50 & 100 YEARS AGO

50 YEARS AGO

In previous communications, the existence of a third normal, embryonic haemoglobin was reported to be present in the blood of foetuses up to five months of intra-uterine life ... By using the column chromatographic procedure described by Huisman and Prins, with some minor modifications, we were able to separate the three distinct fractions from the haemolysate of a four month old embryo ... Thus, we were able to separate not only the two haemoglobin fractions known to be present in the cord blood of full-term new-borns, but also the third, embryonic, fraction (the lowest in the chromatographic column) in the blood of small embryos ... [W]e were, for the first time, able to discover the embryonic haemoglobin fraction in the blood of two full-term new-borns who were severely malformed, whereas twenty other normal new-borns who served as controls did not show this fraction in their blood.
From *Nature* 31 January 1959.

100 YEARS AGO

A striking instance of the assistance which can be rendered by wireless telegraphy in overcoming the difficulties and dangers of navigation was afforded in the case of the collision of the steamship *Florida* with the White Star liner *Republic* in the early morning of January 23. The collision occurred in a dense fog at 5.30 a.m., 175 miles east of the Ambrose lightship, New York. The *Republic* is equipped with a wireless telegraphy installation, and the captain, who was on the bridge at the time of the accident, at once had wireless messages for help sent out ... The messages were received by the liners *Baltic*, the *Lorraine*, and the *Lucania* ... The steamships proceeding to the rescue were able to transmit a wireless message to the *Republic* asking for the latitude and longitude of the collision ... Wireless telegraphy has thus been the means of averting a terrible calamity.
From *Nature* 28 January 1909.

CONDENSED-MATTER PHYSICS

The pnictide code

Jan Zaanen

Hopes are that the emergent family of iron-based superconductors, the pnictides, could act as a Rosetta stone in decoding the two-decade mystery of superconductivity observed at high temperatures.

About a year ago, the announcement of the discovery[1] of a new family of superconductors made from iron-based compounds prompted an army of physicists and chemists to study these pnictides. But what caused — and is perpetuating — this frenzy? The quest for a higher transition temperature, T_c (the temperature above which no superconductivity is attained), stalled[2] at a meagre 56 kelvin, and the focus of the excitement has shifted: it is now hoped that the pnictides will be instrumental in deciphering the 22-year-old mystery behind high-T_c superconductivity in cuprates[3] (compounds containing copper oxide). There are also compelling reasons to believe that pnictides share the main properties of cuprates. In this issue, two studies (Yuan *et al.*[4] on page 565 and Zabolotnyy *et al.*[5] on page 569) report observations of two features in the pnictides that further elucidate how the two families of superconductors compare.

What happens when zillions of quantum particles form a macroscopic quantum wholeness? The electron matter that superconducts is a famous example of such 'quantum matter' that shows quantum effects on a macroscopic scale. The Bardeen–Cooper–Schrieffer (BCS) theory of superconductivity proposed in 1957 seemed to explain the phenomenon in full, but this changed with the discovery of superconductivity in the cuprates in 1986, and transition temperatures as high as 150 kelvin have subsequently been found. In some ways, the ensuing research effort has been spectacularly successful, showing that electrons in solids can form surprisingly rich quantum worlds. But the cause of their superconductivity has become even more mysterious over the years[2].

The key question is: how much is going on in these electron worlds? The normal (non-superconducting) state of ordinary metals such as aluminium is remarkably featureless, despite their being in the grip of the influence of quantum weirdness, which, counter-intuitively, renders things very simple. A quantum magic causes the electrons to 'forget' that they strongly interact, and the resulting 'Fermi liquid' behaves like a gas of non-interacting 'quasielectrons'. According to BCS theory, at very low temperatures the exchange of phonons (atomic lattice vibrations in the metal) leads to a weak attractive interaction between the quasielectrons, causing these to bind in Cooper pairs, which condense into a superconducting state.

But in cuprates, chemistry conspires against the might of this quantum simplicity. Metaphorically, the cuprate electron world is like a quantized form of dense traffic on a busy highway. The electrons are subject to perpetual quantum motions, but can hinder each other's motions to such an extent that the electron 'traffic' jams completely, causing undoped cuprates to become insulating. Chemical doping can clear the way on the 'quantum highway', and at low levels of doping a quantum incarnation of stop-and-go traffic is observed[6]. At high levels of doping the quantum weirdness hits with full force — causing the electrons to forget the busy highway — and the Fermi-liquid state takes over[7].

But both the quantized stop-and-go and the Fermi-liquid states are bad for superconductivity: the best superconducting cuprates are found at intermediate dopings, at the point at which the electron traffic starts to gather speed[3].

The belief is that the electrons in pnictides might well share this 'quantum highway' behaviour. The observed transition temperatures are much too high to be explained by BCS theory, and the iron and arsenic atoms that constitute the pnictide layers create similar jamming conditions to those of copper and oxygen[2]. Moreover, although undoped pnictides do not quite insulate, they do show a muscular antiferromagnetism — a strong sign that the electron traffic is on the verge of coming to a standstill[8]. But even though pnictides and cuprates might share the gross aspects of quantum-highway physics, in other regards they can be quite different. The hope is that by comparing both systems one can find out what really matters in high-T_c superconductivity. This is exactly what Yuan *et al.*[4] and Zabolotnyy *et al.*[5] try to address in their studies.

