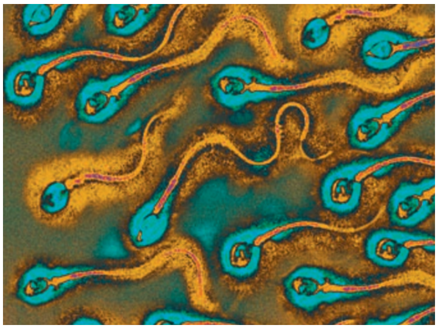
Egg hunt



SPL

Proc. Natl Acad. Sci. USA **104,** 13256–13261 (2007)

The importance of guiding sperm cells to the egg is obvious, but less so are the tactics the sperm cells use to reach their destination. Certain chemicals released by the egg are known to play a role, but now Benjamin Friedrich and Frank Jülicher provide a theoretical framework that could explain how sperm cells find their way in the concentration gradient of these 'chemoattractants'.

Sperm cells (pictured) use an extension — the so-called flagellum — to move around. In the absence of chemoattractants, the swimming path is circular in two dimensions, and helical in three. However, chemoattractant molecules binding to the flagellar membrane change the beat pattern of the flagellum and thus the curvature and torsion of the swimming path.

Friedrich and Jülicher argue that the circular path through the gradient in chemoattractant concentration, and the resulting periodic modulation of the swimming direction, lead to an overall drifting motion that could, eventually, cause the sperm cell to spiral into the egg.

Intrinsically complex

Science doi:10.1126/science.1146006 (2007)

Surface and interface layers are intrinsically different from the bulk, as their physical properties are affected by the termination layer. Take the interface between two oxide-based insulators, for example — it is possible to create an interfacial layer that is metallic. And under certain conditions the electron gas at the interface can even exhibit ferromagnetism, despite the non-magnetic or antiferromagnetic nature of the insulators to either side. But the origin of the effect, or the possibility of other ground states, is not clear.

Nicolas Reyren *et al.* deposited a few layers of $LaAlO_3$ on single crystals of $SrTiO_3$ and observed superconductivity at the hetero-interface. Their transport measurements show the signature loss of electrical resistivity at 200 mK. By analysing the superconducting characteristics, they conclude that the superconductivity is consistent with a two-dimensional Berezinskii–Kosterlitz–Thouless transition. However, they are unable to determine whether the superconductivity is due to oxygen vacancies within a thin layer of $SrTiO_3$ or to an intrinsic effect.

Critical crossover

Phys. Rev. Lett. **99,** 070402 (2007)

Pairs of fermions can flow like a superfluid — just as pairs of electrons (Cooper pairs) flow in a superconductor, described by BCS theory. Paired fermions can also form a Bose–Einstein condensate (BEC). The transformation from one regime to the other, known as the BEC–BCS crossover, has been thrown open to investigation through experiments using ultracold Fermi gases.

The critical velocity of superfluid flow varies across the transition, according to the trade-off between phonon-excitation and pair-breaking effects, and has been predicted to reach a maximum at the point of crossover. D. E. Miller and colleagues now confirm that prediction, using a set-up that allows closer comparison to theory than had previously been possible.

Miller *et al.* use magnetic tuning around a Feshbach resonance to take a superfluid of pairs of ^{6}Li atoms through the BEC–BCS crossover. By probing only a small region of the sample, held at the centre of an optical lattice formed by two laser beams, they alleviated problems associated with density inhomogeneities that have beset previous experiments using bosons.

From there to here

GETTY

Phys. Rev. Lett. (in the press); preprint at http://arxiv.org/abs/0706.0559v1 (2007)

'Thermodynamic length' is a measure of the distance between states of equilibrium and hence useful in the study of tricky out-of-equilibrium systems. The concept has been around for a few decades but with varying definitions, which are equivalent at macroscopic scales yet differ for small systems. Gavin E. Crooks considers how best to define thermodynamic length for small systems and how to calculate it.

What's needed is a quantification of the mean change in collective variables between neighbouring states. That, in turn, requires knowledge of the free-entropy change and, as Crooks explains, a maximum-likelihood method devised by Charles H. Bennett is useful in estimating it.

From there, Crooks makes a connection between the Bennett likelihood and the Jensen–Shannon divergence — defined as the mean of the relative entropy of each distribution to the mean distribution — and this is the key to his definition of thermodynamic length. The Jensen–Shannon divergence between two states can be used to set a lower bound both on the thermodynamic length of any path between them and on the thermodynamic divergence. The calculation should then be repeated using ever finer discrete steps of the path until the length and divergence estimates converge.

When the wind blows

Nature **448,** 780–783 (2007)

As the first variable star to be discovered, Mira has become a prototype for other evolved red giants. Such stars shed a large fraction of their mass through molecular wind, thus shaping the formation of nearby stars and planets. But despite centuries of scrutiny, Mira's bow shock and long comet-like tail, or turbulent wake, were not observed until Chris Martin and co-workers spotted them in ultraviolet images taken by the satellite GALEX.

That there is a bow shock created as Mira passes through the interstellar medium is not surprising, given the star's large space velocity. But the tail is unexpected. With a length of 4 pc, the tail traces Mira's path over a 30,000-year period. It's a unique fossil record of the interaction between the stellar wind and the surrounding interstellar medium.

The authors propose a cooling process involving collisions between H_2 in the cool wind and electrons in the hot post-shock gas. Moreover, the observed periodicity in Mira's wind challenges the theory of thermally pulsing stars. The solution will require complex hydrodynamic modelling of turbulent flow.