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Knowing the mind of God: Seven theories of everything

This story has been edited to clarify that it discusses different approaches being taken to develop a theory of everything.

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Getting inside the mind of God

(Image: John Lund/Getty)

The "theory of everything" is one of the most cherished dreams of science. If it is ever discovered, it will describe the workings of the universe at the most fundamental level and thus encompass our entire understanding of nature. It would also answer such enduring puzzles as what dark matter is, the reason time flows in only one direction and how gravity works. Small wonder that Stephen Hawking famously said that such a theory would be "the ultimate triumph of human reason – for then we should know the mind of God".

But theologians needn't lose too much sleep just yet. Despite decades of effort, progress has been slow. Many physicists have confined themselves to developing "quantum gravity" theories that attempt to reconcile quantum mechanics with general relativity – a prerequisite for a theory of everything. But rather than coming up with one or two rival theories whose merits can be judged against the evidence, there is a profusion of candidates that address different parts of the problem and precious few clues as to which (if any) might turn out to be correct.

Here's a brief guide to some of the front runners.

String theory

This is probably the best known theory of everything, and the most heavily studied. It suggests that the fundamental particles we observe are not actually particles at all, but tiny strings that only "look" like particles to scientific instruments because they are so small.

What's more, the mathematics of string theory also rely on extra spatial dimensions, which humans could not experience directly.

These are radical suggestions, but many theorists find the string approach elegant and have proposed numerous variations on the basic theme that seem to solve assorted cosmological conundrums. However, they have two major challenges to overcome if they are to persuade the rest of the scientific community that string theory is the best candidate for a ToE.

First, string theorists have so far struggled to make new predictions that can be tested. So string theory remains just that: a theory.

Secondly, there are just too many variants of the theory, any one of which could be correct – and little to choose between them. To resolve this, some physicists have proposed a more general framework called M-theory, which unifies many string theories.

But this has its own problems. Depending how you set it up, M-theory can describe any of 10^{500} universes. Some physicists argue that this is evidence that there are multiple universes, but others think it just means the theory is untestable.

Loop quantum gravity

Although it hasn't had the same media exposure, loop quantum gravity is so far the only real rival to string theory.

The basic idea is that space is not continuous, as we usually think, but is instead broken up into tiny chunks 10^{-35} metres across. These are then connected by links to make the space we experience. When these links are tangled up into braids and knots, they produce elementary particles.

Loop quantum gravity has produced some tentative predictions of real-world effects, and has also shed some light on the birth of the universe. But its proponents have so far struggled to incorporate gravity into their theories. And as with string theory, a true experimental test is still some way off.

CDT

Causal dynamical triangulations looks pretty similar to loop quantum gravity at first glance. Just as loop quantum gravity breaks up space into tiny "building blocks", CDT assumes that space-time is split into tiny building blocks – this time, four-dimensional chunks called pentachorons.

The pentachorons can then be glued together to produce a large-scale universe – which turns out to have three space dimensions and one time dimension, just as the real one does. So far, so good, but there's a major drawback: CDT as it currently stands cannot explain the existence of matter.

Quantum Einstein gravity

This idea, proposed by Martin Reuter of the University of Mainz, Germany, takes a rather different tack.

Part of the problem with unifying gravity and quantum mechanics is what happens to gravity at small scales. The closer two objects are to each other, the stronger the gravitational attraction between them; but gravity also acts on itself, and as a result, at very small distances a feedback loop starts. According to conventional theories the force should then become ridiculously strong – which means there's something wrong with the conventional theories.

However, Reuter has come up with a way to generate a “fixed point”: a distance below which gravity stops getting stronger. This could help solve the problem, and lead to a quantum theory of gravity.

Quantum graphity

All the theories above assume that space and time exist, and then try to build up the rest of the universe. Quantum graphity – the brainchild of Fotini Markopoulou of the Perimeter Institute for Theoretical Physics in Waterloo, Ontario, Canada, and colleagues – tries to do away with them.

When the universe formed in the big bang, Markopoulou says, there was no such thing as space as we know it. Instead, there was an abstract network of “nodes” of space, in which each node was connected to every other. Very soon afterwards, this network collapsed and some of the nodes broke away from each other, forming the large universe we see today.

Internal relativity

Developed by Olaf Dreyer of the Massachusetts Institute of Technology, internal relativity sets out to explain how general relativity could arise in a quantum world.

Every particle in the universe has a property called “spin”, which can be loosely thought of as what happens to the particle when it is rotated. Dreyer’s model imagines a system of spins existing independently of matter and arranged randomly. When the system reaches a critical temperature, the spins align, forming an ordered pattern.

Anyone actually living in the system of spins will not see them. All they see are their effects, which Dreyer has shown will include space-time and matter. He has also managed to derive Newtonian gravity from the model: however, general relativity has not yet emerged.

E8

In 2007 the physicist (and sometime surfer) Garrett Lisi made headlines with a possible theory of everything.

The fuss was triggered by a paper discussing E8, a complex eight-dimensional mathematical pattern with 248 points. Lisi showed that the various fundamental particles and forces known to physics could be placed on the points of the E8 pattern, and that many of their interactions then emerged naturally.

Some physicists heavily criticised the paper, while others gave it a cautious welcome. In late 2008, Lisi was given a grant to continue his studies of E8.

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Though it seems abrupt, this is the end of the article. Click any of the links to learn more.