

# Appendix A

## Articles in the press relating our work [27]

Our article [27] has been noticed by the international press and web sites.

On August 21, 2007 the Proceedings of the Royal Society of London A published our article [27] online and the following day it was just noticed by *The Daily Telegraph* [August 22, 2007]. A few days later [August 31, 2007] *Science* magazine [Vol. 317, no 5842, 1151, DOI: 10.1126/science.317.5842.1151a] reported its results too. Our research has also been noticed in *La recherche* magazine [November, 2007, no. 413].

Some websites which liked our results are: *UK Wine Show* [August 25, 2007, <http://www.thirtyfifty.co.uk>], *The Math Gateway* of the Mathematical Association of America [October 9, 2007, <http://mathdl.maa.org/mathDL>] and the website *Cyberpresse.ca* [October 31, 2007, <http://www.cyberpresse.ca>].

Professor Sir Michael Berry, Editor of the Proceedings of the Royal Society A, later included our article in a list of “outliers”, [Editorial Proceedings of The Royal Society A, January 8, 2010 466:1-2; published online before print November 11, 2009, doi:10.1098/rspa.2009.0535].

In the following pages, reproduce these press clippings.

How to remove the cork from a wine bottle - Telegraph

http://www.telegraph.co.uk/earth/main.jhtml?view=DETAILS&grid...

RSS | Britain's No.1 quality newspaper website | Make us your homepage

Wednesday 22 August 2007

# Telegraph.co.uk

NO.1 WEBSITE  
hitwise  
AUGUST 2007

hurry, offer ends 30 September  
terms and fair use policy apply home broadband from Orange

Go  Our site  Web

Home News Sport Business Travel Jobs Motoring Property SEARCH

**Earth home**

Earth news

Earth watch

Comment

Greener living

Science

Messageboards

Announcements

Arts

Blogs

Comment

Crossword

Dating

Digital Life

Earth

Expat

Family

Fantasy Games

Fashion

Features

Food & Drink

Football

Gardening

Health

Horoscopes

My Telegraph

Obituaries

Promotions

Science

Sudoku

Sunday Telegraph

Telegraph e-paper

Telegraph magazine

Telegraph offers

Telegraph PM

Weather

Your Money

Your view

## How to remove the cork from a wine bottle

Last Updated - 12:01am BST 22/08/2007

It is more efficient to remove a cork from a bottle by a combination of twist and pull, rather than pulling alone, according to a team of French and Italian researchers.

A team from Lecce University in Italy and the University of Pierre and Marie Curie in Paris has explored the background mathematics in a paper entitled: "The stress field in a pulled cork and some subtle points in the semi-inverse method of nonlinear elasticity."

In today's Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, Michel Destradre, Riccardo de Pascalis, and Prof Giuseppe Saccomandi say their arcane workings are able to "answer a classic wine party dilemma: which kind of corkscrew system requires the least effort to uncork a bottle?"

After 16 pages of mathematical calculations in which a cork is modelled as "an incompressible rubber-like material", they conclude that their work "backs wine amateurs who favour a system relying on a combination of pulling and twisting over a system relying on pulling."

They point out that the most common corkscrews rely on pulling only - either directly or through levers - but these are inferior to the rarer kinds that rely on a combination of pulling and twisting.



Second rate? Scientists prefer more complex instruments

The authors conclude that they "are confident that they have provided a scientific argument to those wine experts who favour the second type of corkscrew over the first."

advertisement

UBS OPENINGS:  
at Tate Modern

Telegraph.co.uk UBS

Post this story to: [del.icio.us](#) | [Digg](#) | [Newsvine](#) | [NowPublic](#) | [Reddit](#)

EARTH MOST VIEWED

Why women are better at shopping than men  
'We have broken speed of light'  
T rex dinosaur 'as fast as David Beckham'  
Physicists have solved mystery of levitation  
EU rules 'threaten Britain's dairy farms'

Ads by Google

[Buy Michael Antonio Shoes](#)  
The Latest Selection at LOW Prices FREE Shipping on orders \$75 or more  
[www.FlyJane.net](#)

