# THE SEARCH FOR THE BIG TOE

Physicists are looking at present for the *theory of everything* (TOE) – a unified theory of Physics. Physics is the most fundamental system of knowledge: the laws of physics determine Chemistry and Biology, and all other aspects of science. If we could get to the basis of physics, we would have the foundation for the whole of knowledge (According to Stephen Hawking, we would know 'the mind of God'.)

But haven't we got this already? After all, we teach physics on the basis of known laws and structures of matter. No, because all these laws and other pieces of knowledge are separate and not part of a single logical structure.

At the moment, we know that everything that happens in the universe anywhere at any time is the result of just **Four Forces:**

Gravity
Electromagnetism
Strong – holds nucleus together (alpha decay)
Weak – Beta decay, only force that can truly change matter, supernovae

*What* are they between? Where do the forces come from? In fact, we know that these four forces are maintained between just **twelve fundamental particles** (and the same number of anti-particles): six quarks and six leptons.

| Quarks | Leptons |
|---|---|
| Up | Electron Neutino |
| Down | Electron |
| Charmed | Muon Neutrino |
| Strange | Muon |
| Top | Tau Neutrino |
| Bottom | Tau |

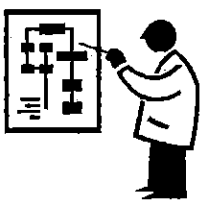
These represent three broadly similar repeating generations.

We also have a set of rules, discovered more or less haphazardly, which determine the way the forces act and related matters, which we call the **laws of physics**. No one has ever listed them nor does anyone know how many there are.

Now, a unified theory suggests that we can reduce all these many things into *one* – one force, one particle, one law. The current idea is that a single **equation** – which could be written on a T-shirt or the back of a postage stamp – would include everything.

Physicists have set about in their different ways to unify

All the forces or
All the particles or
All the Laws



And have devised various schemes for doing this

Supersymmetry
Strings
Cosmology
10-D space-time

Twenty years ago, Stephen Hawking said it would take twenty years to find a unified theory. Today, he still says the same. What has gone wrong? The various approaches being put forward do not look like fitting on a T-Shirt – they lack the fundamental simplicity you would expect. They are too complicated. There's a suggestion of Ptolemy's epicycles about them.

One thing so far left out of the picture is the **parameters**. These are the measurable quantities in terms of which all the laws of physics are expressed:

Space, Time, Mass, Momentum, Energy, etc.

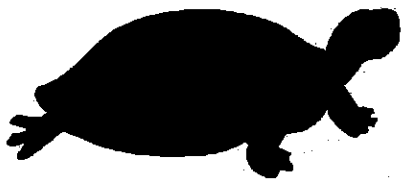
Physical equations show that some are more important than others, and I believe it is fairly easy to show that only four are fundamental:

Space
Time
Mass (source of gravity)
Charge (but as source of three interactions)

I find it strange that physicists searching for the TOE haven't paid closer attention to these. A theory which somehow makes use of the parameters without explaining them is not, in my opinion, a unified theory.

Superstrings and supermembranes in 10-dimensional space-time do not look to me like the 'best candidate we have' as is frequently claimed. It reminds me of the well-known dialogue which goes something like as follows:

'The World is not flat, as it appears, but round, like a ball.'
'Then what holds the World up?'
'The great god Atlas holds the World on his shoulders.'
'But what does Atlas stand on?'
'He stands on a huge island.'
'But on what does the island rest?'
'It rests on the back of a giant turtle.'
'But what ...'
'No need to ask further. It's turtles all the way down!'



(Version: Van Flandern; others in Hawking, etc.) In principle, like the turtles, the theory is too exotic, too arbitrary, too model-dependent.

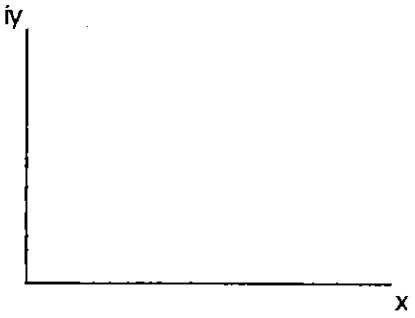
Our theory must be simple and abstract. It should not look like a turtle or any other concrete thing. It should not be based on esoteric mathematics, and perhaps not *directly* on mathematical equations at all.

Well, where do we start? I am convinced that we start with Space, Time, Mass and Charge – and not with forces, particles and laws.

And what do we look for? We look for symmetry. 'Unified' does not necessarily imply 'unity'. Unification may come about by symmetry, rather than trying to make unlike things identical.

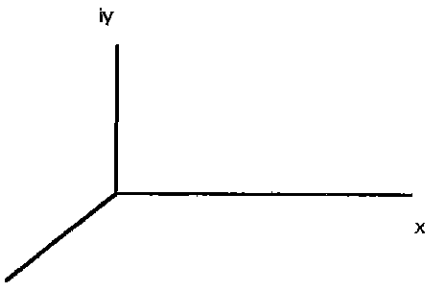
How do we go about this? Let's start with history and go back 150 years. Sir William Rowan Hamilton, Astronomer Royal for Ireland, is looking at complex numbers. The year is 1830. He sets out the Argand Dia-

gram, known since about 1800.




Ordinary real numbers are on the x-axis. Imaginary numbers, multiples of $i = \sqrt{-1}$ are on the y-axis. Now he has a flash of inspiration – we add them up as squares, the same as Pythagoras. So the Argand diagram becomes a natural way of representing 2-dimensional space through numbers. Dimensions are part of the number system, not just something we discover from physical experience. But what about 3 dimensions? This is where Hamilton got stuck.

