Suppose *actual* experimental data *violated* the Bell's inequality we just derived. That is, suppose in laboratory experiments with actual twin-state photons the mismatch rate for the rotation of both polarizers was *greater* than twice the mismatch rate for the rotation of a single polarizer. Since a Bell's inequality, saying it could *not* be greater, was deduced assuming *only* reality and separability, its violation would mean that one or both of those assumptions *had* to be wrong in the actual world. It would mean that our actual world lacked either reality, or separability, or both. We will see that a violation in any one case (actual twin-state photons, for example) means a lack of reality or separability for everything such photons could possibly interact with. In principle, that's anything. (We use the adjective "actual" rather than the tricky word, "real," to refer to the world we live in and the photons we deal with.)

Were Bell's inequality *not* violated, quantum theory, which *predicts* a violation, would have been shown wrong. But nothing would be proven about reality or separability. Incorrect assumptions can lead to *some* correct predictions. In fact, in some situations, Bell's inequality is not violated. Its violation in *any* situation is sufficient to deny that our actual world has both reality and separability.

The Experimental Tests

In 1965, when Bell's theorem was published, it was a mild heresy for a physicist to question quantum theory or even to doubt that the Copenhagen interpretation settled all philosophical issues. Nevertheless, as a physics graduate student at Columbia University in the late 1960s, John Clauser was intrigued.

Off to Berkeley as a postdoc to work on radio astronomy with Charles Townes, Clauser presented his idea for a test of Bell's inequality. Townes released him from his commitment to work on astronomy, and even continued his financial support. With borrowed equipment, Clauser and a graduate student measured what we have called the "mismatch rate" for twin-state photons with polarizers set at different angles with respect to each other. They, in essence, did the Alice-and-Bob experiments. They found Bell's inequality *violated*. Violated in just the way quantum theory predicts.

To avoid a common misstatement, we emphasize that Bell's *inequality* was violated. Bell's *theorem*, the derivation of the inequality from the assumptions of reality and separability, is a mathematical proof not subject to experimental test.

Exactly What Does Quantum Theory Predict?

The actual *amount* by which quantum theory predicts Bell's inequality to be violated requires a rather complicated calculation, one that is not particularly relevant for our discussion. However, for those who want to explore this point, we'll say a bit more, but the following paragraph *can well be skipped*.

A semi-classical calculation considering light as an electric field gives the correct answer for the mismatch rate, even though it cannot deal with the photon correlations needed to establish the *meaning* of Bell's inequality. We note here, without much explanation, the following facts: (1) Alice's observation of an actual photon going through her, say, vertical polarizer means its twin at Bob's polarizer will be vertical. (2) The fraction of light intensity (or photons) *not* going through Bob's polarizer, the mismatch rate, is proportional to the square of the component of electric field perpendicular to his polarizer axis. (3) This fraction is proportional to the square of the sine of the angle Θ of Bob's polarizer to Alice's (Malus's law). Thus, the actually observed mismatch rate, and that given by quantum theory, is proportional to $\text{Sin}^2(\Theta)$. (4) The Bell inequality we derived thus states: $2\text{Sin}^2(\Theta) \geq \text{Sin}^2(2\Theta)$. Try this for $\Theta = 22.5°$, $2\Theta = 45°$. We get $0.3 \geq 0.5$. Very wrong. We thus see that in the actual world, Bell's inequality can be strongly violated. We repeat: this paragraph can be skipped.

The Bottom Line for the Experimental Results

Clauser's experiments ruled out what is sometimes called "local reality," or "local hidden variables." The experiments showed that properties of our world either have only an observation-created reality *or* that there exists a connectedness beyond that mitigated by ordinary physical forces, or both.