More careful examination of the inelastic scattering process has shown that scaling is not exact. This conclusion can be drawn both from the highly precise experiments at SLAC using electron energies up to 20 GeV or so, and from the less precise experiments using beams of higher energy muons at Fermilab near Chicago, and at CERN in Geneva.

Experiments that measure the deviation from scaling constitute a valuable tool for examining the nature of the forces among the partons or quarks. According to modern concepts, these quarks interact through the exchange of certain objects called 'gluons'. The interaction between these particles and the quarks is measured through a coupling constant whose strength in turn determines the deviation of the data from the ideal scaling relationship, which is derived assuming the quarks to be 'free'. Thus the deviation from scaling measures the strength and character of this basic force.

Note here the analogy with the X-ray experiment that I described earlier. The first experiments of Compton demonstrated that X-ray photons indeed bounced off the electron component of the atom, which behaved nearly as if they were 'free'. The more refined experiments of DuMond and collaborators showed *deviations* from pure 'free' Compton scattering, and thus gave evidence of the dynamics of the atom, in particular the momentum distribution of electrons, in turn derived from the strength of the interaction between the electron and the nucleus. In the recent experiments, the existence of scaling as such indicates the existence of partons or quarks, but it is the *deviation* from ideal scaling that gives valuable evidence of the dynamics which bind the quarks together to form a proton or neutron. In the case of the atom, the basic forces involved are purely electromagnetic, and they can be described by what is now known as Quantum Electrodynamics. This theory is well understood, and its validity has been demonstrated experimentally over distances ranging from many Earth diameters down to about 10^{-18} m. The analogous theory of the strong forces acting between quarks and carried by gluons is known as Quantum Chromodynamics: it is now being formulated, although many outstanding questions remain to be answered.

However, irrespective of the nature of these forces, the basic 'rules of the game', namely quantum mechanics and relativity, have continued to apply throughout. I will now turn to a similar story in regard to the study of the simplest possible bound-state systems which consist of just two particles: a particle and its antiparticle.

5. Particle–antiparticle bound states

One of the predictions of relativistic quantum mechanics is that for each of the particles found in nature there should also be a corresponding antiparticle, that is, a particle with not only its electric charge, but also certain of its other characteristics reversed. This, in turn, led to the expectation that a charged particle and its antiparticle could combine to form a quasi-stable system, essentially a planetary system in miniature. Specifically, it was predicted soon after the discovery of the anti-electron, or positron, that there should be an entity now known as 'positronium', which is the bound system of an electron and a positron. Similarly, again looking ahead many decades, if indeed quarks are fundamental constituents of nuclear matter, or more accurately of all hadronic matter, then there should also be 'quarkonium' systems of various kinds consisting of a quark and an antiquark. Such objects are the simplest bound systems one can imagine. One would therefore presume that the positronium system constitutes an ideal test object to examine the validity of the theory of electromagnetic forces, while the quarkonium systems might be a similar laboratory for