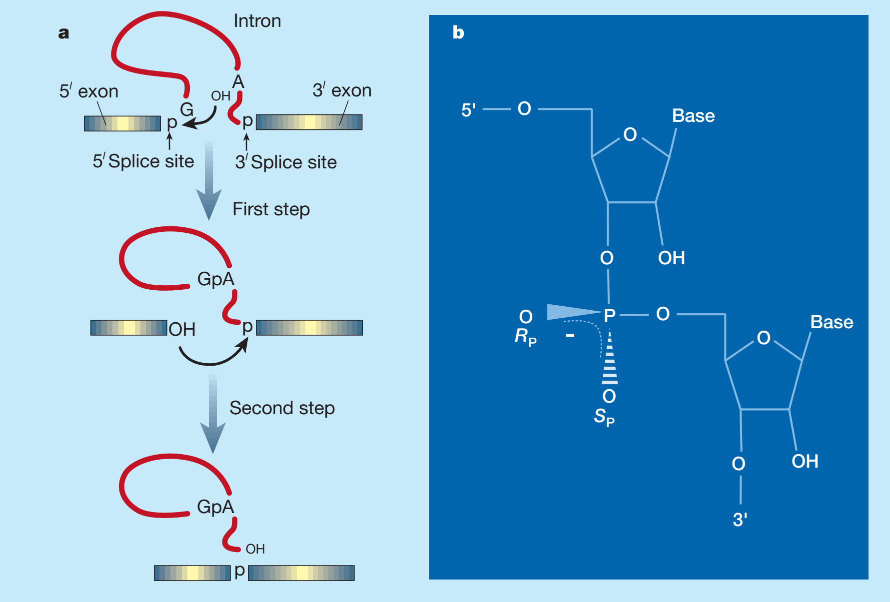

Figure 1 **Is the spliceosome an RNA-based enzyme? a, The two chemical steps in the splicing of nuclear precursor messenger RNAs. First, the 2′ hydroxyl group (OH) of an intronic adenosine nucleotide (the branch-point adenosine, A) attacks the phosphodiester bond (denoted by 'p') at the 5′ splice site. Breakage of this bond is accompanied by the formation of a phosphodiester linkage between the branch-point adenosine and the 5′ nucleotide (guanosine, G) of the intron. In the second step, the 3′ hydroxyl group of the free 5′ exon attacks the 3′ splice site, yielding joined exons and a free intron. These reactions are catalysed by the spliceosome, an enzyme containing five small nuclear (sn) RNAs and more than 50 proteins. b, The details of a phosphodiester bond between two bases in an RNA chain. Each phosphodiester linkage contains two 'non-bridging' oxygens (R_P and S_P) and two bridging oxygens. Yean *et al.*[3] show that a magnesium ion bound by the S_P oxygen at one of the phosphodiester linkages in the U6 snRNA is important in splicing.**

supplemented with manganese. This provides compelling evidence that the defect observed when sulphur was incorporated was due to a disruption of magnesium-ion coordination. Analogous 'metal-specificity-switch' approaches have previously been used to identify catalytic metal ions used by self-splicing introns, and to show that the spliceosome is a metal-dependent enzyme[4,7].

The simplest interpretation of these results is that the metal ion coordinated by U6 participates directly in the chemistry of splicing, either by activating the 2′ hydroxyl group of the branch-point adenosine or by stabilizing the leaving group. But this is not the only possible interpretation. Splicing involves many precatalytic steps, any one of which could, in principle, be compromised by the substitution in U6 snRNA. So Yean *et al.*[3] devised a clever scheme to accumulate fully assembled spliceosomes, stalled just before catalysis, and show convincingly that sulphur-substituted U6 supports all known precatalytic steps.

