More on Units

Particle physics - theoreticians often work in "natural" units where $\hbar = c = 1$. But following our text (Griffiths) we avoid this.

From $E = mc^2$, we shall quote masses in units of MeV/c^2 or GeV/c^2. Likewise, momenta can be stated in MeV/c or GeV/c.

When it is obvious the c and c^2 terms in the units can also be suppressed, like a proton has a (rest) mass of 938.3 MeV

Standard Model

Current experimental status of particle physics is extremely well described by the so-called Standard Model. It is a combination of electroweak and strong forces. According to SM, the following particles are <u>fundamental</u>:

Fermions (spin 1/2 particles) Make up the Matter

	1st Gen.	2nd Gen.	3rd Generation		
	0.511 MeV	106 MeV	1777 MeV		
Leptons	e	μ	τ	$\rightarrow$	$Q = -1$
	ν_e	ν_μ	ν_τ	$\rightarrow$	$Q = 0$
	almost negligible masses				
	~150 MeV	~1.5 GeV	~175 GeV		
Quarks	u	c	t	$\rightarrow$	$Q = +2/3$
	d	s	b	$\rightarrow$	$Q = -1/3$
	~150 MeV	~300 MeV	~4.5 GeV		

Bosons (spin-1 particles) Carry the forces

γ	Massless (as of now)
$W^\pm$, Z	$M_W = 80.42$ GeV, $M_Z = 91.2$ GeV
g	Massless (as of now)

the Higgs mechanism is believed to give rise to these non-zero masses

Antiparticles

One of the triumps of the Dirac equation (relativistic Schrödinger eqn. for spin-1/2 particles) is that it predicts the existence of antiparticles. So, each particle in the SM has an antiparticle. For some (like photon), its antiparticle is itself.

Mesons $(q\bar{q})$

A quark and its antiparticle form nine possible pairs, known as mesons

$$u\bar{u},\ \underset{\pi^+,\ \rho^+}{u\bar{d}},\ u\bar{s}\ ;\ \underset{\pi^-,\ \rho^-}{d\bar{u}},\ d\bar{d},\ d\bar{s}\ ;\ s\bar{u},\ s\bar{d},\ s\bar{s}$$

These are bosons as they have integer spins.

There are other spin combinations like the singlet $\frac{1}{\sqrt{2}}(u\bar{u} - d\bar{d}) \rightarrow \pi^0$ (pion-zero)

There is actually a huge list of mesons that utilize s, b, t quarks.

Baryons (qqq)

These are fermions with spin 1/2 or 3/2

$p: uud \rightarrow 938.3\ MeV/c^2$

$n: udd \rightarrow 939.6\ MeV/c^2$

$$\left.\begin{array}{l} \Delta^{++}: uuu \\ \Delta^{+}: uud \\ \Delta^{-}: udd \\ \Delta^{--}: ddd \end{array}\right\}\ 1232\ MeV/c^2$$