QUANTUM MECHANICS

Indefinite causality

Sci. Adv. **3,** e1602589 (2017)

Causality is a concept deeply rooted in our understanding of the world and lies at the basis of the very notion of time. It plays an essential role in our cognition — enabling us to make predictions, determine the causes of certain events, and choose the appropriate actions to achieve our goals. But even in quantum mechanics, for which countless measurements and preparations have been rethought, the assumption of pre-existing causal structure has never been challenged — until now.

Giulia Rubino and colleagues have designed an experiment to show that causal order can be genuinely indefinite. By creating wires between a pair of operating gates whose geometry is controlled by a quantum switch — the state of single photon — they realized a superposition of gate orders. From the output, they measured the so-called causal witness, which specifies whether a given process is causally ordered or not. The result brings a new set of questions to the fore — namely, where does causal order come from, and is it a necessary property of nature? *YL*

FERROELECTRICS

Learn the hard way

Nat. Commun. **8,** 14736 (2017)

In neural networks like the brain, information flows between neurons through synapses, and learning is achieved by changing the strength of synaptic connections. This strength evolves depending on the relative timing of electrical signals from neighbouring neurons. And now, Sören Boyn and colleagues have demonstrated unsupervised learning using artificial neural networks made from ferroelectric tunnel junctions.

Memristors based on ferroelectric tunnel junctions can act as solid-state equivalents of synapses because their resistance, which depends on the history of their exposure to electrical signals, can emulate synaptic strength. Boyn *et al.* showed that the intrinsically inhomogeneous nature of the polarization switching in such junctions can emulate the necessary conditions for synaptic strength adjustment. They then provided a corresponding model that can predict the evolution of the resistance of ferroelectric synapses for varying neural inputs.

They showed that a network comprising nine input neurons, connected to five output neurons by a crossbar array of ferroelectric memristors, can autonomously learn to recognize patterns made from 3 × 3 pixel images in a predictable way. *LF*

PRIMORDIAL BLACK HOLES

Still missing

Phys. Rev. D (in the press); preprint at https://arxiv.org/abs/1612.07738

Primordial black holes could be the oldest inhabitants of the Universe. Born from density fluctuations shortly after the Big Bang, they are important pieces of the cosmological puzzle and could also account for dark matter. And although the light primordial black holes would have long evaporated, heavier ones could still be lurking around. Various astrophysical observations have put limits on different segments of the allowed mass range. Steven Clark and colleagues used the most recent Planck cosmic microwave background (CMB) data combined with extragalactic gamma-ray background information to constrain the abundance of primordial black holes with masses 10^{15}–10^{17} g: about as heavy as the 67P/Churyumov–Gerasimenko comet, made famous by the Rosetta mission.

The Hawking radiation emitted by primordial black holes since the beginning of the Universe is expected to have left a mark in the CMB, which would manifest itself as a damping of the anisotropies. The analysis of the CMB data combined with bounds from the extragalactic gamma-ray background puts a strong constraint on primordial black holes in this mass range — ruling them out as a dark matter component. *IG*

PATTERN FORMATION

Lizard computer

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BLICKWINKEL / ALAMY STOCK PHOTO

Lizards and snakes — collectively known as squamates — often sport intriguing macroscopic skin patterns, resulting from the different colours exhibited by individual, microscopic skin cells. Changes in a squamate's skin pattern are due to interactions between skin cells, and are traditionally described in terms of reaction–diffusion systems involving nonlinear partial differential equations.

But now, Liana Manukyan and colleagues have found that as the ocellated lizard (*Timon lepidus*; pictured) ages, its skin pattern behaves as a cellular automaton. The reptile's mesoscopic scales form a quasi-hexagonal lattice of cells that are either green or black, and a nearest-neighbour rule defines how the instantaneous pattern follows from the configuration at the previous time step.

Manukyan *et al.* arrived at this conclusion by scanning the skin pattern of three lizards from about two weeks after hatching until they were three years old. From simulations and a mathematical analysis of the observed evolution of the reconstructed colour maps, the authors demonstrated that the changes were indeed compatible with a probabilistic cellular automaton. They were also able to show how the discrete automaton emerges from the continuum reaction–diffusion model. *BV*

MEMBRANE FISSION

Crowd control

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Like life's little filing cabinet, the cell functions by compartmentalizing its contents, often in discrete volumes bound with a membrane of their own. In order to form these compartments, cells need to undergo membrane fission, a process that has been associated with the structural oddities of certain proteins — including ring motifs, helices and hydrophobic insertions. Now, Wilton Snead and colleagues have found evidence to suggest that any protein — regardless of its structure — may be capable of mediating membrane fission, by generating steric pressure through collisions.

Hydrophobic inclusions in membrane-binding proteins are thought to facilitate fission by helping to bend the membrane. But the study by Snead *et al.* supports the notion that this hydrophobicity might have more of an incidental role. Using fluorescence resonance energy transfer techniques, the authors found that fission efficiency was actually independent of hydrophobicity. Instead, they saw that fission became spontaneous with increases in steric pressure derived from protein crowding, implying that these inclusions may function to simply enhance the pressure that drives membrane fission. *AK*

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