50 Years Ago

The Borneo earless monitor lizard (which forms, with two American lizards, the family Helodermatidae) is known from less than ten specimens … A live specimen measuring 13 in. (about average size to date) was obtained only a mile from our own archaeological base camp … In most of its behaviour it resembled a nocturnal snake. Though taken from a hole in the ground, the front legs are so weak that it is difficult to conceive of its burrowing with these. The strong snout and head were used to enlarge any ground weakness, however … It showed no inclination to bite either the handler or anything else (including food). It seems unlikely, therefore, that it is poisonous as has often been suggested.
From *Nature* 24 June 1961

100 Years Ago

Britain's Birds and their Nests — Another gorgeous volume on Britain's birds and their nests! … Happy the publishers, and authors we presume, supported by a public with so insatiable an appetite for British ornithology … We must, however, confess to considerable disappointment in the volume before us. The text is excellent. Indeed, the various biographies are pleasantly written … But it is with the plates that fault is chiefly to be found. They are all "very pretty," but we have more of art than of nature in them. Without exception the species … depicted are the most "proper" series of British birds we have ever made the acquaintance of. They never foul the ground, when 'tis their nature to; they never disturb a blade of grass or a single petal of the beautiful flowers that emborder their nests in nearly every case. They are indeed the most aesthetic company we have yet met with, in the choice of nesting sites.
From *Nature* 22 June 1911

metabolic disorders. But regardless of whether phospholipids can mitigate decades of bad eating habits, this study illustrates a potentially powerful role for phospholipid signalling in the nucleus. ■

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QUANTUM PHYSICS

Correlations without parts

Quantum correlations between the parts of composite systems have long fascinated physicists. There is now compelling evidence that such correlations can also occur in systems in which no parts can be identified. SEE LETTER P.490

ADÁN CABELLO

Quantum mechanics is arguably the most accurate and successful theory in the history of science. But unlike the case for special relativity, for which two physical principles suffice to derive the whole theory, physicists are still seeking the entire set of underlying principles for quantum mechanics. Recently[1,2], they have been trying to understand one of the most intriguing predictions of quantum mechanics: that quantum correlations violate mathematical relationships known as Bell inequalities, which are valid for any local realistic (classical) theory, but that they do so only up to a certain value, whereas more general theories allow violations up to greater values. On page 490 of this issue, Lapkiewicz *et al.*[3] describe an experiment suggesting that a wider perspective, beyond Bell inequalities, is needed to understand why quantum correlations can attain only certain values.

In Bell-inequality experiments (Fig. 1a), tests are performed on two widely separated parts of a composite system. The experimenters then extract the correlations between the outcomes of each of several pairs of tests. In any theory in which the outcomes of these tests are pre-established, the sum of these correlations cannot take a value beyond a certain upper limit. However, quantum mechanics predicts greater values.

In Bell-inequality experiments, the physical separation between the tests has a crucial role: if it is large enough, then the decision of what test is performed in one location cannot influence the outcome of the test performed in the other location, unless there is an instantaneous influence of the two tests on each other. If the outcomes were pre-established, then instantaneous influences would be required to explain quantum correlations. But this is too high a price to pay, because it is impossible to fit instantaneous influences into any theory in which such influences travel at a finite speed.

Quantum correlations have been experimentally observed in tests that are separated widely enough to prevent any influence that travels at the speed of light[4] (Fig. 1a). However, they have been found to have the same values whether the distance between the two experiments is one metre[5] or a few micrometres[6]. What's more, quantum correlations display the same values when two compatible tests are performed on a single system[7] (Fig. 1b, c). Therefore, although distance makes quantum correlations more fascinating, it apparently plays no part in the values that quantum correlations can attain.

