

quasi-two-dimensional, Mott–Hubbard charge transfer antiferromagnetic insulators in their undoped ground state. These last three properties are believed to be key to high-temperature superconductivity, and are about the only criteria on which you can find (almost) universal agreement among those trying to choose between the bespoke fashions hanging in the high- T_c theoretical closet.

However, observe in Figure 1 that the Fe ions, although nominally Fe^{2+} , analogous to Cu^{2+} , are tetrahedrally coordinated relative to the pnictide anions, as opposed to the square-planar symmetry of the copper oxide compounds. In the first-row transition metals — scandium to zinc — there are ten d -electron states (five described by orbital momentum), each of which can hold two electrons with one spin up and another down. We can play with these states to build various cationic configurations. A simple yardstick, called Hund's rule, helps build possible combinations in isolated atoms and ions. It says we have to start filling from the bottom, first occupying each orbital with an up-spin and then starting over again with spin-down, until all available d -electrons are consumed. Thus Fe^{2+} , with six electrons at large, will result in a ground state one electron in excess of a half-filled Hund's occupation distribution, and Cu^{2+} , with nine electrons to spend, will yield one electron fewer (a 'hole' or effective positive charge) than a filled d -orbital shell. Therefore, in a very crude sense, the new FeAs superconductors can be thought of as the electron analogues of the hole-transporting CuO complexes, and both measurements and theoretical studies bear this out.

The real situation is far more complex than just stated, and simple Hund's rule arguments are confounded by symmetry, position and overlap of neighbouring anions (O^{2-} , $\text{As}^{-(3-x)}$), and by Coulomb repulsion that tends to separate spins in otherwise 'Pauli-allowed' cation states from the next nearest cation neighbour. The trade jargon for these effects is 'crystal field splitting', 'hybridization' and 'Hubbard U ', respectively. You can be assured each of these is currently undergoing intense exploration. All this notwithstanding, the simple Hund's rule picture that the ferrous pnictides and copper oxides are electron–hole 'duals' may not be simply fortuitous. It may be the reason that, after years of intense searching, nickel and cobalt complexes have not yielded high-temperature superconductors (at least not yet).

In fact, with T_c now at 55 K, are these ferrous pnictides truly 'high-temperature superconductors'? Simply answered, we don't know at present. But it is useful to remember that the expression 'high-temperature superconductivity' did not originate with Bednorz and Müller's paper¹ of 1986. Those who, like myself, are of mature years will recall that this description was coined as a result of studies^{7,8} in the 1960s that superconductivity mediated by electron–

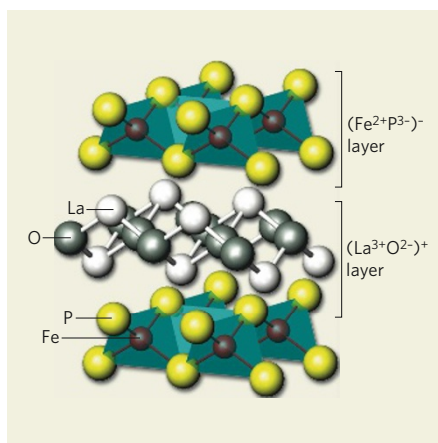


Figure 1 | The unit cell of LaOFeP . In this generic example³ of the family of lanthanum-series oxyfluoride ferrous pnictides, the overall cell charge is neutral but the individual layers are not, implying electron doping of the FeP layer. Note also that the P coordination of Fe is tetrahedral, not square planar as is the case for the high- T_c copper oxide perovskites. (Reproduced from ref. 3.)

phonon pairing would top out at around 30 K, and compounds showing anything above this value would be referred to as 'high-temperature materials'. Although the mechanism of high T_c in the copper oxide perovskites remains in question, we do have evidence⁹ in MgB_2 that electron–phonon coupling can achieve a transition temperature of 40 K. Is 55 K really that much higher?

Although most of the theoretical tailoring for the various ferrous pnictides is styled after fashions for the cuprate superconductors, one experimental study harks back to much earlier designs. Chen *et al.*¹⁰ report direct measurement of the superconducting energy gap and its temperature dependence in polycrystalline samples of $\text{Sm}(\text{O}_{0.85}\text{F}_{0.15})\text{FeAs}$, with $T_c = 42$ K. The technique used is called Andreev spectroscopy. This is a variant of tunnelling spectroscopy whereby, at a contact between a normal metal and a superconductor, an electron from the metal injected into the superconductor at energies lower than the superconducting gap gives rise to a superconducting pair (Cooper pair of electrons of opposite spin), which are subsequently spin-charge compensated by a 'reflection' of positive polarity (a hole) back into the normal metal. The resulting current–voltage dependence is a direct measurement of the superconducting pairing energy.

Astonishingly, Chen *et al.*¹⁰ find that their results best fit the time-honoured Bardeen–Cooper–Schrieffer (BCS) theory¹¹, the breakthrough in the mid-twentieth century that solved the riddle of superconductivity in all materials available up to that time. Although originally formulated to accommodate the pairing of electrons mediated by lattice vibrations (phonons), in its broadest sense the BCS framework can encompass pairing

of fermions in a boson field — perhaps even the 'flavours' found in neutron stars, quarks and gluons, giving rise to 'colour' superconductivity at the relatively low cosmological temperature of 10^9 (the units don't matter). So Chen and colleagues' identification of classic BCS behaviour does not rule out the possibility that some more exotic bosonic glue than phonons might be behind superconductivity in these ferrous pnictides.

Whenever a new superconductor with a T_c higher than 30 K appears on the scene, I inevitably get asked if it will bring applications closer. The question is perhaps more pertinent when the material involves particularly noxious elements such as arsenic. My answer is always "Just follow the money." If the pot at the end of the rainbow has enough gold inside (and so far it does not for applied superconductivity), the environmental issues can be overcome. I give you semiconductor manufacture and processing, which uses some of the most toxic compounds (including arsenides) in creation, yet is tolerated and brought under control because its financial return is in the trillions. Again, the units don't matter.

Will T_c in the pnictides continue to go up, and perhaps double or triple as happened in 1987–88? I doubt it. We've now been on standby for several months, and to my mind the best hope is that the discovery of pnictide high-temperature superconductivity will help us understand better the physics of the cuprates. The iron age has yet to dawn. ■

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Correction

The News & Views article "Genomics: Protein fossils live on as RNA", by Rajkumar Sasidharan and Mark Gerstein (*Nature* **453**, 729–731; 2008), contains the following incorrect statement: "...reads' found using the Solexa sequencing technology¹⁴ can be intersected with some seven pseudogenes, for an average of roughly two reads each." In fact, these reads intersected with some 70 pseudogenes, for an average of roughly 12 reads each. Also, in the text of Box 1, 'nt' (nucleotide) was omitted from one passage, which should read "...to -27 nt Piwi-interacting RNAs (piRNAs)." These corrections have already been made to the online versions of this article.