DEVELOPMENTAL GENETICS

A sex-specific switch

BLICKWINKEL/ALAMY

Those who are intimate with the fruitfly *Drosophila melanogaster* will recognize this fine specimen as a male. Most notably, the last two of its abdominal segments are pigmented. The equivalent segments in the posterior abdomen of females lack pigment, and sexual dimorphism of this and many other forms is responsible for all sorts of male–female behavioural differences in all sorts of organisms — vertebrate and invertebrate. Thomas Williams and colleagues have dissected this instance of fruitfly sexual dimorphism in molecular detail to reveal the genetic switch concerned (T. M. Williams *et al.* *Cell* **134,** 610–623; 2008).

The pigmentation is regulated by the tandem duplicate *bab* genes, whose protein products repress the enzyme system that produces pigment. The authors' investigations centred on their discovery of two *cis*-regulatory elements that respectively control *bab* expression in the anterior and posterior segments, these elements being themselves binding sites for transcription factors. One of the transcription factors is ABD-B, a member of the famed HOX family; two others are forms of the Doublesex protein, one specific for males, the other for females.

The sex-specific differences in the posterior segments arise from different control of the *cis*-regulatory element. In females, a combination of the transcription factors ABD-B and the female-specific form of Doublesex activates *bab* expression (and so prevents pigmentation). In males, the male-specific form of Doublesex overrides the activating effect of ABD-B: *bab* is repressed, so unleashing the enzyme system that pigments the final two male segments.

The most intricate part of the authors' work, however, comes in their studies of the evolution of this switch. From comparisons with transcription-factor binding sites on the equivalent *cis*-regulatory element of another species of *Drosophila*, *D. willistoni*, they aimed to identify the molecular changes that occurred in the lineage of *D. melanogaster* arising from a putative monomorphic common ancestor. The authors' conclusion is that rather than a wholesale gain of ABD-B or Doublesex binding sites, the advent of male pigmentation was due to a suite of fine-scale changes in the number, polarity and topology of sites.

Williams *et al.* don't go into the possible evolutionary and ecological factors that drove the production of male pigmentation. Instead, they end with the thought that, in evolutionary history, some of the main differences in the body plans of arthropods, like *Drosophila*, and vertebrates have arisen from alterations in the pattern of gene expression along the principal body axis. Their work, they say, shows a general way in which such expression patterns could evolve through the accumulation of many fine-scale alterations to a gene's *cis*-regulatory elements.

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nature of electron pairing in cuprates, the binding energy of the Cooper pair is highly anisotropic, and vanishes in certain directions (known as nodal directions) in momentum space. The wave-properties of electrons excited from such a nodal, superconducting state produce unique scattering interference patterns[3–5]. Electronic standing waves in real space are therefore a good probe of superconductivity in momentum space.

Kohsaka *et al.*[2] performed Fourier-transform STM/STS on crystals of the cuprate superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$. They observed standing waves associated with the nodal superconductivity for low-energy electrons, but these diminished for electrons that had energy greater than a certain 'extinction' value. By analysing these data, the authors identified the segment of the Fermi surface that supports superconductivity. Their measurements on a selection of cuprate crystals that have different carrier densities showed that the extinction energy is only weakly dependent on the density of carriers, but that the superconducting segment of the Fermi surface shrinks with decreasing carrier density.

Each superconducting segment terminates near a specific line in momentum space: the extinction line. Boundaries in momentum space are often associated with periodicities in real space. For example, the periodicity of a crystal's atomic lattice produces boundaries in momentum space that partition that space into small regions, known as Brillouin zones (Fig. 1). The extinction line of $Bi_2Sr_2CaCu_2O_{8+\delta}$ forms a diamond shape that connects the midpoints of the Brillouin zone boundaries.

Using the real-world imaging capabilities of STM/STS, Kohsaka *et al.* observed 'glassy' electronic domains at higher electron energies, beyond the extinction line. These domains locally break the symmetry of the underlying atomic lattice (Fig. 1d) and had previously been discovered by the same group in similar, lower-resolution measurements[6]. But in their latest experiments[2], the researchers were able to sufficiently resolve the energy of the electrons to show that these glassy domains are most prominent at the characteristic energy of the pseudo-gap state. The electronic state of cuprates is thus duplicitous: it adopts either a low-energy superconducting state supported by a segment of the Fermi surface, or a high-energy pseudo-gap state, characterized by unusual real-space structures.

The observations of Kohsaka *et al.* provide definitive proof of the intricate relationship between real and momentum spaces in cuprates, and suggest several exciting directions for future research. For starters, the cause of the diagonal extinction line needs to be studied in more detail. As the real-space domains observed at the pseudo-gap energy break the symmetry of the underlying atomic lattices and have a characteristic width[6], the appearance of an associated new boundary in momentum space is not strange in itself. But the direction of the boundary associated with the observed real-space structure in the pseudo-gap state differs markedly from that of the measured extinction line, which defines the superconducting segment in momentum space (Fig. 1). This might have profound implications for the nature of the pseudo-gap and, by extension, for the mechanism of superconductivity in cuprates.

The effects of a wider range of dopings also remain to be explored — for example, those that bridge the pseudo-gap and Mott insulator states. And it will be necessary to repeat direct momentum-space measurements using ARPES. These should not only reinforce the current data, but will also make clear the differences and similarities between ARPES and the emerging technique of Fourier-transform STM/STS. ■

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