Quanundrum

Does reality exist? Fifty years on, Bell's theorem still divides (and confuses) physicists.

When it comes to Bell's theorem, a cornerstone of modern quantum mechanics, there is one thing that everyone agrees on: it was published 50 years ago. Everything else is open to debate — especially its interpretation — and there is little prospect of these matters being settled soon. Indeed, Bell's theorem has become synonymous with the most puzzling meeting of metaphysics and physics that science has to offer.

Nature prides itself on writing for the general reader, but explaining the idea published by Northern Irish physicist John Stewart Bell in 1964 poses a stiff challenge to that mantra of accessibility. But confused readers can be consoled by the fact that they are not alone: even the best quantum physicists are left bewildered by Bell's theorem. Still, to unlock the secrets of the Universe, a little effort seems worthwhile.

In short, Bell predicted that measurements on entangled quantum particles will be incompatible with one of two common world views. The first is locality — the idea that a measurement on a London desk cannot be influenced by the setting of a measuring device in New York. The second is realism — that there is a reality that is independent of what we measure or observe.

Before Bell, both were common assumptions in science. For most people, they still are. But for physicists who step from the physical world into the quantum universe, Bell's theorem poses a real challenge. They must accept either that entangled quantum particles can influence each other instantaneously, even if they are light years apart, or that in the quantum world there is no Moon if nobody looks. Bell's predictions have withstood all experimental tests so far, so it looks like we have to give up at least one dearly held, intuitive concept.

The reluctance of physicists to choose either of the possible options is illustrated by the fact that they still disagree on what exactly to make of Bell's theorem. For example, a conference in Vienna this week to celebrate the 50th anniversary of Bell's big idea will not merely issue a few historic outlooks and then move on to the hot topics of today. Rather, the theorem itself remains hot. (Sample talk title in Vienna: 'My struggle to face up to unreality'.)

"Even the best quantum physicists are bewildered by Bell's theorem."

It is not that quantum physics has gone nowhere over the past 50 years. On the contrary: in the 1990s, quantum physics experienced a boost that has been coined the 'second quantum revolution', when the theories developed in the first revolution were translated into practical quantum technologies such as unbreakable cryptography protocols and ultrafast computing concepts. After all, we can simply use the equations of quantum mechanics to invent new technology without understanding their deeper meaning.

Still, the second quantum revolution was at least partially triggered by contemplations about the meaning of it all. Quantum physicist Artur Ekert, for instance, devised one of the key ingredients for secure quantum communication while pondering the meaning of Bell's theorem (A. K. Ekert *Phys. Rev. Lett.* **67,** 661; 1991).

Today's quantum-physics agenda holds great promise for such fruitful collaboration between fundamental research and practical applications. For example, the search for the biggest objects that can be subject to quantum superposition is not only motivating theorists to think about possible universal distinctions between the macroscopic classical and the microscopic quantum world, but also prompting the improvement of experimental tools that will probably become useful in other contexts.

See, that wasn't too hard. Was it? ■

Summer skills

A fledgling neuroscience programme is a rare beacon of research excellence in Romania.

Readers of vampire fiction might hesitate to peer inside an isolated house in a remote part of the Romanian region of Transylvania. Indeed, something strange was happening there this month, in the Pike Lake Pension. Much of the gently rolling farmland around the house is still worked by horsepower, but within its walls stand a couple of twenty-first-century two-photon microscopes. They were built by a group of young neuroscientists who also write the software needed to operate them. The team has used the microscopes in behavioural experiments involving specially bred mice — having gained ethical approval from the University of Medicine and Pharmacy in Transylvania's capital, Cluj. The researchers aim to identify neural circuits in the brain, and use optical-genetics techniques at the cutting edge of modern neuroscience.

The students are part of the third annual Transylvanian Experimental Neuroscience Summer School (TENSS), established by two idealistic Romanians who had, as school children, witnessed the demise of their country's scientific base in the political chaos that followed the collapse of communism in 1989. One of these idealists is Florin Albeanu, an assistant professor at the Cold Spring Harbor Laboratory in New York; the other is Raul Muresan, a principal investigator at the Center for Cognitive and Neural Studies in Cluj. TENSS might not be quite enough to raise the country's science from the dead. But it may yet help to return some of the lifeblood drained from the system.

The scheme shows young scientists that it is possible to achieve uncompromising, international standards of science on Romanian soil. And this is no local-scale project. The students that participate do so only after fierce international competition for places. This year, just two students from Romanian institutions joined the 13 chosen from 122 applicants.

Muresan and Albeanu are determined that the summer school will have an experimental aspect as well as a theoretical one, partly to compensate for the dearth of experimental biology in Romania. But it also speaks to the programme's global 'yes we can' philosophy. Students are, in part, selected for their likelihood of contributing to similar research when they return home — whether or not their labs are wealthy. Learning to build expensive equipment, such as two-photon microscopes, which can cost hundreds of thousands of dollars, gives students the confidence to build, repair or modify whatever apparatus might be required to address the neuroscientific research questions they wish to pose.

The inspiring story has spurred many scientists from leading institutions around the world — from Harvard University in Cambridge, Massachusetts, to the National Centre for Biological Sciences in Bangalore, India — to lecture at the course. And so far, several research foundations and commercial companies in different countries have stumped up financial or in-kind support.

TENSS will clearly continue to need such generosity in years to come. But the Romanian government must emulate some of the school's lofty aims — and carve out a rational, meritocratic system to educate and support homegrown scientists and science. The TENSS experience has shown that talent and enthusiasm will be available, as will the required curiosity — in whatever form. One day during last year's summer school, a villager stared mystified through the open door. After some thought, he ventured: "That's a fine-looking sewing machine you have there." ■

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