specifically stimulated by antigen-presenting cells[13]. Such 'bystander activation' generally requires high concentrations of antigen. Bystander activation also appears to occur frequently *in vivo*. Indeed, this is consistent with the lack of complete polarity of interleukin-4 secretion observed by Poo *et al.* when they stimulated D10 cells with low concentrations of anti-T-cell receptor antibody, and the complete loss of polarity observed when they used high concentrations of antibodies. Perhaps most importantly, their work emphasizes that the immune system is not a free-floating collection of independent cells, but exists as an organized entity, whose structure is critical for its regulated function. □

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Low-temperature physics

Superfluidity of ^{3}He films

P.V.E. McClintock

THE superfluid flow properties of ^{3}He films can now be studied in considerable detail, thanks to a new and highly sensitive technique developed at Berkeley by J.C. Davis, A. Amar, J.P. Pekola and R.E. Packard, described in *Physical Review Letters* (**60**, 302–304; 1988).

The original discovery of superfluidity, 50 years ago, arose in part through the astonishing observation by J. G. Daunt and K. Mendelssohn (*Nature* **141**, 911–912; 1938) that any open-topped vessel of liquid helium, at a sufficiently low temperature, gradually empties. These authors established that a thin film of liquid creeps up the inside wall of the vessel, passes over its rim, slithers down the outside wall and then drips off the bottom. The process occurs because liquid ^{4}He, below its transition temperature of 2.17 K, becomes superfluid; that is, it loses its viscosity and hence becomes able to flow rapidly through very tiny channels. One such channel is the 10–20-nm-thick adsorbed film of liquid that forms on the walls of the container under the influence of the van der Waals attraction.

Since 1972 it has been known that the rare isotope of helium, ^{3}He, also undergoes a superfluid transition, and it is natural to ask whether it too can form a creeping superfluid film. The experimental difficulties in attempting to address this question are formidable, mainly because the ^{3}He superfluid transition temperature (1 mK) is over 1,000 times lower than for ^{4}He, but also because the maximum superflow rates should be orders of magnitude lower. In addition, there are sound theoretical arguments for supposing that, though undoubtedly superfluid in bulk, liquid ^{3}He need not retain its superfluidity when in the form of a thin film. This is because of a characteristic length scale, the 'coherence' length ξ_0, that represents the minimum distance over which the superfluid wavefunction can be significantly changed. For superfluid ^{4}He, ξ_0 is comparable with the interatomic spacing so that superfluidity is to be expected (and is observed) down to extremely thin films consisting of only a very few layers of atoms. For superfluid ^{3}He, on the other hand, ξ_0 is of the same order as the thickness calculated for a 'saturated' film, (a film that is in equilibrium with bulk liquid below). Thus, the superfluidity of ^{3}He films need not exist at all.

Positive evidence of superflow in ^{3}He films, however, was reported in 1985 by the late J. G. Daunt (co-author of the historic paper cited above) and co-workers (*Phys. Rev. Lett.* **55**, 1602–1605; 1985). Their experiment, based on measurements of the rate of filling or emptying of a small stainless steel beaker, caused consternation, because the superflow appeared to persist to temperatures above that of the bulk superfluid transition T_c^B. It had been anticipated, on the contrary, that 'finite-size effects' on scales comparable to ξ_0 would depress the superfluid transition temperature for the film T_c^F. More recent experiments by the same group (*Jap. J. appl. Phys.* **26**, 145–146; 1987) suggest that the effect could have arisen from unsuspected temperature gradients.

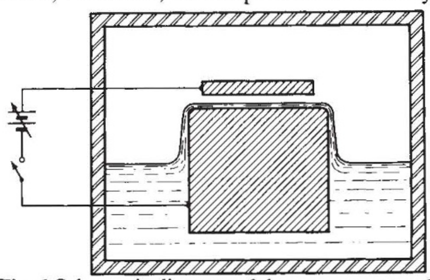

Fig. 1 Schematic diagram of the apparatus used for generation and detection of superfluid ^{3}He film flow. When the potential difference across the capacitor plates is increased, liquid is drawn into the narrow space between the plates. The rate of flow is determined by measuring the change in capacitance. (From Davis *et al. Phys. Rev. Lett.* **60**, 302–304; 1988).

The new experiment by Davis *et al.* is based on a very different approach. Their apparatus (Fig. 1) consists in essence of a horizontal parallel-plate capacitor partially immersed in liquid ^{3}He. The potential difference between the plates can be changed and the capacitance can be monitored continuously. At the temperatures in question (less than 1 mK), the saturated vapour pressure is negligible, so that the space above the liquid contains a vacuum. When a potential difference V is applied between the plates, there is a tendency for the dielectric liquid helium to be drawn into the capacitor (a classical electrostatic phenomenon). In practice, this process would take an exceedingly long time at temperatures above T_c^F because the liquid is viscous. Below T_c^F, on the other hand, because of the superfluidity, progress towards a new equilibrium film thickness happens relatively quickly. The thickness of the film can be determined, to the remarkable accuracy of 0.1 nm within 1 s of observation time, by measuring the total capacitance, which is increased slightly by the liquid between the plates.

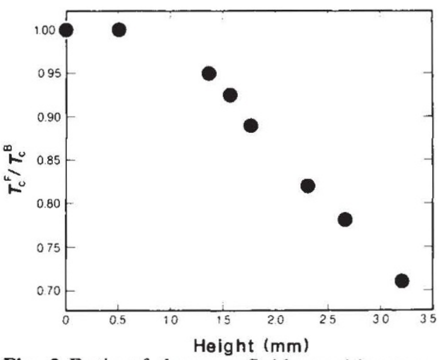

Fig. 2 Ratio of the superfluid transition temperatures for films and for bulk liquid ^{3}He, T_c^F/T_c^B, as a function of the height of the film above the bulk liquid surface. At small heights (thick films), the transition temperatures are equal; for the thinner films at larger heights, T_c^F falls well below T_c^B, indicating the presence of finite-size effects. (From Davis *et al. Phys. Rev. Lett.* **60**, 302–304; 1988.).

The ratio T_c^F/T_c^B is shown in Fig. 2 as a function of the height of the capacitor above the main liquid bath — in effect, as a function of the film thickness, which decreases with increasing height. It is immediately obvious that the superfluid transition temperature, at which liquid first flows into the capacitor in response to an increase of V, is equal to the bulk value for thick films, but falls by up to 30 per cent for thinner films, presumably because of the anticipated finite-size effects. Davis *et al.* also measured the critical (maximum) flow rates for the film; but these cannot be converted into the corresponding critical velocities because the lower capacitor plate is microscopically quite rough.

It seems that several interesting variations on the new technique are possible. Given its great sensitivity — the authors estimate it is better by a factor of 1,000 than earlier methods — it is reasonable to hope for rapid progress towards a detailed understanding of the superfluidity of the ^{3}He creeping film. □

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