He drew another axis at right angles to the first two.




This couldn't be real numbers, because there was only one set of real numbers, but it could be another set of imaginary numbers, with $j = \sqrt{-1}$, because we don't really know what imaginary numbers are, and there could be more than one type. Only it couldn't. When Hamilton tried multiplying i by j he got nonsense.

And so it went on for thirteen years. Every so often Hamilton got out a piece of paper and fiddled with his 'triads', as he called them, only to give up defeated.

Then one day – on 16 October 1843 – he had a second flash of inspiration. He recalls that he was walking over Brougham Bridge with his wife, paying no attention to her conversation, when an 'electric circuit' seemed to connect in his brain, and he immediately wrote down the equations he had so long sought.

$i^2 = j^2 = k^2 = ijk = -1$
$ij = -ji = k$

Only he didn't have a pen and paper and scratched them on the bridge instead.

What he had realised is that if there were **three** imaginary numbers **i, j, k**, then the system would work. He called it the **quaternion** system because it had four parts – three imaginary and one real.

He immediately associated them with the idea of 3-dimensional space.
Now it was the real axis that was the problem, but Hamilton quickly associated this with time, and sought a kind of four-dimensional connection between space and time. As he put it in what he considered 'poetry':

And how the one of time, of space the three
Might in the chain of symbol girdled be.

(Hamilton, for some reason, was rather proud of his verse, and asked his friend Wordsworth's opinion on it. You can imagine Wordsworth's reply.)

Hamilton knew that his system was unique. It couldn't be extended to any other number, as was later proved, and he was convinced that it actually *explained* three-dimensional space.

Later scientists thought otherwise. His system was inconvenient because it gave negative answers when you applied Pythagoras, and an alternative system based on three **real** parts – vectors – was devised for physical application. Later on, an imaginary part was added on to represent time – to give the **4-vector** system of **special relativity**, of which a version was anticipated, in a qualitative sort of way, in H. G. Wells' famous novel, *The Time Machine* (1895): 'There are really four dimensions, three of which we call the planes of Space, and a fourth, Time. There is, however, a tendency to draw an unreal distinction between the former three dimensions and the latter because it happens that our consciousness moves intermittently in one dimension along the latter from the beginning to the end of our lives ... *There is no difference between Time and any of the three other dimensions of Space except that our consciousness moves along it.'*

The time component in the 4-vector is like an extra term added on to Pythagoras' theorem, only it is negative because time is made into an imaginary parameter. (c, the velocity of light, changes time units to space units.)

| | |
|---|---|
| 3-D Space: | x,y,z |
| 4-D Space-time: | x,y,z,ict |
| Pythagoras: | $x^2 + y^2 + z^2$ |
| 4-vector: | $x^2 + y^2 + z^2 - c^2t^2$ |

The time-term leads to what are called relativistic corrections, and all the peculiar things that happen to space, time and mass measurements at high speeds. The magnetic field is a relativistic correction to the electric field.

So Hamilton fell out of favour and the historian E. T. Bell, in his *Men of Mathematics*, called his career an 'Irish Tragedy' and said of Hamilton's belief that he had discovered one of the great secrets of the universe: 'Never has a great mathematician been more hopelessly wrong.'

It is my belief that it was Bell who was hopelessly wrong.

The reason is that, though, as Hamilton's opponents said, quaternions do not apply to Space and Time, they do apply to **Mass** and **Charge**, and are **symmetrical** to the 4-vectors that apply to Space and Time.

Let us look at two force laws: Newton's for Gravity, and Coulomb's for electricity:
Newton: F(g) = -constant x Gm(1)m(2)/r2
Coulomb: F(e) = constant x q(1)q(2)/r2

For identical particles, the gravitational force Fg is negative (attractive), while the electric force Fe is positive (repulsive). This makes no sense unless, say, m1, m2 are **real** and q1, q2 **imaginary**. Then we can write
Newton: F(g) = -constant x m(1)m(2)/r2
Coulomb: F(e) = -constant x iq(1)iq(2)/r2

Which are now identical in form. When we realise that there are two other forces (strong and weak) caused by something like charge, with similar rules, then a **quaternion** description for mass and charge becomes extremely plausible.

We have established a symmetry between
Space – Time
And Mass – Charge

One is represented by a 4-vector (3 real, one imaginary):
x, y, z, ict

And one by a quarternion (three imaginary, one real):
ie, js, kw, m

and these are mirror images of each other.

Space – Time and Mass – Charge thus seem to be exactly symmetrical to each other. But it doesn't end there. There are many other symmetries between them. I have investigated all the properties of Space, Time, Mass, Charge, and find that they are **all** connected by symmetry.

In principle, given the existence of a symmetry, all the properties of the four most important concepts in physics can be described by those of any one. This is truly 'E pluribus unum'. This is what can be put on a postage stamp or a T-shirt, and it is in this sort of area that we should be looking for a TOE.

| | | | |
|---|---|---|---|
| Space | Real | Nonconserved | Divisible<br>Dimensional |
| Time | Imaginary | Nonconserved | Indivisible<br>Nondimensional |
| Mass | Real | Conserved | Indivisible<br>Nondimensional |
| Charge | Imaginary | Conserved | Divisible<br>Dimensional |

Peter Rowlands
Liverpool University