Into the eleventh dimension

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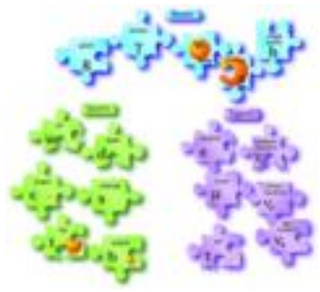
IS THERE a Final Theory in physics? Will we one day have a complete theory that will explain everything from subatomic particles, atoms and supernovae to the big bang? Einstein spent the last 30 years of his life in a fruitless quest for the fabled unified field theory. His approach has since been written off as futile.

In the 1980s, attention switched to superstring theory as the leading candidate for a final theory. This revolution began when physicists realised that the subatomic particles found in nature, such as electrons and quarks, may not be particles at all, but tiny vibrating strings.



Fundamental particles

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Superstring theory was a stunning breakthrough. It became one of the fastest growing and most exciting areas of theoretical physics, generating a feverish outpouring of thousands of papers. Then, in the early 1990s, progress seemed to grind to a halt. People became discouraged when they failed to find the answers to two key questions: where do strings come from, and is our Universe among the many solutions of superstring theory? But now the Internet is buzzing again as papers pour in to the bulletin board at Los Alamos National Laboratory in New Mexico, the official clearing house for superstring papers.

The trigger for this excitement was the discovery of "M-theory", which may answer those two vital questions about superstrings. "I may be biased on this one, but I think it is perhaps the most important development not only in string theory, but also in theoretical physics at least in the past two decades," says Harvard physicist Cumrun Vafa. M-theory led John Schwarz of Caltech, one of the founders of superstring theory, to proclaim a "second superstring revolution". And it inspired a spellbinding three-hour lecture by another leading exponent, Edward Witten of the Institute for Advanced Study at Princeton, New Jersey. The aftershocks of the breakthrough have spread to other disciplines, too. "The excitement I sense in the people in the field and the spin-offs into my own field of mathematics...have really been quite extraordinary," says Phillip Griffiths, director of the Institute for Advanced Study. "I feel I've been very privileged to witness this first hand."

In one dazzling stroke, M-theory has come close to solving superstring theory's two long-standing questions, leaving many theoretical physicists (myself included) gasping at its power. M-theory, moreover, may even force

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string theory to change its name because, although many features of M-theory are still unknown, it does not seem to be a theory purely of strings. Other strange beasts seem to emerge, including various types of membranes. Michael Duff of Texas A&M University is already giving talks with the title "The theory formerly known as strings".

M-theory does not prove the final correctness of superstring theory. Not by any means. Proving or disproving its validity may take years more. But it still marks an astonishing breakthrough. Remember that some of the finest minds of this century have been stumped by the problem of creating a "Theory of Everything". Einstein summed up the problem when he said: "Nature shows us only the tail of the lion. But I do not doubt that the lion belongs to it even though he cannot at once reveal himself because of his enormous size." The "tail" is what we see in nature, which can be described by the four fundamental forces-gravity, electromagnetism and the strong and weak nuclear forces. The lion is the ultimate theory that will unify them in one short equation.

Today, physicists believe that the first force, gravity, can be described by Einstein's general relativity, based on the smooth warping of the fabric of space-time. This is an elegant theory that describes the macroscopic world of black holes, quasars and the big bang. But gravity has stubbornly refused to unite with the other three forces, which are described by quantum theory. Here, instead of the smooth fabric of space-time, we have the discrete world of packets of energy, or quanta.

The form of quantum theory that goes furthest in describing matter and its interactions is the Standard Model, which is based on a bizarre bestiary of particles such as quarks, leptons and bosons (see Diagram). The Standard Model may be one of the most successful theories in science, but it is also one of the ugliest. Its inadequacy is betrayed by some 19 arbitrary constants not derived by any kind of theory that have to be put in "by hand" to make the equations work.

Capturing the "lion", which unites these two great theories, would be a crowning achievement for physics. But while Einstein was first to set off on this noble hunt, tracking the footprints left by the lion, he ultimately lost the trail and wandered off into the wilderness.

Crazy departure

Today, however, physicists are following a different trail-the one leading to superstring theory. Unlike previous proposals, it has survived every blistering mathematical challenge ever hurled at it. Not surprisingly, the theory is a radical-some might say crazy-departure from the past, being based on tiny strings vibrating in 10-dimensional space-time.

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