Theoretical physics

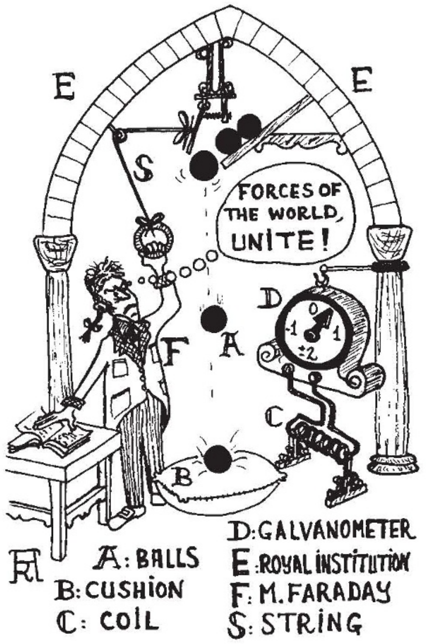
Superstrings and supersymmetry

from Alvaro De Rújula

ONLY two years ago almost all elementary particle physicists considered the subject of 'superstrings' abstruse and irrelevant, perhaps because the number of space-time dimensions in which string theories can be consistently defined is somewhat unrealistic — either 10 or 26 or an astonishing 506. But in September 1984 Michael Green and John Schwarz published a paper[1] on the cure of certain diseases (called anomalies) in these elaborate theories. Overnight, most particle theorists shelved whatever they were thinking about (mainly 'supersymmetry' and 'supergravity') and turned their attention to superstrings. So far, none of these fashionable subjects has proved to have any convincing relationship with physical reality, and yet they have the irresistable power of addiction. Such a gregarious fascination for theories based almost exclusively on faith has never before charmed natural philosophers, by definition. What is the rationale for this seemingly unscientific revolution?

The key to understanding this fashion among particle theorists lies in the colossal potential attributed to superstring theory, defended by many as the 'theory of everything'. Many think that all the known and unknown elementary particles and forces, as well as the correct predictions for all their properties, will follow from superstring theory. Perhaps a more realistic claim is that superstrings may provide the first example of a consistent quantum theory of gravity, and of a unification of this force with all of the others: Michael Faraday's dream irresistably come true.

Strings are the simplest generalization of conventional elementary point-particles: they are extended objects along a single space-like direction[2-4]; they may vibrate and rotate; and their quantum 'normal modes' describe particles with different masses and spins. Some of these particles mysteriously turn out to behave as the graviton[5,6] (the spin=2 carrier of the gravitational force) or as gauge bosons[7,8] (the spin=1 mediators of electromagnetic, weak and strong forces). The 'old string' theory of particles of integer spin is known to be consistent only in 25 space dimensions and 1 time dimension, and has other even more appalling problems. But strings can be made supersymmetrical, that is, forced to describe particles with integer and half-integer spin[9,10] related to each other in a specific and highly non-trivial fashion. Supersymmetrical strings, or superstrings, are consistent in a mere 10 space-time dimensions: a modest but significant step towards the real world. Theorists are much less concerned about the four dimensions in which they live than about the internal consistency of their theories. Superstrings used to be disreputable because they contain anomalies — breakdowns by quantum effects of a conservation law obeyed by the theory at the 'classical' level — which are thought to be fatal. Some superstring anomalies are associated with gravitation, others with the remaining 'gauge' forces that the theory may encompass.



Michael Faraday pioneered the efforts to unify gravity and electricity by unsuccessfully attempting to observe electrical currents induced by accelerating bodies. Note his premonitory use of a string.

The explosive discovery of Green and Schwarz[1] was the cancellation of all anomalies for two particular cases of gauge groups: SO(32) and $E_8 \times E_8$ (ref. 11). These groups are 496-dimensional, and describe that number of independent gauge bosons. But only 12 gauge bosons are required to describe the known elecromagnetic, weak and strong forces: 1 photon; 3 weak intermediate vector bosons; and 8 gluons. We are thus presented with a beautifully unified theory, with 6 more dimensions than the real world and 484 extra carriers of interactions (see ref. 12 for review). The incantation invoked to avoid this embarrassment of riches is: "compactify!"

In general relativity, the local structure of space-time is determined by the interactions of the gravitational field with matter and with itself. Something a thousandfold more elaborate is hoped to happen in a 10-dimensional superstring world. Six dimensions are expected to compactify spontaneously, that is, to warp around themselves into a finite space of unobservably tiny dimensions, leaving behind our flat four-dimensional reality. The geometry of the 'lost' six-dimensional space must be gruesomely contrived, if one is to explain why the relative strengths of the known forces are so different[13], and why many fewer than 496 gauge bosons are observed[14]. Enormous progress in the understanding of compactification is needed for superstrings to become realistic and to move beyond the stage of a beautifully inspired game.

If strings are to offer a unified description of all interactions, their natural energy scale is that at which gravitation and the other forces between elementary particles are of comparable strength. This energy domain at which one could directly test string theories is some 16 orders of magnitude greater than the maximum energy of the largest existing accelerators. Only the very low energy limit of string theories can be tested in the foreseeable future. This requires no new experiments, say the superstring extremists, only further development of theory. If they are right, much of the fun of the discipline — to make empirically testable predictions and to bet on the results of experiments — would be forever gone.

It is presumably unreasonable to believe that we have already stumbled on the theory of everything. This does not mean that strings (whose beautiful properties are undeniable) may not survive as part of the 'truth'. But it may be wiser to admire the surprising potential of the natural world than to overestimate recent progress in theoretical physics. Michael Faraday was clearly aware of this in the 1850s, when he described his hopes to unify electricity and gravitation: "If the hope should prove well-founded, how great and mighty and sublime in its hytherto unchangeable character is the force I am trying to deal with, and how large may be the new domain of knowledge that may be open to the mind of man?" □

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