Classification of particles: Baryon Hadrons

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Classification of particles

All fundamental particles fall into one of three families:

Quarks

Although quarks are fundamental particles, they ex- ist in isolation, as single, free quarks. The standard model suggests there should be six 'flavours' of quark (i.e. six quarks and six antiquarks, which match the twelve leptons). These all experience all of the four forces, and always combine to form heavier particles called .
The six quarks are:

Quark	Symbol	Charge (Q) / e	mass / m_{p}
	u	$+\frac{2}{3}$	
antiup	$\bar{\mathrm{u}}$		0.33
down	d		0.34
	$\bar{\mathrm{d}}$		
charm			1.59
anticharm		$-\frac{2}{3}$	
	s		0.53
	$\bar{\mathrm{s}}$	$+\frac{1}{3}$	
	b	$+\frac{2}{3}$	185.5
	$\bar{\mathrm{b}}$		
	t	$-\frac{1}{3}$	
	$\bar{\mathrm{t}}$	$+\frac{1}{3}$	4.80

We shall only consider combinations of up, down and strange quarks (and their antiquarks), although the other quarks follow the same patterns. However, it is more difficult to make the heavier quarks as much .

Experimental evidence for quarks was first provided in 1969 when electrons of de Broglie wavelength 10^{-16} m were fired at protons. As this is about 10 times smaller than the proton, these electrons can resolve internal structure, finding three particles inside the proton.

The particles that quarks make up (called) fall into two categories, and .

Baryons (qqq or $\bar{q}\bar{q}\bar{q}$)

Baryons have a baryon number B of +1, are made of three quarks, and have a lepton number L of 0. They may or may not have a strangeness, which depends on whether they contain strange quarks. (Antibaryons contain three antiquarks, and have a baryon number of −1.)

There are many more baryons than the combinations of the six quark flavours suggests ($^6C_3 \times 2 = 40$), as the quarks have energy levels (like electrons). The Δ^+ (delta plus) particle, for example, has the same quark structure as the proton, but is more massive as its quarks have more energy, and spin differently.

Of all the baryons, only the is stable (and the standard model suggests its half life may be around 10^{32} years, cf. present age of the universe). All other baryons are unstable and will eventually decay into protons (e.g. free neutrons which are not bound up in nuclear matter will decay to protons with a half-life of about [1]).

Name	Symbol	Charge (Q)	Baryon No. (B)	Strangeness (S)
proton				
antiproton				
neutron	n			
antineutron				
lambda	Λ^0	0	1	−1
antilambda	$\overline{\Lambda}^0$	0	−1	+1
sigma plus	Σ^+	+1	1	−1
antisigma plus	$\overline{\Sigma}^+$	−1	−1	+1
sigma zero	Σ^0	0	1	−1
antisigma zero	$\overline{\Sigma}^0$	0	−1	+1
sigma minus	Σ^-	−1	1	−1
antisigma minus	$\overline{\Sigma}^-$	+1	−1	+1
xi minus	Ξ^-	−1	1	−2
antixi minus	$\overline{\Xi}^-$	+1	−1	+2
xi zero	Ξ^0	0	1	−2
antixi zero	$\overline{\Xi}^0$	0	−1	+2
omega	Ω^-	−1	1	−3
antiomega	$\overline{\Omega}^-$	+1	−1	+3

[1] When bound up in nuclear matter, neutron instability via beta decay is balanced against the instability of the nucleus as a whole from the coulomb repulsion of the resulting additional proton, so bound neutrons are not necessarily unstable...