The science of shoelaces - How shoelaces come undone

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ENGINEERING brings great benefit to humanity, from aircraft to bicycles and from bridges to computer chips. It has, though, had difficulty creating a shoelace that does not accidentally come loose. At least in part, this is because no one has truly understood why shoelaces come undone in the first place. But that crucial gap in human knowledge has just been plugged. As they report in the *Proceedings of the Royal Society*, Christopher Daily-Diamond, Christine Gregg and Oliver O'Reilly, a group of engineers at the University of California, Berkeley, have now worked out the mechanics of shoelace-bow disintegration.

A shoelace bow is a type of slip knot that has, at its core, a reef knot. Like conventional reef knots, bows can be mistied as "granny" knots, which come undone more easily than a true reef does. But even a shoelace bow with a true reef at its core will fail eventually, and have to be retied.

Walking involves two mechanical processes, both of which might be expected to exert forces on a shoelace bow. One is the forward and back movement of the leg. The other is the impact of the shoe itself hitting the ground. Preliminary experiments carried out by Mr Daily-Diamond, Ms Gregg and Dr O'Reilly showed that neither of these alone is enough to persuade a bow to unravel. Both are needed. So they had to devise experiments which could measure and record what was going on while someone was actually walking.

The "someone" in question was Ms Gregg, who endured numerous sessions on a treadmill so that the behaviour of her shoelaces could be monitored. Using cameras, and also tiny accelerometers attached to the laces, the researchers realised that two things are important. One is how the act of walking deforms the reef at the centre of a bow. The other is how the different inertial forces on the straight-ended and looped extremities of the bow conspire to pull the lace though the reef in the way a wearer would when taking a shoe off.

The first thing which happens during walking is that the reef itself is loosened by the inertial forces of the lace ends pulling on it. This occurs as a walker's foot moves first forward and then backward as it hits the ground during a stride. Immediately after that, the shock of impact distorts the reef still further. The combination of pull and distortion loosens the reef's grip on the lace, permitting it to slip.

In principle, the lace could slip either way, giving an equal chance of the bow eventually undoing completely or turning into a non-slip knot of the sort that long fingernails are needed to deal with. In practice, the former is far more common. The reason turns out to be that the free ends of the bow can swing farther than the looped ends do. The extra inertial force this causes favours slippage in the direction of the longer of the free ends. To start with, the effect is small. But as the free end in question continues to elongate, the disparity in inertial force gets bigger—and, eventually, only two or three strides are needed to take a shoe from being apparently securely tied to being untied.

Probably, nothing can be done about this differential elongation. But it might be possible to use the insights Mr Daily-Diamond, Ms Gregg and Dr O'Reilly have provided to create laces that restrict the distortion of the reef at a bow's centre, and thus slow the whole process down. Regardless of any practical benefit, though, the three researchers, are **surely contenders for an Ignobel prize.** That award is made every year for work which "first makes you laugh, and then makes you think". Their study of laces looks like a shoo-in.

The 2000 Ig Nobel Prize in Physics went to Andre Geim (University of Nijmegen) and Michael Berry (University of Bristol) for levitating a frog with magnets. In a bit of redemption, Geim won the Nobel Prize in Physics a decade later for graphene research, making him the only person to have won the Ig Nobel and the Nobel.

