COULOMB FISSION

Caught in the act . . .

binding to the ACS, it would assist in activation of a replication origin. In favour of this possibility are the facts that DNA replication is required for establishment of silencing¹⁵, at least one silencer is a replication origin in the chromosome¹⁶ and all four silencers are ARS elements¹⁴ (replication origins in plasmids). An alternative is that ORC assists, with other proteins bound to other *cis*-acting silencer components, in tethering additional proteins which are necessary for silencing. In this case origin function would not be required. The requirement for DNA replication to establish silencing¹⁵ would be explained by the ability of replication to alter existing chromatin structure and permit formation of new chromatin structure. This possibility is supported by the observations that two silencers do not detectably function as replication origins in the chromosome¹⁷, and silencer mutants exist which are inactive as ARS elements but active as silencers¹⁸. Distinguishing between these possibilities will require improved definition of the *cis*-acting components of silencers and elucidation of the roles of the *trans*-acting factors required for silencer function.

A chapter in the story of ORC has ended, one in which it is plainly revealed that ORC has at least two functions. But another chapter now opens, in which we may hope to learn of the precise identification of the *cis*-acting sequences required for origin and silencer functions, and of the exact roles and cell-cycle regulation of the subunits of ORC, CDC6p, the MCM proteins, and other proteins required for replication and for silencing. □

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... but charges will be dropped. Above, an electrically charged heptane droplet ruptures to produce a fine spray of tiny offspring, each only about 10 μm in diameter. The large droplets are part of a stream expelled from a fine nozzle. They acquire charge as they leave the nozzle, which is held at a potential of a few kilovolts above a ground electrode, so coulombic repulsion between the charges acts against the surface tension holding the droplet together. If the surface charge is sufficiently high, the electrostatic charge overcomes surface tension and the drop bursts, as shown here.

The theory has been around for a while — the ever-curious Lord Rayleigh first looked into the problem in 1881, and derived an expression for when the droplet should disintegrate — but actually catching a drop mid-explosion has proved difficult. Alessandro Gomez and Keqi Tang snapped this one using a shadowgraph technique with 25-nanosecond flashes of light combined with a fast CCD (charge-coupled device) camera; as more than 10 thousand droplets per second are sprayed from the nozzle, there was a fair chance of photographing at least a few at the critical moment. In fact, they captured enough images to conclude that the common view of a violent, convulsive explosion is not borne out; instead, a well defined jet typically forms, as shown above. Their results are published this month in *Physics of Fluids*.

The Rayleigh limit on stability is reached when $q^2 = 8\pi^2\epsilon_0\gamma D^3$ where q is charge on the droplet, ϵ_0 the permittivity of the surrounding medium, γ the liquid surface tension and D the droplet

diameter. In real life, nothing is quite that simple, and effects such as aerodynamic distortion of the droplet as it falls, and the electric field between the nozzle and the ground electrode combine to reduce the limit (Gomez and Tang find disruption in general at charges of 70–80 per cent of the Rayleigh limit).

Rayleigh might have been surprised at the range of applications found for 'Coulomb fission'. Fine, evenly dispersed jets of liquid are needed for ink-jet printers, fuel combustion and, the application that sparked the experiments here, electrospray ionization as a basis for mass spectrometry of large, delicate biological molecules. John Fenn and collaborators at Yale University first demonstrated the principle in 1984: the species to be analysed are dissolved in a carrier liquid and electrostatically sprayed into fine droplets, divided by Coulomb fission into ever finer droplets, until the radius of curvature is so small and the electric field at the surface so high that ions are desorbed into the gas phase. More established ionization techniques, such as fast-atom bombardment, chemical ionization or inductively coupled plasmas, produce molecular ions with just one or two charges; the common run of mass spectrometers can detect these low-charged ions at relative molecular masses up to about $M_r = 10,000$. The electrospray method can dump 30 to 50 charges on each molecule, permitting the detection and identification (give or take a hundred atomic mass units or so) of molecular masses up to about $M_r = 100,000$, so proteins and other biological molecules can readily be analysed.

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