Did you know?

Murray Gell-Mann borrowed the word *quark* from the passage "Three quarks for Muster Mark" in James Joyce's book *Finnegans Wake*.

very unusual property—fractional electric charge. In other words, the charge of the electron is no longer thought to be the smallest possible nonzero charge that a particle can have. The charges for all six quarks that have been discovered and their corresponding antiquarks are summarized in **Table 8.**

Table 8 Quarks and Their Charges

Quark	Charge	Antiquark	Charge
up (u)	$+\frac{2}{3}e$	$\bar{u}$	$-\frac{2}{3}e$
down (d)	$-\frac{1}{3}e$	$\bar{d}$	$+\frac{1}{3}e$
charm (c)	$+\frac{2}{3}e$	$\bar{c}$	$-\frac{2}{3}e$
strange (s)	$-\frac{1}{3}e$	$\bar{s}$	$+\frac{1}{3}e$
top (t)	$+\frac{2}{3}e$	$\bar{t}$	$-\frac{2}{3}e$
bottom (b)	$-\frac{1}{3}e$	$\bar{b}$	$+\frac{1}{3}e$

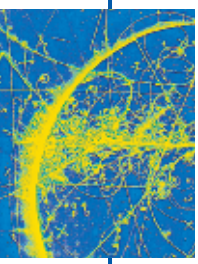
Figure 14 represents the quark compositions of several hadrons, both baryons and mesons. Just two of the quarks, u and d, are needed to construct the hadrons encountered in ordinary matter (protons and neutrons). The other quarks are needed only to construct rare forms of matter that are typically found only in high-energy situations, such as particle collisions.

The charges of the quarks that make up each hadron in **Figure 14** add up to zero or a multiple of e. For example, the proton contains three quarks (u, u, and d) having charges of $+\frac{2}{3}e$, $+\frac{2}{3}e$, and $-\frac{1}{3}e$. The total charge of the proton is $+e$, as you would expect. Likewise, the total charge of quarks in a neutron is zero ($+\frac{2}{3}e$, $-\frac{1}{3}e$, and $-\frac{1}{3}e$).

You may be wondering whether such discoveries will ever end. At present, physicists believe that six quarks and six leptons (and their antiparticles) are the fundamental particles.

Why it Matters

Conceptual Challenge



1. Particle-Antiparticle Interactions

An antibaryon interacts with a meson. Can a baryon be produced in such an interaction? Explain.

2. Strong and Weak Interactions

Two protons in a nucleus interact via the strong interaction. Are they also subject to the weak interaction?

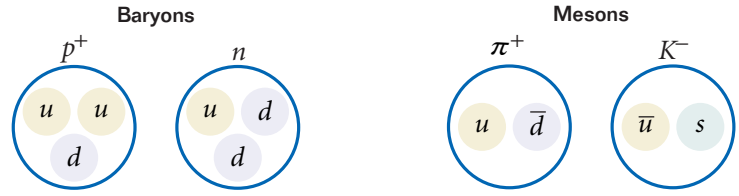


Figure 14
Baryons contain three quarks, while mesons contain a quark and an antiquark. The baryons represented are a proton (p^+) and a neutron (n). The mesons shown are a pion (π^+) and a kaon (K^-), both rare particles.