Why should one care about quantum correlations between compatible sequential tests on the same physical system instead of about Bell experiments? There are two reasons. The first is that, to violate a Bell inequality, a particular type of quantum state is needed; these are called entangled states and cannot be prepared by local operations and classical communication. This might suggest that composite systems and entangled states are essential for quantum correlations. However, before Bell inequalities were introduced, Kochen and Specker[8] noticed that quantum mechanics is in conflict with classical physics even for non-composite systems. This conflict can be converted into experimentally testable violations of classical correlation inequalities[9] and

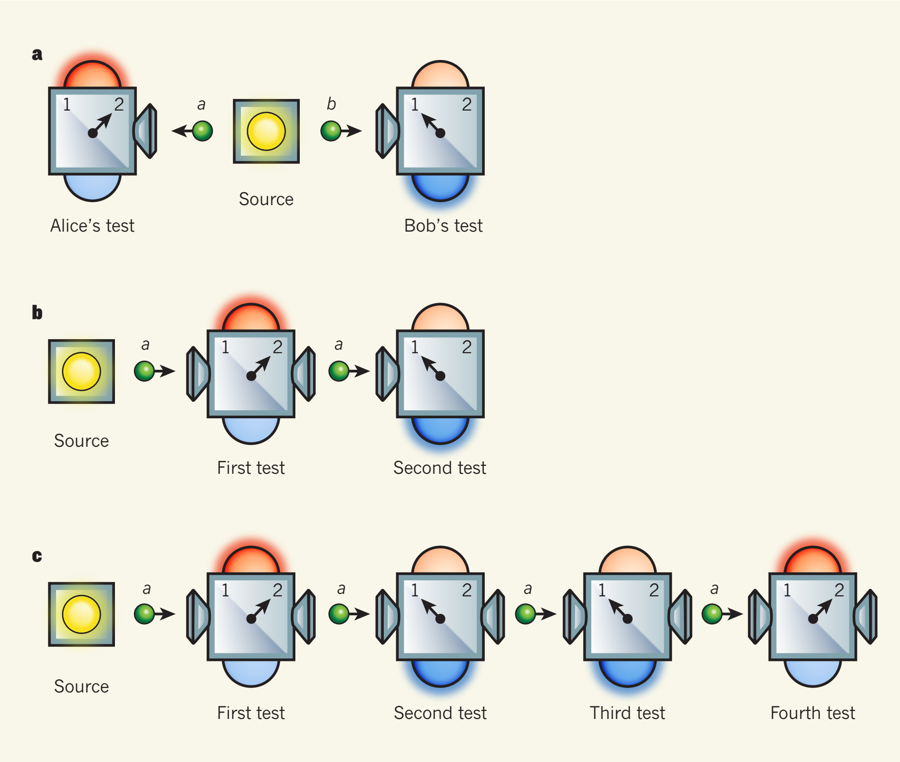

Figure 1 | Comparing separate and sequential tests. a, In a Bell experiment, a source emits a pair of particles (*a* and *b*), and an observer (Alice) performs one of two possible measurements (1 or 2) on particle *a*. The measurement has two potential outcomes (either the red light or the blue light flashes). Similarly, a second observer (Bob) performs one of the two measurements on particle *b*. In this example, the red light flashes as a result of measurement 2 on particle *a* and the blue light flashes as a result of measurement 1 on particle *b*. **b**, In an experiment involving sequential compatible measurements, such as that performed by Lapkiewicz and colleagues[3], a source emits particle *a* on which compatible measurements 2 and 1 are performed sequentially. **c**, Measurements 1 and 2 are compatible when, for each particle prepared by any source, each measurement always gives the same outcome, no matter how many times the measurements are performed or in which order.

into experiments[10,11] showing that quantum correlations occur for any quantum state — not necessarily just for entangled ones.

The second reason is the one that makes Lapkiewicz and colleagues' experiment[3] special. Whereas all previous experiments were performed on systems in which two parts can be defined, the work of Kochen and Specker suggests[8] that quantum correlations should occur even in simpler systems, in which no parts can be defined. They identified[8] a physical system in which three states can be distinguished (a 'qutrit') as the simplest one in which the predictions of quantum mechanics clash with those of theories in which unperformed experiments have pre-established outcomes. The authors' experiment[3] provides compelling evidence for quantum correlations in just such a system.

The experiment[3] is conceptually simple: a photon that can travel along three different paths is subjected to several pairs of compatible measurements (such as in Fig. 1b). If the results of these measurements were pre-established and were independent of the compatible measurements, then the correlations would not exceed a certain number. However, the experiment shows a clear violation of this limit, in agreement with the predictions of quantum mechanics.

