MATERIAL WITNESS

CELL PHYSICS

PHILIP BALL

Do living cells exploit statistical physics? It's strange that the question need be asked, as phase transitions and critical phenomena are universal features of condensed matter, and of many-particle systems more broadly. There is no obvious reason why the mere fact of being alive should confer exemption, and indeed phase transitions are seen in biology at the macroscale of communities of organisms, including humans — in flocking behaviour, say, and crowd movements. Yet they have, until recently, been afforded little attention in cell biology, where the dominant paradigm of genetic control has been tacitly supposed to supersede the influence of such generic, physical influences.

That's now changing. There is a growing body of evidence suggesting that cells are constructed to actively manipulate and exploit phase changes. It has long been recognized that the clustering ('rafting') of different lipids in the two-dimensional fluids of cell membranes is an example of liquid–liquid phase separation that permits the sequestering of membrane proteins, with consequences for exo- and endocytosis and cell signalling[1]. Phase separation within the cytoplasm creates structures such as the protein–RNA complexes called P granules involved in germline formation, and the liquid-like nucleoli within which ribosomes are formed[2]. A phase transition analogous to capillary drying (abrupt expulsion of water) may drive the hydrophobic collapse of proteins and formation of some multi-subunit protein arrays[3,4]. Phase transitions create a large response to small changes in environmental conditions: a widely useful phenomenon that might result in many biological systems, such as neuronal networks and protein conformations, being tuned to sit close to a phase boundary[5].

That possibility is further supported by a proposal that the two-dimensional liquids of biological membranes might operate close to the miscibility critical point of its components[6]. In this situation they would experience large fluctuations that can give rise to a relatively long-ranged Casimir force, an attractive interaction that could be exploited in the rearrangements that accompany cell signalling.

The most familiar manifestation of the Casimir force results from the restriction in wavelength of vacuum fluctuations in a confined space, creating an effective pressure that draws the confining surfaces together. Fisher and de Gennes showed that an analogous effect — a 'critical Casimir force' — operates at the critical point of miscible fluid phases, where again an interaction is caused by the constraints on fluctuations in fluid composition that can become very long-ranged close to criticality[7]. It's a real effect, as recent experiments demonstrated[8].

Some biological membranes contain surprisingly large (around 100 nm) rafts of segregated lipids that seem to arise from proximity to a two-dimensional critical point. Using a lattice model of these structures, Machta *et al.* calculate that the resulting critical Casimir force experienced by membrane-bound proteins, although rather weak, has a longer range (of the order of tens of nanometres) than the screened electrostatic potentials that may dominate at shorter distances[6]. Cell signalling following the binding of a substrate to a protein is commonly accompanied by a reorganization of the proteins in the membrane, which Machta *et al.* suggest is mediated by these critical Casimir forces. If so, it suggests that cell membranes embody an implicit understanding of their ineluctable statistical physics. ❒

References

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SUPERHYDROPHOBIC SURFACES

Leidenfrost becomes a fakir

When cooled in water from high temperature, superhydrophobic surfaces stabilize the vapour layer on them, thus avoiding the typical vapour explosions associated with the nucleation of bubbles.

David Quéré

There are two classical ways to make a solid water-repellent. It can either be heated to at least 200 °C to make water levitate on a cushion of its own vapour (for example, as occurs on any sufficiently hot frying pan) or the solid can be coated with a textured hydrophobic material at room temperature. The former was first described in 1756 by the German physician Leidenfrost[1]. The latter is known as the fakir state[2], in which the water sits on top of the micronails of the texture and is suspended above the air entrapped between them.

Writing in *Nature*, Sigurdur Thoroddsen and colleagues show that the Leidenfrost