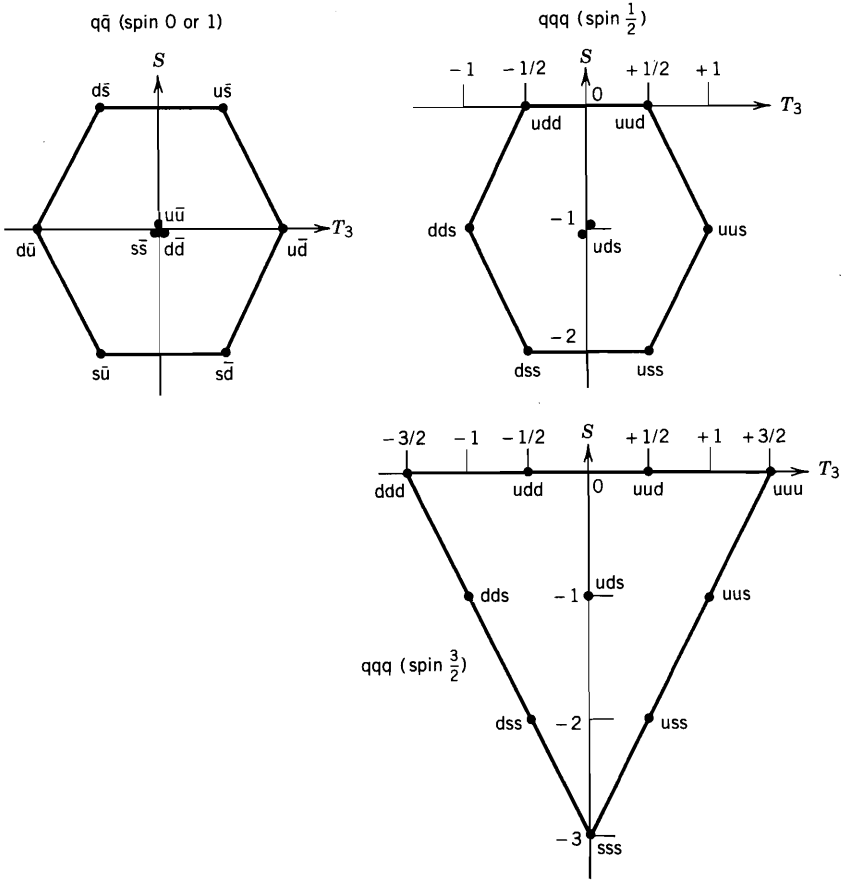

Figure 18.13 Quark-antiquark and three-quark couplings.

quarks of which the hadrons are composed. It has become customary to call the u, d, and s as three *flavors* of quarks. The quark model for the internal structure of hadrons was first suggested in 1964 by Murray Gell-Mann and (independently) George Zweig.

Two features of the quarks are particularly unusual: if we are to have the identifications ddd $= \Delta^-$, uuu $= \Delta^{++}$, and sss $= \Omega^-$, then it is immediately apparent that we must assign fractional electric charges of $+\frac{2}{3}e$ to u and $-\frac{1}{3}e$ to d and s. These charges then reproduce the known charges of the multiplets of Figure 18.11 using the identifications of Figure 18.13 (assigning antiparticles charges opposite to the corresponding particle). Second, if three quarks are to make a baryon, then each quark must have a baryon number of $\frac{1}{3}$. Another property of the proposed couplings is that the quarks must obviously have spin $\frac{1}{2}$; thus a quark and an antiquark in a meson can couple to a total spin of 0 or 1, while three quarks in a baryon can couple to $\frac{1}{2}$ or $\frac{3}{2}$. (We are neglecting the relative orbital angular momentum of the quarks that might contribute to the total intrinsic angular momentum of the mesons or baryons. All of the low-lying states, particularly those shown in Figure 18.11, are $\ell = 0$ states.)