Lapkiewicz and colleagues' results can still be explained using 'contextual' models, in which the outcome of one measurement depends on the previous (compatible) measurement. But there is no difficulty in converting quantum correlations produced in sequential compatible tests on single systems into correlations between separated systems in which contextual models become 'non-local'[12].

The authors' findings are therefore of fundamental importance, because they confirm that quantum correlations also occur in systems in which entanglement, which is supposed to be the most emblematic feature of quantum mechanics, cannot be defined. It seems that Bell experiments, composite systems and entangled states are not enough to provide a complete understanding of the physical principles behind quantum mechanics: quantum correlations exist without them. ■

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AERODYNAMICS

The cost of flight in flocks

There are well-known aerodynamic and energetic benefits to flying in an orderly formation. By contrast, it seems that the flocking flight seen in pigeons is metabolically expensive. So why do they do it? **SEE LETTER P.494**

GEOFFREY SPEDDING

Formation flight has long been known to confer aerodynamic advantages on appropriately spaced fixed-wing aircraft. Flying with a wing positioned in an updraft is a little like finding a free source of lift, which, in turn, reduces drag. Drag is directly related to fuel consumption, so formation flight in birds is seen as a way for these creatures to increase their migratory range or cut the costs of general commuting. All a bird must do to reap the rewards of formation flight is stay in formation. The potential benefits of the V-formation[1] or of certain more complex clusters[2] have been noted in idealized mathematical models. However, many bird flocks apparently lack the order and precision required to make such energy savings, and it is far from obvious how to formulate a tractable theoretical model for such complex patterns.

On page 494 of this issue, Usherwood *et al.*[3] describe how they made the first measurements of body accelerations in individual birds involved in voluntary, loosely formed flocking flights. The reasonable inference from the assembled data is that such flights do not save energy, but rather come at a cost. Energy saving is not of overriding importance in such flight excursions, and the flocks must form for other reasons.

Forty years ago, Lissaman and Shollenberger[1] pointed out that the aerodynamic advantages of formation flight could be especially accessible to birds: local wing twist and wing flexibility allow these animals to configure their aerodynamic profile according to the local air-flow field. The positioning accuracy required seemed reasonable, and the stable and preferred shape of V-formations was explained as the best configuration for evening out the drag distribution in a flock. Planar V-shaped formations, as observed in migrating geese for example (Fig. 1), could increase migratory range by as much as 70%; similar energetic advantages have been proposed for fish schooling[4]. And the potential cost savings in full-scale aircraft[5], and in fleets or swarms of unmanned autonomous vehicles in the air or underwater, are topics of renewed interest.

Noting that bird flocks are not always in neat, linear arrays, Higdon and Corrsin[2] analysed a more general cluster formation. In contrast to Lissaman and Shollenberger[1], they ignored details of the air-flow distribution on the wing, and replaced each bird with a mathematically convenient function, with almost identical far-field properties. They showed that, in three-dimensional flocks, drag savings could be either positive or negative, depending on the spanwise or vertical positions of the flock members. Their tentative conclusion was that "improved flight efficiency is not an important reason for migration in large, three-dimensional flocks".

There are many possible reasons for flying in a flock, which may include mutual observation, collective guidance and navigation, enhanced security as a result of greater numbers of individuals or of eyes, fitness display, and assessment of group numbers. Energy saving may be of paramount, or little, importance. Even if energy saving is not an explicit goal, then avoiding excessive energy

N. TAYLOR WILDLIFE/ALAMY

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Figure 1 | Flight formations and clusters. Canada geese migrate in a characteristic V-formation (left); such an orderly, planar arrangement can reduce drag, resulting in energy savings. Complex swirls and flocks of organisms, such as those of pigeons (right), have less apparent order, and in their research with pigeons Usherwood *et al.*[3] find that flocking flight patterns are energetically costly. Group travel in flocks (birds), schools (fish) and herds (large vertebrates) is common, but there are probably several, often overlapping, reasons for such behaviours.