The physical world: quantum
Testing EPR

v/o:
In the 1960's John Bell, a Physicist from Northern Ireland, moved things on by turning the EPR Experiment into something that could be practically tested. This was finally done over a tiny distance by a French team, led by Alain Aspect, in the early 1980's.
In 1997 a team in Geneva attempted the experiment on a much larger scale. They tried to demonstrate that a pair of quantum particles actually do have a strange, spooky connection, this time across a whole city. If Nicolas Gisin and his team were right, then they would have proved one of the greatest scientists of all time was wrong.

Nicolas Gisin - University of Geneva:
Well it's a long, long journey of course and it goes back to Einstein and even before, I mean Newton, you can go back, and it's also certainly not the end of the journey. So if we go back to, let's say Einstein at his time and Einstein – Bohr debate, at that time they had to swallow the revolution of quantum mechanics, and to accept the new physics and the new views, and indeed the products, it's like EPR products, and well my part of the journey probably was to test that, to understand it, to test it, and to participate in this new way of looking at quantum mechanics as a resource to produce new things: computing and so on, and with my team at Geneva University we had the chance to test experimentally the issue, and I hope I will continue that journey.

v/o:
For this experiment they had to create a pair of quantum particles; they used photons, which are particles of light. Like gloves, one photon must be opposite to the other. The key was to separate them by 10 kilometres and then measure them at exactly the same moment. There would be no time for a message to pass between the photons.

Wolfgang Tittel - University of Geneva:
So this is where the experiment started. We created our photon pairs and then sent them to the other stations where they are measured. It starts with laser which you see here, just see the reflects on my finger, and this laser light is then focused into the non-linear crystal which you'll find here. And this is actually the heart of our experiment.

Nicolas Gisin - University of Geneva:
The idea is to have two photons which are produced at the same time. Principally you take one photon, and in a non-linear crystal you let it divide into two twin photons. There are two photons but they together form one system, one quantum system.

Wolfgang Tittel - University of Geneva:
One of the photons is then coming out of this fibre, going through the fibre network which is usually used for phone calls, going all the way down to Bernex there in this direction. The other photon is coming out here, again in fibre network, going all the way to the other side, to Bellevue who'll make the other measurement.

Nicolas Gisin - University of Geneva:
Going to Telecom fibres gives us a possibility to go over long distances because these fibres are very well tuned for that. One village is north, it's near the Lake Geneva and is about 5 kilometres north, and the other one is about 5 kilometres south, and so we have this 10 kilometre direct special separation.
So we've been on the north of Geneva you see on one side. We do our measurement, then the photon on that side acquires a property and instantaneously in theory, and sadly faster than light in practice, the other one there also gets the opposite property. The output on one side is random, completely random. The outcome on the other side is also completely

random. However, two outcomes are always opposite. Not only do we not know which photon has which property, but according to the theory, well confirmed by the Experiment, the photons themselves don't know. I mean sometimes nature itself doesn't know, and we find that on this very rare occasion Einstein was wrong.

v/o:
So nature really is weird. Until someone makes a measurement, two photons can exist in a tangled up state, both being, and not being, at the same time. This entangled pair of photons are somehow connected across vast distances.

Nicolas Gisin - University of Geneva:
And the property still holds. Probably, according to quantum mechanics, if you go to the moon, it's still there. It's more difficult to test but it's quite a fascinating prediction.

V/O:
Einstein: nil – Bohr: one.

Paul Davies, visiting professor - Imperial College, London:
Poor Einstein, I'm sure he'd be very upset if he saw the results of the Aspect experiment and these others that have been done, because it would force him to make a choice between his beloved Theory of Relativity that forbids faster-than-light signalling, or his implacable opposition to the idea that nature was fundamentally in deterministic. It's fascinating to wonder which side he would come down on.