Trefil, J. The Nature of Science

String Theories

The ultimate particles of matter can be thought of as microscopic strings vibrating in a multi-dimensional world

1948 • BIG BANG

1961 • STANDARD MODEL

1968 • STRING THEORIES

21st C? • THEORIES OF EVERYTHING

Fasten your safety belts, because I'm about to describe one of the strangest theories now making the rounds among scientists whose quest is the ultimate nature of the universe. It is a theory so weird that it might even be right!

String theories are the current leading candidates for a THEORY OF EVERYTHING. This is the holy grail of particle physicists and theoretical cosmologists—a theory which encapsulates in a few equations all of the information about the interactions of the most fundamental constituents of the universe. String theory has been combined with a concept called *supersymmetry* to produce *superstring theory*, and that may prove to be our closest approach so far to unifying the four fundamental interactions (forces). Supersymmetry is itself built on the modern notion of forces being associated with the exchange of one kind of particle between others (*see* STANDARD MODEL). Think of the particles undergoing interactions as the bricks of the universe and the particles being exchanged as the mortar.

In the standard model the bricks are quarks and the mortar is provided by the mediators (called gauge bosons) that are exchanged between them. The idea of supersymmetry is that for every brick (quark or lepton) there is a much heavier but as yet undiscovered particle corresponding to mortar (mediator), and that for every mediator (mortar) there are as yet undiscovered particles corresponding to the quarks or leptons (bricks). None of the so-called supersymmetric partners has ever been seen in the laboratory, but they have been given names nonetheless—the supersymmetric partner of the electron, for example, is the *selectron*, the supersymmetric partner of the quark is the *squark*, and so on. The existence of these as yet unseen particles is one of the firm predictions of the theories.

The picture of the universe given to us by these theories is, in some ways at least, easy to visualize. On distance scales of 10^{-35} m, a scale fully 20 orders of magnitude smaller than a particle such as the proton or the quark, the structure of matter is very different from what we're used to. At these tiny distances (and incredibly high energies), matter appears to be a series of oscillating, stringlike fields. As with a guitar string, there are many ways, or modes, in which the string can vibrate: there is the main note, the fundamental, and the overtones, the higher harmonics. Each mode then corresponds to a different energy. By the principle of RELATIVITY, energy and mass are equivalent, so higher-energy vibrations correspond to higher-mass particles.

But while vibrating strings may be easy to visualize, the fact that the theory requires these vibrations to take place in 10 or 11 dimensions is not. The world we're used to has four dimensions: up–down, right–left, *If string theorists are right, elementary particles consist of minute strings, bundled up in a multiplicity of dimensions.*

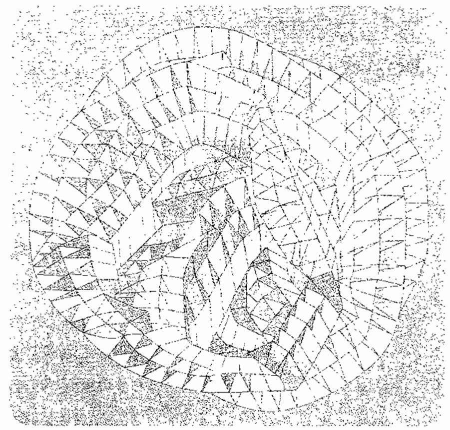
How Many Dimensions?

We humans have been happily using three dimensions to describe our surroundings since prehistoric times (the saber-toothed tiger is 60 feet ahead, 10 feet to the left and 15 feet up, on that rock!). Relativity has accustomed most of us to the concept that time is in some manner a fourth dimension (the sabre-toothed tiger is there *now!*). In the 20th century, though, theoretical physicists began to postulate the existence of 10, 11, even 26 spatial dimensions. Of course, they then have to explain why we do not perceive all those extra dimensions, however many there might be. This is where compactification comes in.

Imagine a garden hose. If you are close to the hose, you can see that it is a three-dimensional object. But from a distance, it appears just to have the one dimension of length: its thickness has become too small to perceive. The thickness of the hose has become compactified—curled up on too small a scale to be detected.

This, the theorists suggest, is what happens to the extra dimensions needed to explain the properties of the subatomic world—they are compactified down to a scale of 10^{-35} m and so are too small to be detected by any of our present-day techniques. Of course, this could all be wrong. It is only speculation —informed speculation perhaps, but speculation nonetheless.

front–back, and past–future. The world of strings has to have many more dimensions than this (*see* sidebar). Theorists get around the problem of there having to be more dimensions than we can observe by saying that the extra dimensions are tucked away (the technical term is *compactified*) and can't be seen at normal energies.



Recently, the concept of strings has been extended to multidimensional membranes, or *branes*, which are essentially strings that have been expanded into sheets. As one wag put it, the theorists' picture of the world has gone from a plate of spaghetti to a plate of lasagna.

So these are some of the characteristics of the best current candidate for a THEORY OF EVERYTHING. At the moment, though, there are some problems. For one thing, working out the mathematics of these theories turns out to be excruciatingly difficult. Almost all of the work over the last 20 years has been devoted to learning how to do calculations and proving that different versions of the theory are equivalent to one another. More importantly, the simple fact is that string theorists have yet to produce a single prediction that can actually be tested in the laboratory. Until they do, I'm afraid that their work, while a fascinating and esoteric exercise in logic, will remain outside the mainstream of science.