Ig Nobel

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Ig Nobel
The 2009 Ig Nobel Prize in Physics was shared by three American researchers – Katherine K. Whitcome, Daniel E. Lieberman, and Liza J. Shapiro – for their analytical explanation of **why pregnant women are not constantly tipping over**.
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Ig Nobel
The 2014 Ig Nobel Prize in Physics was shared by four researchers – Kiyoshi Mabuchi, Kensei Tanaka, Daichi Uchijima, and Rina Sakai – for explaining the physics behind the pinnacle of physical comedy: slipping on a banana peel.
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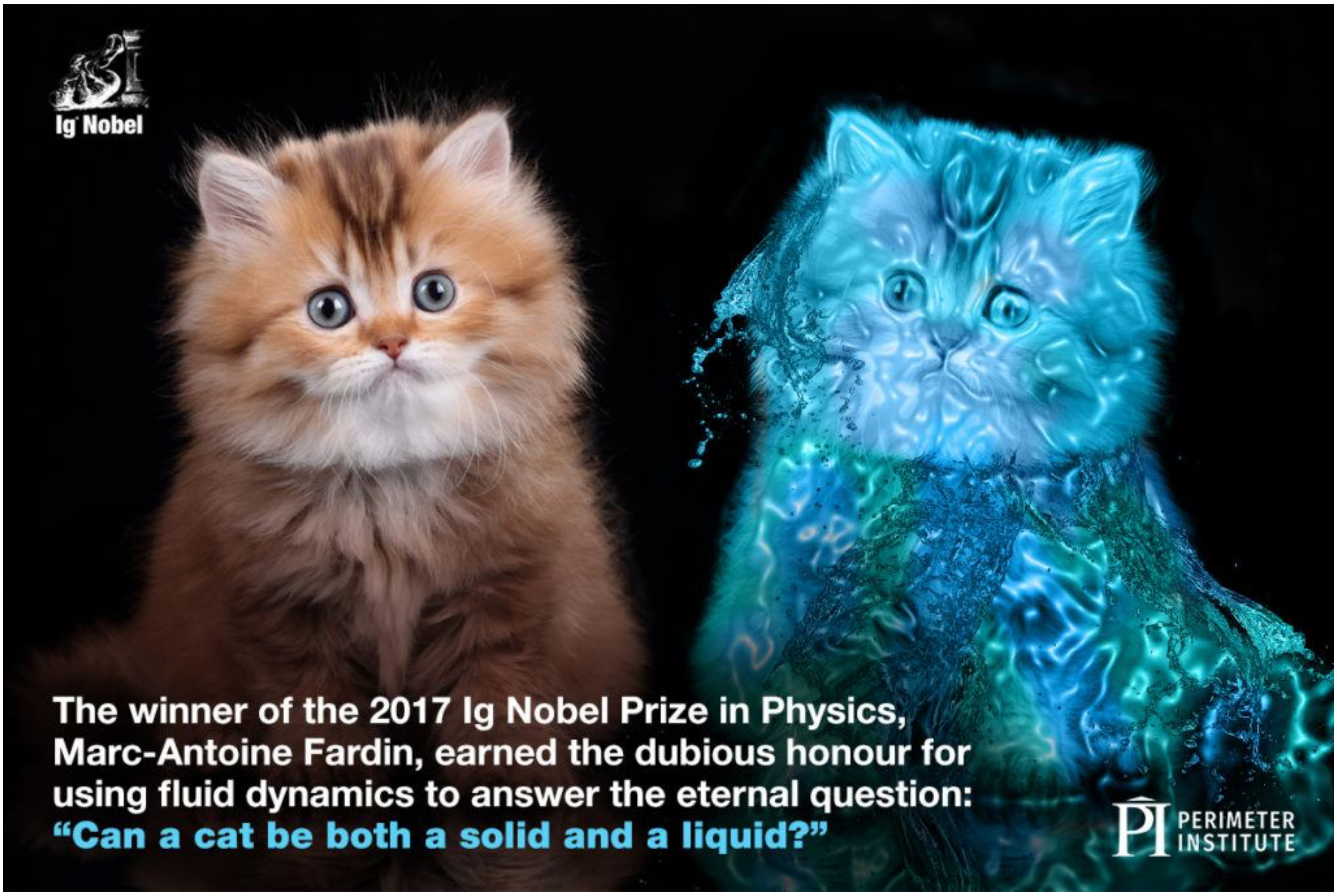
Ig Nobel
The winner of the 2017 Ig Nobel Prize in Physics, Marc-Antoine Fardin, earned the dubious honour for using fluid dynamics to answer the eternal question:
"Can a cat be both a solid and a liquid?"
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