These experiments indicate that the metal ion coordinated by U6 may be a critical element of the active site of the spliceosome. When viewed against the extensive backdrop of other circumstantial evidence, the case for RNA-mediated catalysis in the splicing of precursor mRNAs becomes compelling. But is it definitive? Unfortunately not. Metal ions need not be catalytic to be essential, and metal-ion rescue, even in the simplest of cases, can be difficult to interpret unambiguously (see, for example, ref. 8).

Proof that an RNA catalyses splicing would require either the demonstration of splicing in a reaction that does not include the protein components, or high-resolution structural information analogous to that obtained for the ribosome[9]. Although neither result seems imminent, the work of Yean *et al.*[3] could conceivably pave the way for such studies. The network of RNA–RNA interactions in spliceosomes assembled with sulphur-substituted U6 might be sufficiently stable to withstand the removal of proteins while retaining manganese-triggered catalytic activity. Alternatively, stalled spliceosomes poised for catalysis might be ideal for structural studies. ■

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Superconductivity

Geometry spawns vortices

Alan T. Dorsey

The properties of superconductors can be affected by their shape. This effect is increasingly noticeable as the size of the superconductor decreases.

In addition to having zero electrical resistance, superconductors have the ability to expel magnetic fields. It is this fundamental property that allows a permanent magnet to be levitated above a superconducting sample. But under certain conditions the situation changes and magnetic field lines (flux) can partially penetrate some superconductors in a most remarkable way. The result is the creation of magnetic vortices, each carrying one unit (quantum) of magnetic flux.

On page 833 of this issue, Chibotaru *et al.*[1] show that in small superconducting samples, the magnetic flux patterns are greatly affected by the sample's geometry. For instance, when they tried to place three vortices in a square superconducting sample — rather like pushing a triangular peg into a square hole — the superconductor spontaneously generated a vortex–antivortex pair, so that the four vortices formed a square with an antivortex in the centre. This surprising arrangement has not been seen in previous studies of disc-shaped superconductors.

Whether or not a superconductor expels an applied magnetic field, H, depends on the field's strength. An ordinary type-I superconductor completely expels the magnetic flux if the applied field is less than a 'critical field', H_c. Above H_c, the sample's superconductivity is destroyed — in other words, the magnetic flux fully penetrates the sample. But in type-II superconductors (which include the copper oxide, or high-temperature, superconductors) the behaviour is more complex because there are two critical fields, H_{c1} and H_{c2}. The magnetic flux is completely expelled from the sample when the applied field is less than the lower critical field H_{c1} and partially expelled when the applied field is larger than H_{c1}. As before, the sample stops being a superconductor when the applied field is greater than H_{c2}. Quantized magnetic vortices appear in the intermediate region when the applied field is between H_{c1} and H_{c2}.

The vortices can be thought of as long filaments of concentrated magnetic flux, surrounded by a flux-free region of circulating 'supercurrents'. Because the supercurrents do not dissipate energy, the quantized vortices are stable (in contrast to vortices formed by vigorously stirring a bucket of water, which eventually dissipate because of viscous effects). If there are no significant thermal fluctuations or sample imperfections, the vortices arrange themselves into a stable pattern. Because the vortices repel each other, the minimum energy configuration for the vortices is one in which they are as far away from each other as possible. The favoured configuration is a triangular lattice. The characteristics of high-temperature superconductors, such as the maximum superconducting current they can support, are limited by the behaviour of this vortex lattice. So a lot of effort has gone into understanding the patterns of vortices, or controlling them by introducing defects into the superconductor.

So far we have only discussed the bulk properties of superconductors. But what happens when the sample is small and the surfaces or edges play a significant role? A flat surface parallel to the applied magnetic field tends to enhance the superconductivity[2], so that superconductivity persists near the sample's surface for fields above H_{c2}, and is finally destroyed at a field $H_{c3} = 1.69H_{c2}$. More complex behaviour might be expected to occur for samples with dimensions that compare to the vortex spacing (a micrometre or less).

