No-Bell announcement

It's widely accepted that quantum theory, combined with experiments that verify its predictions, implies that any 'hidden variable' theory that would account for quantum processes in a more realistic way (that is, with physical properties existing before they're measured) must involve non-local, faster-than-light connections. This is the consequence of John Bell's celebrated theorem, and the basis for a small industry in contemporary physics.

Recent experiments have gone further, even ruling out some non-local theories (S. Gröblacher *et al.* *Nature* **446,** 871–875; 2007); those clinging to a belief in reality seem stuck with non-locality of a disturbing kind (such as in the bohmian interpretation of quantum mechanics).

But what of the assumptions in Bell's theorem? What if Bell's argument were wrong? In a paper guaranteed to be contentious, Joy Christian has suggested as much (http://arxiv.org/abs/quant-ph/0703179). A paper entitled "Disproof of Bell's Theorem" has to be greeted with scepticism, yet the argument is so unusual, and elegant, as to warrant serious consideration.

Bell's argument was that a set of hidden variables, λ, would determine the outcomes of measurements of pairs of entangled variables, say spins, located in space-like separated regions. Bell worked out the correlations between such measurements that could follow from classical physics and found a result in conflict with quantum theory. Because experiments have since verified the predictions, Bell's theorem implies the impossibility of local hidden variable theories.

But Christian argues that Bell made an important assumption in taking the variables λ to be real numbers. Mathematically speaking, this means they're elements of a 'scalar' algebra, in which multiplication is commutative; but is there any reason, in principle, that real hidden variables would have to belong to this particular algebra?

The algebra most natural for representing rotations in 3D space is the Clifford algebra, of which William Rowan Hamilton's quaternions form a sub-algebra. Rotations, of course, do not in general commute, and the Clifford algebra respects this fact; it also reflects how it takes a rotation of 720°, rather than 360°, to bring

What if Bell's argument were wrong?

an object back into its original orientation. (This weird effect occurs for fermions within quantum theory, but it's actually a peculiarity of rotations in 3D space, not a quantum phenomenon).

Taking Bell's λ to be elements of a Clifford algebra, Christian shows how the argument runs differently. Originally, the values of a particle's spin, measured along different directions, were assumed to commute with one other. Not so for Clifford-algebra-valued functions. As a result, Christian apparently demonstrates, the correlations allowed in a local realistic theory are identical to those of quantum theory.

Not surprisingly, this argument has been strongly criticized (arxiv:0707.2223). Christian has made equally strong rebuttals (arxiv:quant-ph/0703244), and the argument is likely to rage for some time, given the immense consequences. If he's right, then nothing in the quantum formalism, or in any experiments, implies the impossibility of finding hidden variables that might explain quantum processes in a realistic, even classical way. Einstein might have been talking sense all along.

Mark Buchanan

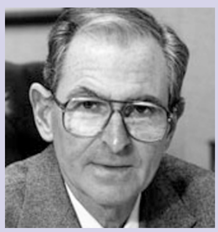
Onwards and upwards

The philosophy of science that began with Sir Francis Bacon's view of the disinterested scientist collecting observations culminated in Karl Popper's view that science proceeds by proving good ideas wrong, to be replaced by better ones. Along the way, it encountered Thomas Kuhn's idea that science proceeds by means of mutually exclusive paradigms.

Scientists are not baconian observers of nature, but all scientists become baconians when describing their observations. Scientists are rigorously, even passionately, honest about reporting scientific results and how they were obtained, in formal publications. Data are the coin of the realm in science, and they are always treated with reverence. Those rare instances in which data are found to have been fabricated or altered are always traumatic.

Scientists are also not popperian falsifiers of their own theories, but they don't have to be: they don't work in isolation. If a scientist has a rival with another theory for the same phenomena, that rival will be more than happy to perform the popperian duty of attacking the first theory at its weakest point.

Moreover, scientists hold verification to a very high standard. If a theory makes novel predictions, and those predictions are verified by experiments that reveal more interesting phenomena, then the chances that the theory is correct are greatly enhanced. Even if it is



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not correct, it has been fruitful in the sense that it has led to further discovery.

Science does not, as Kuhn seemed to think, periodically self-destruct and need to start over again. However, it does undergo startling changes of perspective that lead to new and, invariably, better ways of understanding the world. Thus, science is one of the few areas of human activity that is truly progressive. There is no doubt that twentieth-century science is better than nineteenth-century science, and we can be absolutely confident that that of the twenty-first century will be better still — one cannot say the same about many other fields of human endeavour.

David Goodstein