[Wine stoppers - Synthetic](#)  
high FDA quality for your wine - why not avoid problems with TCA  
[www.resincork.com](#)

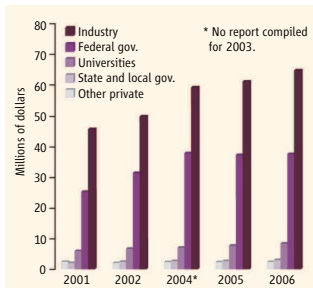
[Vois pas cher Pour Cork](#)  
Billets d'avion à bas prix -65% Comparez les Compagnies Aériennes  
[Vol-Cork.bill-et-avion.cc](#)

## RANDOMSAMPLES

EDITED BY ROBERT COONTZ

### Health Research Funding: No Relief in Sight

Some policy wonks have suggested that foundations and other private sources will compensate for the flat National Institutes of Health (NIH) budget (*Science*, 11 May, p. 817). That's wishful thinking, says Research!America, a nonprofit group in Alexandria, Virginia, that tracks U.S. health research funding. Its latest analysis (below) shows that nonindustry private funding represented 2% of the \$116 billion spent on U.S. health research in 2006 and has been "completely flat" since 2001, says Research!America policy analyst Stacie Propst.



Spending by industry has risen slightly since NIH's budget stalled at about \$29 billion after 2004, but Propst predicts a dip because industry research funding typically follows federal patterns with a lag of a few years. The proportion of each U.S. health care dollar that now goes to research is 5.5 cents and falling, Propst adds; meanwhile, countries such as the United Kingdom and Singapore, although still behind the United States, are expanding their investments. "The trends are not good," says Research!America President Mary Woolley.

### Filet of Zebrafish

Long a favorite of developmental biologists, the zebrafish is now catching on with researchers studying cancer, drug addiction, and numerous other conditions. A new anatomical atlas for this scientific school is FishNet from the Victor Chang Cardiac Research Institute in Sydney, Australia. The reference, which features 36,000 images captured using optical projection tomography, is the first to detail the fish's structure from embryo to adult. For each stage, visitors can call

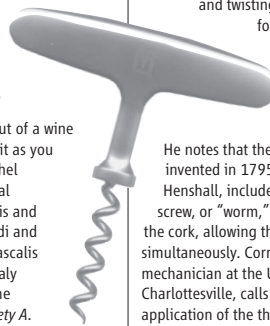
CREDITS: TOP TO BOTTOM: RAJENDRA KANODIA/CONSCIENCE/CON; RESEARCH!AMERICA; J. SANDERSON



up lengthwise or cross-sectional slices, many of which include labels that pinpoint nascent organs and other features. Additional image sets highlight the developing nervous system and the skeleton. >>  
[www.FishNet.org.au](http://www.FishNet.org.au)

### Crisp, With a Hint of Calculus

It's official: A cork will come out of a wine bottle more easily if you twist it as you pull. That's what physicist Michel Destrade of the French national research agency, CNRS, in Paris and engineer Giuseppe Saccomandi and mathematician Riccardo De Pascalis of the University of Lecce in Italy reported last week online in the *Proceedings of the Royal Society A*. The team analyzed the problem to underscore that solids can deform in



counterintuitive ways. For example, they show that a cork can twist internally even if it is pulled straight up. Such "secondary deformations" should not be overlooked, Destrade says. As a sidelight, the team also showed that pulling and twisting extracts the cork with less force than pulling alone.

That result won't surprise enophiles, says Rajendra Kanodia, proprietor of the Web site Corkscrew.com. He notes that the first patented corkscrew, invented in 1795 by Englishman Samuel Henshall, included a disk just above the screw, or "worm," that butts up against the cork, allowing the user to twist and pull it simultaneously. Cornelius Horgan, an applied mechanic at the University of Virginia, Charlottesville, calls the analysis "a very nice application of the theory of nonlinear elasticity," which is currently undergoing a renaissance with its applications to biological materials.