Advances in nanotechnology over the past ten years mean that it is possible to make such mesoscopic devices and measure their properties. For example, Geim and collaborators[3–5] have uncovered a great deal of exotic behaviour in micrometre-sized discs; and Bolle *et al.*[6] have used micromechanical oscillators to detect the motion of single vortices in mesoscopic samples. This experimental work has spawned a great number of theoretical studies of vortex nucleation in small superconducting discs and rings[7,8]. There has also been great interest in using these mesoscopic superconductors as logic elements in a quantum computer[9]. If such a 'qubit' were operated in a magnetic field its maximum superconducting current would depend on the arrangement of vortices, just as in a macroscopic superconductor, so understanding vortex behaviour would be crucial to the operation of the qubit.

The work of Chibotaru *et al.*[1] is different because they have studied magnetic vortices in square superconducting samples. This geometry produces a much richer set of phenomena than the more simple disc geometry studied previously. The group measured the critical temperature (below which the sample becomes superconducting) as a function of magnetic flux in square (2 µm by 2 µm) aluminium samples. (Bulk aluminium is a type-I superconductor, but a thin sample can behave as a type-II superconductor.) The resulting curve has oscillations characteristic of vortex creation (see Fig. 1b on page 833).

To interpret their results the researchers solved the equations that describe the onset of superconductivity in the square geometry, and got a surprising result: the vortices respect the sample's symmetry by organizing themselves into a square with a fifth vortex at the centre. The nature of this central vortex changes as the magnetic flux is increased, from a vortex, to a giant vortex (which carries a double, rather than a single, quantum of magnetic flux), to an antivortex (responsible for the expulsion of magnetic fields). The theoretical results agree nicely with the researchers' measurements, and the picture they propose for vortex creation is compelling. But imaging the vortices (perhaps using a scanning tunnelling microscope) would provide a more direct and dramatic confirmation.

The results of Chibotaru *et al.* highlight geometry's influence on the patterns of vortices in superconductors, and raise several questions. For instance, what are the dynamics of the vortex nucleation process[10]? How do the vortices enter the sample, and what are the barriers[8] to nucleation? What about other sample shapes — do five vortices in a triangular sample form a hexagon with an antivortex at the centre, or a triangle with a giant vortex at the centre?

It is also possible that the findings of Chibotaru *et al.* might apply to materials that show 'super-behaviour' such as superfluid helium or Bose–Einstein condensates[11]. These can also flow without resistance and generate stable vortices when rotated in a container. Earlier this year[12], giant vortices were generated for the first time in superfluid helium-3. Chibotaru *et al.* suggest that superfluid helium, rotated in a triangular or square vessel, might generate antivortices. Similarly, the laser fields used to confine Bose–Einstein condensates could be arranged to encourage the production of antivortices in triangular or square traps. ■

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Daedalus

David Jones

David Jones, author of the Daedalus column, is indisposed.

Plant biology

Volatile defence

Plants can't run away from trouble and have developed sophisticated chemical defences instead. Maize, for example, releases a cocktail of volatile indole and terpenoid compounds when attacked by the beet armyworm caterpillar (*Spodoptera exigua*, pictured). These compounds attract a parasitic wasp, which deposits its eggs in the caterpillar; the wasp larvae then devour the caterpillar.

Writing in *Proceedings of the National Academy of Sciences USA* (online early edition, 5 December), two groups describe their investigations of how maize produces the substances. Monika Frey and colleagues have identified a gene, *Igl*, that is involved in the synthesis of indole. And Binzhang Shen and co-workers show that another gene, *stc1*, is required for maize to make a sesquiterpene compound (a terpenoid).

Maize releases the compounds only when under attack, so it seemed likely that the genes are activated only temporarily. Using techniques such as treating maize plants with volicitin, an 'elicitor' substance in the caterpillar's saliva, both groups show that each gene is indeed switched on only in response to damage.

Finally, Shen *et al.* look at maize plants in which the *stc1* gene is mutated, and discover that they do not produce a major volatile compound seen in the normal plants. **Amanda Tromans**

HOLT