The holy grail for defining the functional impact of L1 activation in neuronal development would be a method that can selectively switch on and off retrotransposition events using genetic or pharmacological tools. Given the sheer number and genetic complexity of transposable elements, this remains a daunting task, although targeting the reverse transcriptase enzyme or other mission-critical determinants of L1 activity may represent a potentially tractable approach. Until then, we are left to wonder whether playing dice during development of the central nervous system is indeed part of what makes each of us unique in both health and disease. ■

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QUANTUM PHYSICS

Entangled quartet

Quantum physics is known for its counter-intuitive principles. One such principle — that a single photon can be in as many as four places at the same time — has now been demonstrated. SEE LETTER P.412

VLADAN VULETIC

When light is shone through two closely separated slits and onto a distant screen, a periodic light pattern emerges as a result of interference between the light waves emanating from the two slits. Where quantum physics is concerned, some of the deepest mysteries — or, in the opinion of the iconic Richard Feynman, the only mystery — arise when that experiment is performed not with strong classical light waves but with a single particle. Although indivisible, a single particle also produces an interference pattern, so it must have passed simultaneously through both slits.

Building on recent advances[1] enabling the storage of single photons in atomic gases, Choi *et al.*[2] (page 412 of this issue) investigate what happens to interference when light is stored simultaneously in as many as four spatially distinct atomic clouds. The authors demonstrate quantum correlations (entanglement) in this composite matter–light system, and study how entanglement ultimately fades away to leave only classical correlations.

Classical correlations can arise in situations in which there is limited knowledge of a system. For instance, if we know only that one coin (or photon) has been hidden in one of four boxes, then detecting the coin in one box would instantaneously tell us that the other three boxes are empty — even if they were separated from each other by light years. It is hardly surprising that such 'particle-type' detection (Fig. 1a) can reveal classical correlations between the numbers of coins found in the different boxes if the total number of coins is known a priori.

Classical correlations can also arise between multiple light waves that are combined on partially reflecting mirrors before detection, such that the origin of the detected light is unknown (wave-type detection). For example, if identical light waves have been stored simultaneously in all four boxes — or, for that matter, coins sufficiently small to display quantum, wave-like character — and the light emerging from the boxes is combined through a series of partially reflecting and totally reflective mirrors before reaching four detectors (Fig. 1b), then the outputs of the detectors would vary as the path length between each box and the corresponding first mirror is varied.

In a classical world, something is either a particle or a wave, so a physical system will exhibit correlations either in the particle-type or wave-type detection set-up — but not in both. However, in the quantum world that we live in, it is possible to place, for example, a single photon simultaneously in all boxes such that correlations are observed in both detection set-ups. And this is exactly what Choi *et al.*[2] have done in their experiment.

Choi and colleagues used four atomic ensembles as the storage boxes. Such systems not only can hold the photon, but also can act as highly directional light emitters that can be triggered on demand through the application of a laser pulse[1,3]. The authors measured correlations between the different boxes, either in
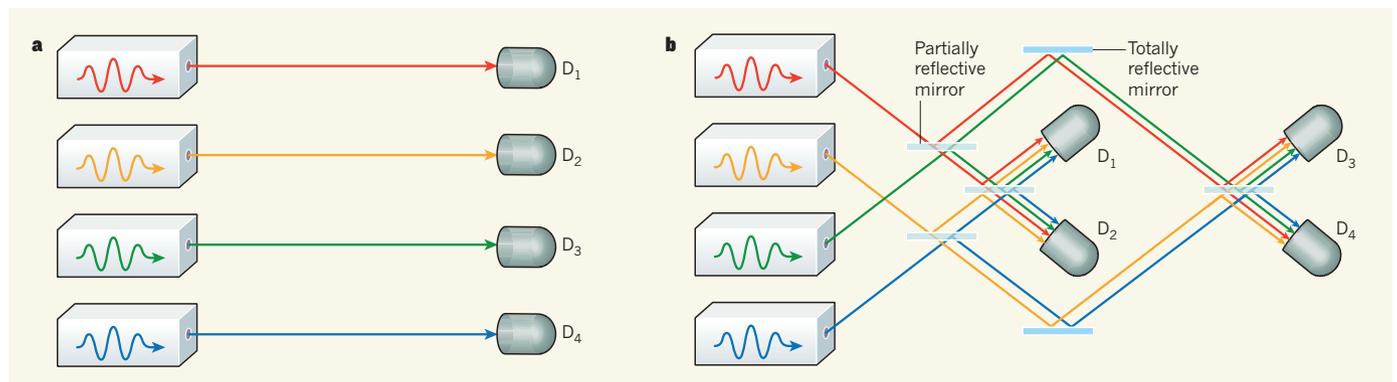
Figure 1 | Particle-type versus wave-type measurements. Choi *et al.*[2] have measured quantum entanglement in a composite matter–light system by combining results from particle-type and wave-type measurements. The matter component of the system consists of four atomic ensembles (illustrated by the boxes) and the light part is a single photon (waveform). **a**, In the particle-type set-up, a photon stored in one box can reach only one detector (D_1, D_2, D_3 or D_4). **b**, In the wave-type measurement, the photon is placed simultaneously in all four boxes and the light emerging from the boxes is combined through an arrangement of partially reflecting and totally reflecting mirrors such that light from any box can reach any detector. The colours and multiple waveforms are for illustration of the photon path only; the light in all four boxes is identical, has the same wavelength, and contains only one photon in total.

the particle-type detection set-up (Fig. 1a) or in the wave-type set-up (Fig. 1b). From the combination of these measurements, they extracted the degree of entanglement of the light shared between the four boxes. Using a method previously developed[4] for a single photon travelling simultaneously along four possible paths, they identified quantitative criteria, involving combinations of particle-type and wave-type detection results, that allowed them to distinguish among entanglement between all four boxes, or three, or just two of them. In the presence of noise and other imperfections, they observed a gradual transition from four-party entanglement to no entanglement.

