NEWS

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A demon of a device

Light makes molecular machines perform trick.

Katharine Sanderson

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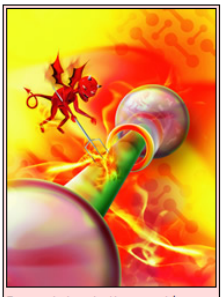
David Leigh at Edinburgh University has managed to make a molecular machine inspired by "Maxwell's demon" — a thought experiment that defies the second law of thermodynamics.



Demonic inspiration: an idea from 1867 has prompted an odd invention.

Illustration by Peter Macdonald, Edmonds UK

Leigh's molecular machine can, he says, drive a chemical system away from equilibrium. According to the second law of thermodynamics — that a system tends towards equilibrium — this shouldn't happen.

Fortunately, Leigh's device doesn't completely blow away the laws of physics: he needs to add energy to the system by shining light on it to make it work. The added energy explains how the system can move away from equilibrium.

James Clerk Maxwell came up with his thought experiment in 1867. In it, a demon guards a door between two rooms filled with gas. Using its sprightly demonic powers, the creature could open the door when he spotted a particularly fast-moving molecule coming his way. The molecule could then pass into a room, which would become progressively hotter. Likewise, the demon could allow particularly slow-moving molecules to pass out of the warmer room and into the cooler one. By doing so, he creates a growing temperature difference, and therefore, potential energy in the system, without having expended any energy to do it (assuming our magic demon doesn't eat).

In the real world, researchers have made little devices that might be used to make a demon-like machine. One of these is a ring-shaped molecule, which is slotted onto a tiny molecular axle. The ring can move along the axle between two different sites, A and B. If left to its own devices, the normal, random movement of molecules will shunt the ring back and forth. When there are many devices, at any given time, half of them should have a ring at one site, and half at the other.

Leigh's system uses these devices, but with a twist. The middle of his axle can change shape so that it blocks the ring from moving back and forth, but only when the ring is at position A, and only when light is shone on it. If a light is shone on a number of such machines, the rings at position A will get stuck. And as time goes on, many of the rings at position B will shunt over and also get stuck at position A.

Real-world magic

In a pot of billions of these devices, the proportion of rings at one spot or another was shifted in a matter of minutes from 50:50 to about 70:30 — just like the demon who turns two equally heated rooms into a warmer one and a colder one.

"Unlike all other artificial molecular machines, this allows you to drive a chemical system away from equilibrium," says Leigh.

"This is not an easy thing to do," says Stuart Rowan, at Case Western Reserve University in Cleveland, Ohio — although, he adds that it is the kind of process that happens in nature all the time. Ions flowing in and out of cells, for example, work against the equilibrium.

Fraser Stoddart, director of the California NanoSystems Institute at the

University of California, Los Angeles, says that Leigh's system signals a new approach to chemistry. "It will open up new possibilities," he says. And the technical achievement of actually creating these devices, he says, is also truly impressive.

Leigh can envisage making a similar system that pushes ions across a membrane, against a concentration gradient, mimicking these natural ion pumps. "Nature uses controlled molecular motion for everything," says Leigh, "by contrast, mankind uses controlled molecular motion for nothing."

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