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Frontiers

In brief

Physics of brain folding recreated in lab

The distinctive folds of the human brain are the result of mechanical compression caused by growth during development, according to an international team of scientists. Using a 3D-printed gel model of the brain, the researchers have shown that forces generated during expansion can create the brain's wrinkled shape. This mechanical model was first proposed in 1975 but has been difficult to test. In humans, the "cerebral cortex" folds in a process known as "gyrification". The new work shows that the cerebral cortex expands faster than the rest of the brain, while changing little in thickness. Essentially, the cortex remains the same as its surface area grows, producing compressive stress, which leads to the mechanical folding (*Nature Phys.* 10.1038/nphys3632).

Diamonds and quantum logic boost NMR

A new technique that uses diamond defects and quantum logic to detect nuclear magnetic resonance (NMR) signals from single molecules has been unveiled a team in the US and Germany. It is based on a previous method that uses nitrogen vacancy (NV) centres in diamond to detect zero-field NMR signals. The researchers have now made the NV sensor more sensitive by locating it as close as possible to the surface of the diamond. They also devised a new read-out procedure that allows them to measure the NV centre's electronic magnetic moment non-destructively, by utilizing its quantum entanglement with the nuclear magnetic moment of the nitrogen atom. The method could reveal the structures of some rare proteins (*Science* 10.1126/science.aad8022).

Trees break at fixed wind speed

During storms there is a critical wind speed, of around 42 m/s (90 mph), at which almost all tree trunks break, according to a new study by researchers in France. The team's curiosity was piqued by data from the 2009 "Klaus" cyclone – which caused widespread damage across parts of Europe – showing that the greatest damage to forests occurred in regions where the wind speed exceeded 42 m/s, irrespective of tree age and type. The researchers conducted experiments on horizontal beech rods – fixing one end of each and applying increasing weights to the other end, and then measuring the curvature of the bending rods until they broke. They showed that the breaking phenomenon can be explained via a simple scaling law and is largely independent of the tree's diameter, height or elastic properties (*Phys. Rev. E* **93** 023001).

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Daya Bay confirms anomalies

Roy Kaltschmidt, Lawrence Berkeley National Lab

Light flashes Inside one of the Daya Bay detectors.

An analysis of more than 300 000 electron antineutrinos, carried out by the international Daya Bay Reactor Neutrino Experiment, has provided the best evidence yet that the flux and energy distribution of such particles does not agree with theoretical predictions. While the disparities could be caused by deficiencies in current models, a hitherto unknown fourth neutrino could also explain some of the disagreement with theory.

This latest measurement was made using six of the experiment's eight antineutrino detectors and data were collected over 217 days, allowing the team to measure the energies of the antineutrinos to within 1% uncertainty – the team claims this is the most precise measurement to date. But instead of agreeing with current models of antineutrino production, the energy spectrum contained a large excess of antineutrinos at an energy of 4–6 MeV with a statistical significance of 4σ. Although not a 5σ "discovery" just yet, the existence of this bump is backed up by two other reactor neutrino experiments – Double Chooz in France and RENO in South Korea. Both have already seen excesses at 4–6 MeV with significances of 3σ and 3.5σ respectively.

Despite the excess, however, the total number of antineutrinos detected at Daya Bay with energies in the 1–7 MeV range was 6% less than predicted by theory. This deficiency was first identified in 2011 by Thierry Lasserre and colleagues at CEA Saclay in France, who say it could be because the missing particles have oscillated into a hypothetical fourth type of neutrino as they travel from reactor to detector. One candidate is the "sterile" neutrino, which is predicted by certain extensions of the Standard Model.

If they exist, sterile neutrinos would interact extremely weakly, if at all, with ordinary matter and so would be even harder to detect than conventional neutrinos. The existence of sterile neutrinos could be inferred from discrepancies between measured and predicted neutrino fluxes, but this will require more experimental evidence.

Lasserre says, however, that the excess of antineutrinos at 4–6 MeV, it is unlikely to be related to sterile neutrinos. It could instead be related to limitations in our understanding of how antineutrinos are produced in reactors or of how the detectors work and Daya Bay researchers concur (*Phys. Rev. Lett.* **116** 061801).

Quantum heat stretched

Physicists in Finland have shown that it is possible to conduct heat over macroscopic distances at close to the maximum efficiency permitted by quantum mechanics. They say their technique could be used to cool chips inside future quantum computers.

Quantum mechanics dictates that heat flow can be quantized. If a wire is so thin that an electron's wavefunction can only assume one possible configuration as it travels, there is an upper limit to the rate at which electrical energy can be transmitted for any given voltage. Likewise, there is a maximum rate at which heat energy can be transferred along a single channel connecting a hot bath to a cold one.

Physicists have previously observed such "quantum-limited heat conduction" but it has been limited to distances of up to 50 μm. Now, Mikko Möttönen and colleagues at Aalto University have extended this distance to macroscopic scales by using photons as heat carriers. The team carved a spiral-shaped superconducting waveguide into a small silicon chip with each end connected to a metal resistor. Thermally induced voltage fluctuations across one of the resistors generate microwave photons that travel along the waveguide with a specifically shaped transverse electric field (*Nature Phys.* 10.1038/nphys3642).

The researchers cooled down the electrons in one of the resistors and measured the subsequent temperature drop in the other, using superconducting tunnel junctions. Carrying out the experiment with 20 cm and 1 m waveguides, operating at a temperature of about 0.1 K, they compared their measured temperature changes with predictions from a detailed thermal model they had developed and found that their set-up reached between 80% and 110% of the theoretical maximum.