Twisted symmetry

Beautiful though it is, symmetry is not half as intriguing as the alternative. Physicist **Frank Close** tours the cosmos to show us why

SYMMETRY is deeply satisfying. It has harmony and balance – it feels right. But while physicists use it as a guide in building theories, nature is more often lopsided than manifestly symmetric. Asymmetries are often far more informative. Trying to understand why a particular asymmetry exists can reveal clues about the profound nature of reality. That's exactly what Peter Higgs and François Englert were doing 50 years ago when they came up with what's now known as the Higgs mechanism, which imparts mass to fundamental particles. In October last year, their efforts were rewarded when they shared the Nobel prize in physics.

Sometimes symmetry itself springs from asymmetry. We are made of atoms, which are held together by the attraction of opposite electrical charges. The simplest atom, hydrogen, consists of a single negative electron and a positive proton. These electrical charges counterbalance so precisely within matter that they cancel out one another, leaving gravity as the dominant long-range force outside.

This is a case where perfect balance is crucial. Yet the way it is achieved is utterly lopsided. The electron, as far as we know, is a fundamental particle whereas the proton is not: it is made of three quarks. If the electron carries a charge of value -1, each quark carries a charge of +2/3 or -1/3 and they combine in threes to give the proton with a charge of +1 and the neutron with zero charge. Even the simplest atom is cockeyed: its protons are complex, yet its electrons are simple. That their charges conspire so beautifully suggests that some deeper symmetry relates electrons to quarks, but as yet we do not know what it is.

It is not just charge: the clustering of quarks also creates a skew in the way mass accumulates. When clumped to make a proton, quarks' energies are high. This is the price quantum uncertainty demands to localise quarks within the proton, which is only about 10^{-15} metres in size. Their total energy – using the equivalence between energy and mass, $E = mc^2$ – gives a proton a mass of nearly 2000 times that of an electron. Thus an atom is lopsided: flighty lightweight electrons encircle a massive, static nucleus of protons and neutrons.

Asking other questions about reality at the level of particles reveals more asymmetries. Why are there not positively charged electrons and negative protons? The laws of electrical attraction and the quantum rules that stabilise atoms would work just as well to make such "antimatter". As fans of *Star Trek* and Dan Brown know, matter and antimatter annihilate upon contact, emitting radiant energy – photons. So if the universe erupted in a hot big bang out of nothing, the radiant energy of that event should have spawned equal amounts of matter and antimatter, which would then have destroyed one another. Yet the known universe does not show this symmetry, and consists instead of matter without antimatter.

The mystery of the missing antimatter – this fundamental asymmetry of the universe – is a great unsolved question. Perhaps it is born of some intrinsic asymmetry in the underlying laws of nature, though if so, we have yet to identify it. Or could this be an example where fundamental symmetries become hidden, such that the appearance of the physical world differs radically from its deep structure? It is this concept of "hidden symmetry" that led Higgs and Englert to their Nobel prize.

Lopsided life

Life itself is built on hidden symmetry. At first glance the human body appears to be mirror symmetric. There are superficial asymmetries, such as the side on which we part our hair. More profoundly, however, our internal organs are mirror asymmetric, in part because the heart has an intrinsically ›

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