Although entanglement among more than four parties has been observed (the current record is for a system of 14 ions[5], and entanglement has been inferred among 100 atoms[6]),

Choi and colleagues' system[2] is special because the entanglement can be efficiently mapped on demand from a material system onto a light field. Atomic ensembles such as those used by the authors have already reached light-storage times of milliseconds at the single-photon level[7,8]. If those storage times can be extended to seconds, and some other technical performance parameters improved, such sources will have a variety of potential applications in secure quantum communication over long distances[1]. The ensembles could then be used to build quantum networks over which quantum information can be distributed.

The astute reader may wonder how it is that quantum correlations can be observed with a single photon given that any correlation requires more than one system. The controversy about this issue can be resolved[9]

by viewing the four boxes as the systems that exhibit correlations (in photon number), rather than considering a single photon with qualms about its parent box. ∎

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Measuring biodiversity in marine ecosystems

The use of catch data to determine indicators of biodiversity such as 'mean trophic level' does not adequately measure ecosystem changes induced by fishing. Improved ways to assess those changes are required. SEE LETTER P.431

JOSEPH E. POWERS

Accurate indicators of biodiversity are essential for managing exploited marine ecosystems. The currently most widely adopted indicator is the 'mean trophic level' of catches, the position of a specific species in the food chain (trophic level) averaged over all the species in the catch. Declines in catch mean trophic levels have been interpreted as showing shifts in ecosystem diversity from high-trophic-level predators to lower-trophic-level species. But are indicators based on catch data accurately depicting what is happening to an ecosystem? This question has now been addressed by Branch and co-workers on page 431 of this issue[1].

Catch databases from marine fisheries are a reflection of economic, biological, ecological and technological factors. As a result, some species are unduly emphasized in the catches, distorting their true occurrence in the ecosystem. Additionally, catch databases, or more correctly 'reported catches', might not reflect the full extent of exploitation. Discarded bycatch, recreational fisheries and rare species are difficult to monitor and are therefore often not fully represented in the data. Finally, the databases themselves are often organized around political jurisdictions and do not necessarily encompass the entire ecosystem. Nevertheless,

catch databases are easily accessible and have relatively comprehensive species composition. So, despite the drawbacks, they remain attractive for formulating diversity indicators such as indices of mean trophic level.

Branch *et al.*[1] examined how useful these databases really are. They did this by comparing the mean trophic level of catches with the mean trophic level of ecosystems (mean trophic level weighted by the estimated true abundance of species in the ecosystem), using two avenues of research.

First, they collated 25 existing and well-documented marine-ecosystem models, representing regions in the Northern and Southern Hemispheres, over a wide range of latitudes. For each model, components encompassing the existing fisheries of the region had already been incorporated. Time series of catch and abundance were projected under four fishing scenarios: 'fishing down', in which higher trophic levels were fished to depletion followed by the advent of fishing on lower trophic levels; 'fishing through', in which there was an expansion of fishing from some higher trophic species to other higher and lower trophic species; fishing 'based on availability', in which those species that were most abundant and accessible were exploited first, followed by expansion to less available and abundant species; and 'increase to overfishing', in which exploitation

rates of all species gradually increased until they were overfished. The simulation projections were used to compute catch- and abundance-weighted trophic indices and compare their time series.

Branch and colleagues' second method was to compare catch- and abundance-weighted mean trophic levels for individual ecosystems. They used relative abundance from trawl surveys from 29 ecosystems, representing regions in the Northern and Southern Hemispheres, five continents and various latitudes, to calculate ecosystem (abundance-weighted) trophic indices. Additionally, estimates of absolute abundance from a database of 242 single-species stock assessments were also used to compute abundance-weighted trophic indices.

The results showed an inconsistent relationship between catch- and abundance-weighted trophic indices. In other words, catch-weighted trophic indices are not generally indicative of the changes in trophic level of the ecosystem. For example, simulated trophic indices from the ecosystem models, as depicted in the top two rows of the authors' Figure 1 (page 431), showed that in some cases the decline in ecosystem mean trophic level (blue lines) was more rapid than that of the catch mean trophic level (red lines), particularly when 'fishing down' occurred. In other cases, the change in mean trophic level of either the catch or the ecosystem was hardly noticeable, yet many species were depleted.

When the individual ecosystems were examined, almost half of the comparisons between catch mean trophic level and ecosystem mean trophic level from trawl or stock-assessment data were found to be negatively correlated. In particular, the relationship between catch and ecosystem trophic level tends to break down when fishing is not distributed across all portions of the ecosystem. On the face of it, then, the way forward is to use abundance-weighted rather than catch-weighted indices.