In the cuprates, one invariably finds that the electrons can move freely only in the copper-oxide planes. This led researchers to believe that superconducting electronic properties, such as the quantum-highway behaviour, were two-dimensional, and that this was a necessary prerequisite for superconductivity at high temperatures. But Yuan *et al.*[4] now report on a demanding experiment with a simple conclusion that changes this view: despite the layered crystal structure of the pnictides, superconductivity in these materials can be three-dimensional. The implication is that, if both systems do share the secret of high-T_c superconductivity, two-dimensionality has been a red herring all along, causing theorists to look in wrong directions.

To appreciate the results of Zabolotnyy and colleagues[5], one has to dig a bit deeper into the weird side of the quantum world. The quantity that matters most in the Fermi liquid is the Fermi surface — a boundary in the abstract space of quasielectron quantum numbers that at absolute zero temperature separates the unoccupied states from the occupied ones. Photoemission experiments, which measure the energy of electrons emitted from the metals when these are subjected to electro–magnetic radiation, show sharp Fermi surfaces in cuprates in the Fermi-liquid regime at high levels of doping. At low levels of doping, where the electrons are in the stop-and-go regime and so are far from forming quasielectrons, these measurements show that there are still fuzzy remnants of these Fermi surfaces[9]. Although not at all understood, these remnants can be taken as a signal that the quantum weirdness is already in action in an attempt to simplify the electron traffic flow in the direction of the Fermi-liquid state.

Moreover, the observed, simple rounded-square shape of the single cuprate Fermi surface seems to be in accord with the predictions of the naive LDA (local density approximation) electronic-band-structure theory of metals, which completely ignores the quantum highways. But the Fermi surfaces in pnictides are more complex, and there is much more to investigate. According to the LDA, it is a semimetal-like affair of circle-shaped pockets of electrons and electron holes. Using high-resolution photoemission data, Zabolotnyy *et al.*[5] manage to observe the pockets, but instead of the predicted circles, these look like design wheels and aircraft propellers. Does this scrambling of the LDA Fermi surfaces in the pnictides tell us about a close victory of quantum weirdness over electron jamming[4], or is there an alternative, more conventional explanation?

It is too early to tell. At present, it is not at all certain whether pnictides code for cuprates or just for themselves. But there is yet another excellent reason to believe in the 'pnictide code'. Temperature is the mortal enemy of quantum physics. Therefore, one anticipates that when quantum weirdness is in a tight battle with the quantum highway, the influence of temperature might be disproportionate. This is such a difficult problem that, according to some, the mathematics of string theory is needed to understand it[10]. But we already know what this means empirically: at temperatures well above T_c one finds cuprates in a 'bad metal' state, in which the electron matter shows extreme forms of dissipation in stark contrast to the very small friction that characterizes the Fermi-liquid state[7]. There are indications that the pnictide metals can be as 'bad' as the cuprates, and I am impatiently waiting for a concerted effort that will nail this down. ■

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PLANT GENOMICS

Sorghum in sequence

Takuji Sasaki and Baltazar A. Antonio

The drought tolerance of sorghum is just one of the features that make it a valuable crop plant. There is much for agronomists to learn from the complete genome sequence of this type of grass.

It is almost four years since the genome sequence of the rice plant, *Oryza sativa*, was completed[1]. Rice is the world's most important crop, and the availability of an accurate, complete, map-based sequence of a cereal genome prompted ground-breaking studies of the genetic underpinning of valuable agricultural traits, both in rice itself and in other cereals.

The genomes of more than ten plant species have since been completely sequenced, to which can now be added that of a second cereal species, *Sorghum bicolor*, as reported by Paterson *et al.* on page 551 of this issue[2]. This constitutes another milestone in plant biology, but it won't, of course, mean that the sequencing machines will now lie idle: among commercially important crop plants, the genomes of other members of the grass family Poaceae (which includes maize, wheat and barley, as well as rice and sorghum), in addition to representatives of the Fabaceae (soybean) and Solanaceae (tomato and potato) families, will be completed in the next few years.

Worldwide annual production of sorghum is about 60 million tonnes, less than that of the other major cereal crops. It is nonetheless a staple for both humans and livestock, and is also a potential source of biofuel. Sorghum originates from tropical Africa, which makes it highly tolerant to drought and well adapted to arid countries in northeast Africa, where it is mainly grown, as well as to dry areas in the United States and India. Most notably, sorghum provides an example of a plant that carries out the C_4 type of photosynthesis. This photosynthetic pathway, found in many plants growing in conditions of high temperature and light intensity, and low water availability, is considered to be more efficient in fixing carbon dioxide than the C_3 route that is found, for instance, in rice and wheat. Research into the genomic basis of sorghum's adaptation

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In the field — sorghum under cultivation.