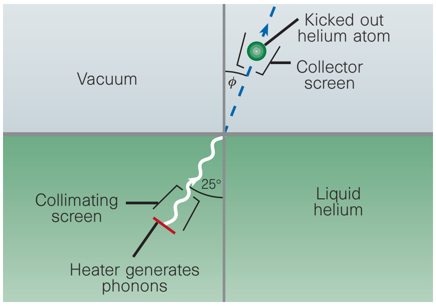

Figure 1 **Quantum evaporation with liquid helium. Phonons from a heated metal film are collimated at 25° to the vertical, and kick atoms from the surface of a tank of superfluid ^{4}He. These atoms come off at an angle ϕ of around 20° to the vertical, implying that they start with zero momentum parallel to the surface — in other words, that they form a ground-state Bose–Einstein condensate. (Adapted from ref. 2.)**

component had its origin in the macroscopic occupation of atoms of a single quantum state. The superfluid component is a new, coherent, collective degree of freedom which moves without resistance.

It took many years to properly develop this BEC picture of London and Tisza, and it was overshadowed by the phenomenological theory developed in 1941 by L. D. Landau, who derived the two-fluid equations of motion describing superfluidity without any explicit reference to a Bose condensate. However, by about 1960, it was generally agreed that the Landau theory could be understood as a consequence of a condensate described by a macroscopic wavefunction (for a review, see ref. 6). The superfluid velocity is given by the gradient of the phase of this condensate wavefunction.

The superfluid fraction can be easily measured, but in a Bose liquid it is not simply related to the underlying condensate (in contrast to a Bose gas), as shown by the fact that the entire liquid forms the superfluid at zero temperature. In spite of this, the condensate fraction and its temperature dependence have been accurately determined by indirect methods over the past two decades. Computer simulations[7] show consistently that it is about 9% at absolute zero, and vanishes at the superfluid transition temperature of 2.17 K. That agrees with inelastic neutron-scattering experiments, which allow one to extract the atoms' momentum distribution. Although the condensate peak at zero momentum is masked by finite energy resolution and final-state effects, it is possible instead to find the number of atoms with finite momentum (the non-condensate fraction)[6,8], and thus obtain the condensate fraction.

Those studying liquid helium could only look on with envy, three years ago, when Bose condensation was clearly observed in alkali atoms in magnetic traps[9]. But now Wyatt's evaporation experiment has finally provided direct evidence for a condensate in liquid ^{4}He at 100 mK, where the liquid is essentially in its ground state. The large number of atoms that emerge near the expected angle of 20° to the vertical (after absorbing mono-energetic phonons) means there must be macroscopic occupation of the state with zero momentum parallel to the liquid surface. In contrast, the flux of evaporated atoms initially in states with finite momentum leads to a broad angular spread of low intensity. Before we can estimate the condensate fraction, measurements of greater sensitivity are needed to detect the evaporation from the non-condensate atoms.

Crucial to the success of the new quantum evaporation experiment is the ability to produce a narrow mono-energetic beam of long-lived, high-energy (10.15 K) phonons. The remarkable physics of the anharmonic up-scattering phonon processes which gives rise to this beam was clarified only a few years ago[10].

The observation that the evaporated atoms have absorbed a single high-frequency phonon implies that these atoms come from the region very close to the liquid surface, otherwise there would be energy losses via collisions before the atom evaporates. That limits Wyatt's technique to the study of ^{4}He atoms in the surface region — perhaps a blessing in disguise, as the zero-temperature condensate fraction is predicted to go from 9% in the bulk liquid to 100% in the low-density surface tail (due to lack of collisions)[11,12]. Future evaporation experiments promise to give detailed information about the profile of the inhomogeneous Bose condensate at liquid ^{4}He surfaces.

Wyatt's experiment has put the Bose condensate in liquid ^{4}He back into the spotlight, 60 years after it was suggested by London[3]. As an agreeable side-benefit, this quantum evaporation technique might be adapted to produce a phase-coherent mono-energetic beam of ^{4}He atoms, as they all come from the same initial quantum state. This would be similar to the beam produced in 1997 by allowing a Bose-condensed gas of ^{23}Na atoms to leak out of a trap[13] — another type of 'atom laser'. □

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Daedalus

The Brain-cleaner

The brain is a statistical computer. Its neurons are richly connected by synapses, each of which holds a probability that a pulse from one neuron will trigger the other. Everything we know, it is claimed, has been acquired and is stored as innumerable synaptic firing probabilities.

This cannot be the whole truth. Nerves fire in milliseconds; but it can take many weeks or months to learn a skill, see an argument or change our mind. We all waste years of life nursing unrealistic hopes, recovering from emotional set-backs, coming to terms with limitations or advancing age, or abandoning foolish compulsions or delusions. Why is mental change so slow? Daedalus points out that nerves are hollow; they are filled with fluid axoplasm. This contains not merely the ions of nerve action, but cell nutrients, enzymes, and so on. These diffuse slowly along the nerve, typically at a few millimetres a day. (The rabies virus makes its relentless, deadly passage from bite to brain by diffusing up the nerves at this sort of rate.) If the firing probability of a synapse can be altered only by the diffusion of some key component down the axon, the slow pace of human mental change would be explained.

Daedalus now plans to speed it up. A blow on the head is popularly supposed to shake one's ideas up; and shock could well help to stir the cerebral axoplasm. But ultrasonics seems more controllable. An ultrasonic cleaning bath works by very small-scale stirring indeed. DREADCO's cunning new 'Brain-cleaner' launches a highly asymmetric, ultrasonic waveform into the skull. Axoplasm has a non-newtonian viscosity. The sharp leading edge of each cycle shifts it abruptly one way, but the reduced shear of its gentler trailing edge does not reverse the shift exactly. So the axoplasm convects strongly, updating the synaptic probabilities in minutes rather than months.

Regular brain-cleaning will save us all years of life. Emotional traumas, from failed love-affairs to bereavements and sackings, will be swiftly put behind us. The economic cycle will speed up or even be damped out, as economists and business tycoons no longer lag behind the changing reality. Generals may at last cease to prepare for the previous war. Psychoanalysts will go bankrupt in droves: their patients will be transformed after mere days on the couch. Technological advance will become even more breathless, and the world of fashion will change with dizzying speed.

David Jones