarks, now known as *charm, top,* and *bottom.* These six quarks seem to fit together in pairs: up and down, charm and strange, and top and bottom.

All quarks have a charge associated with them. The charge of a hadron is equal to the sum of the charges of its constituent quarks and is either zero or a multiple of *e,* the fundamental unit of charge. This implies that quarks have a

Classification of particles

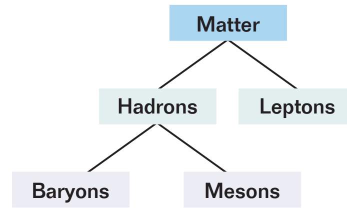

Figure 13
Leptons appear to be elementary, while hadrons consist of smaller particles called *quarks.* As a result, hadrons can be further subdivided into baryons and mesons, based on their internal composition.

Table 7 Hadrons

Particle	Composition
meson	one quark and one antiquark
baryon	three quarks
antibaryon	three antiquarks