Elementary particles: forces

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Elementary particles

From about 1945 to the present, about 400 types of mostly unstable particles have been detected.

From about 1970, particles have been reduced to a much smaller number: almost all are made of **quarks,** which are tightly bound.

The **standard model** divides elementary particles into two categories:

- Fermions (spin-$\frac{1}{2}$)—quarks and leptons, the "matter" particles.

- Bosons (integral spin)—photons, gluons, etc., the "field" particles.

The four forces

Forces are mediated by exchange particles. You can see the broad range of ranges and strengths:

interaction	**strength**	**range**	**particle**
Strong	1	~ 1 fm	gluon
EM	$\sim 10^{-2}$	∞	photon
Weak	$\sim 10^{-6}$	$\sim 10^{-3}$ fm	$W^{\pm}, Z^0$
Gravity	$\sim 10^{-43}$	∞	graviton

Strong force

Resonsible for binding quarks to form protons, neutrons, and other heavy particles. Very short range. The low energy nuclear force of last chapter is believed to be a "residual" effect of the basic strong force, just as van der Waals forces are a residual effect of the electromagnetic forces in molecules.

Electromagnetic force

The familiar binder of electrons and protons in atoms. Long range, following inverse-square law. Mediated by the exchange of virtual photons. About 100 times weaker than the strong force.

Weak force

Short range force responsible for β decay. About a million times weaker than the strong force. Weak and EM forces appear to merge to the *electroweak* force at high energies.

Gravitation

Long range, but by far the weakest. Dominates the universe at large scales because it affects all forms of matter and energy. At elementary particle scales, its strength is negligible. There is not yet a coherent quantum mechanics of gravity.

The graviton has not been directly detected. Gravitational waves have been indirectly detected in astrophysical phenomena.