heat flux), deepening of the mixed layer has been observed, and convection is recognized as the responsible process (Lacombe, H. *et al. Nature* **227**, 1037–1040; 1970). Under net-positive heat flux, the mixing mechanisms work against the tendency of the surface heat flux and penetrating solar radiation to create a stable stratification near the surface. In this situation it is suspected that relatively large scale, coherent flows such as Langmuir cells are important in mixing, but it has been exceptionally difficult to verify such a hypothesis experimentally.

Part of the difficulty in looking for evidence of mixing associated with Langmuir cells, breaking waves or other large eddies is that the measurements must be made close to a moving interface populated with energetic surface waves. Surface waves introduce large-amplitude, high-frequency noise and, in particular, complicate the task of making accurate direct measurements of three-dimensional flow near the surface. Also, because the mixing is rapid, the anomaly signals of water carried down from the surface are small, and are easily confused with signals that result from process other than vertical mixing. For example, Langmuir circulation draws water from the surface where heat exchange occurs, into convergent regions where it is carried down into the mixed layer; the anticipated temperature anomaly associated with the downwelling flow is small, approximately 5 mK.

Thorpe and Hall overcome these difficulties by innovative methods. Their catamaran, which rides the waves, permits measurements near the interface without disturbing the fluid below. They observe the air bubbles that are produced by breaking waves and find that they rise very slowly and thus are reliable passive tracers of currents. If the wind is stronger than about 3 m s^{-1}, breaking surface waves produce discrete bubble clouds; stronger winds produce proportionately more bubble clouds. Under various wind conditions, then, bubbles are created near the surface and are excellent independent indicators of vertical transport. Thorpe and Hall were thus able, using combined bubble and temperature measurements, to develop conclusive evidence for downward transport of surface water. Their techniques can be used to observe Langmuir circulation, injection of fluid by breaking waves and other large-scale structures associated with vertical mixing. It remains now to monitor when such processes are present, to determine the forces that drive such flows, and to quantify the transport associated with them. Once that is done, there is a good chance that dynamically correct models of upper ocean mixing can be constructed. □

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Experiment ahead of superconductor theory

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THEORETICIANS attending last week's international workshop on novel mechanisms of superconductivity (22–26 June) were largely agreed only that the mechanism accounting for superconductivity at liquid-helium temperatures will not suffice for the new ceramic materials. But even that opinion, that the phonon-mediated interaction between electron pairs which is the basis for the standard BCS theory must be supplemented by something else, is not unanimous.

Several groups now agree that substitution of ^{18}O for ^{16}O causes no change of T_c, the onset temperature of superconductivity. This absence of an isotope effect is why most people believe phonon-based (BCS) mechanisms are unlikely. But some theorists argued last week that it is possible that the isotope effect may be suppressed; thus A. Zettl (University of California, Berkeley) showed that substitution of Cu and Ba in $YBa_2Cu_3O_{7-\delta}$ causes no shift of T_c, but oxygen substitution in a La–Sr superconductor lowers T_c by about 1 K. On the reasonable assumption that similar mechanisms operate in both the Y–Ba and La–Sr compounds, this suggests to some that phonons should not be forgotten altogether.

All remaining theories are based on pairing interactions mediated, in some way, by various electronic motions: the collective motions of electrons (plasmons), local polarization of electron orbitals (excitons) and spin fluctuations travelling through the lattice (magnons). What became apparent as last week's meeting progressed was that, while theorists are still arguing whether various mechanisms can even produce the observed high-temperature transitions, experiments are revealing a variety of surprising and sometimes subtle effects beyond the scope of present theories.

The dependence of T_c on the proportion of oxygen in $YBa_2Cu_3O_{7-\delta}$ is well known. In a series of experiments at Argonne National Laboratory (I. W. Schuller), samples were quenched from different sintering temperatures, freezing in a controllable oxygen fraction. The transition temperature of the resulting products varied smoothly, until the superconductivity disappeared at $\delta = 0.5$.

Simple counting of valence electrons shows that with less oxygen than this, no Cu^{3+} is present. X-ray diffraction also reveals that this is the point at which the structure changes from orthorhombic to tetragonal. But in a variation on this experiment (B. Batlogg), oxygen was removed at room temperature or below by using a zirconium getter. Here, too, T_c decreases, but in a stepwise fashion, from 90 K to 60 K and then to 30 K. These results are not inconsistent; when oxygen is removed at low temperature, the lattice cannot easily readjust, and indeed Batlogg reported no change in structure at $\delta = 0.5$. Findings such as these suggest a remarkable sensitivity of the superconductivity to details of the lattice structure; Batlogg believes that the exact placement of oxygen vacancies, not simply their overall number, is important. In a similar vein, Russian work reported by N. Zavariskii (Soviet Academy of Sciences) showed that superconductivity can be destroyed by slight neutron irradiation.

Other experimental results promise to be of more direct use to the the theorists, although the 'dirty' nature of the ceramics complicates measurement of their microscopic properties. A fundamental quantity, yet to be pinned down, is the energy gap Δ that represents the binding energy of the superconducting electron pairs. Zettl showed measurements of the absorption edge in infrared reflectivity indicating a gap of $2\Delta/kT_c = 2\cdot4$, lower than the standard BCS ratio of 3·5. But S. Maekawa (Tohoku University) showed that the absorption edge in strongly anisotropic materials (such as these ceramics) is substantially lower than the gap energy; Zettl's result may be consistent with BCS.

The other standard way of measuring the gap, by tunnelling conduction, has been attempted, but because the ceramics have such irregular surfaces, no reliable values have emerged. The values reported were nevertheless reasonably close to the BCS ratio, perhaps telling against resonant valence bond (P.W. Anderson, Princeton) or superexchange (J. Appel, University of California at San Diego) mechanisms, both of which suppose a small or vanishing gap.

This meeting was unusual for the almost complete absence of speculation about superconductivity at temperatures above 100 K. Most comments on the various reports were sceptical. Workers at Westinghouse (A. Braginski) had partially substituted fluorine for oxygen in the Y–Ba superconductor and, although they found anomalous behaviour of the resistivity at about 220 K, they found no indication of a complete loss of resistance.

There was also controversy about a report that the compound $Y_3Ba_3Cu_6O_{14}$ is superconducting at 90 K (M. Beasley, Stanford). Beasley presented X-ray diffraction spectra purporting to show that his sample consisted of a single phase, called 3-3-6. Others, however, argued that the sample had more than one phase, including that known as 1-2-3 which is known to be a superconductor. The significance, according to Beasley, is that the 3-3-6 phase does not incorporate the Cu–O chains said by some to be central to the superconducting mechanism.

David Lindley