### No Mean Cat Feat

Researchers working in central China have photographed one of the world's most poorly studied mammals, the Chinese mountain cat. First described by scientists in 1892, the cat (*Felis bieti*) is known only from a few skins in museums and six live animals in Chinese zoos, says Jim Sanderson, a mammalogist and founder of the Small Cat Conservation Alliance. In May 2003, Sanderson and colleagues Yin Yufeng and Drubgyal (his single Tibetan name) set out to find it in the wild. The effort paid off this summer, when their camera traps on the Tibetan Plateau in northwestern Sichuan Province caught eight photos of the cats hunting at night. Sanderson hopes the images will encourage conservation of the cat.



Downloaded from [www.sciencemag.org](http://www.sciencemag.org) on May 21, 2009

## CURIOSA

### Arbres à ours

Dans les forêts de Colombie-Britannique, des « arbres à ours » ont été repérés où les grizzlis aiment à se frotter, mordillant et griffant l'écorce. Ce sont toujours quelques mêmes troncs qui sont choisis, selon une expérimentation menée durant les nuits de printemps de 2005 et 2006 à l'aide de caméras cachées. Quatre arbres ont été ainsi la cible d'ours qui s'y sont frottés 52 fois. Les bêtes étaient principalement des mâles dominants, ce qui fait penser aux chercheurs que chaque animal passant près d'un de ces arbres a à cœur d'effacer toutes traces de possibles rivaux. Mais les auteurs de l'étude ne savent toujours pas pourquoi les ours choisissent tel ou tel arbre.



• [www.sciencemag.org/content/vol317/issue5844/r-samples.dtl](http://www.sciencemag.org/content/vol317/issue5844/r-samples.dtl)

### Maison vendue après la virgule

Les publicitaires savent depuis des lustres qu'à 99,99 euros un bien apparaît plus attractif aux yeux du consommateur qu'à 100 euros. C'est la même chose pour le prix des maisons, selon une nouvelle étude de l'université américaine Cornell. En Floride du Sud et à Long Island (état de New York), une maison cotée à 484 700 dollars a été vendue, au final, 1 300 dollars de plus qu'une autre affichant un prix de départ de 485 000 dollars. Selon les chercheurs, lors du processus d'achat, le nombre précis sera perçu comme plus bas et plus « définitif » que le nombre rond, ce qui découragerait les tentatives de marchandage. Mais cette tendance a-t-elle résisté à la crise des « subprimes » ?

• [www.sciencemag.org/content/vol317/issue5845/r-samples.dtl](http://www.sciencemag.org/content/vol317/issue5845/r-samples.dtl)

### Ballon taille 42

Plus une balle se rapproche d'une sphère parfaite, plus précise sera sa trajectoire. Un Sud-Africain, géologue et fou de foot, a décidé de s'attaquer à la question après que, durant la dernière Coupe du Monde, des goals se sont plaints de « trajectoires imprévisibles » des ballons Adidas « Teamgeist » à 14 faces utilisés pendant cette compétition. Jos Luris propose un ballon à 42 faces, combinaison la plus équilibrée selon lui : 12 faces d'un dodécaèdre pentagonal et 30 d'un triacontaèdre rhombique où les faces sont en forme de losanges. Le professeur émérite de l'université de Johannesburg a envoyé son design à Adidas, espérant ainsi le voir testé par la firme lors de la prochaine Coupe du monde, en 2010 en Afrique du Sud. Mais Adidas a botté en touche : elle défend son Teamgeist, « un ballon parfaitement rond alliant précision et contrôle ».

• [www.sciencemag.org/content/vol317/issue5843/r-samples.dtl](http://www.sciencemag.org/content/vol317/issue5843/r-samples.dtl)

### Cigales en bout de ligne

L'année dernière au Japon, plus de 1 000 pannes ont affecté un réseau de communication pourtant ultramoderne avec ses lignes en fibres optiques. Responsables, les cigales *Cryptotympana facialis* qui utilisent les fils pour pondre leurs œufs. Connue au Japon sous le nom de Kumazemi, l'insecte de 7 centimètres de long prolifère en zone urbaine. Il semble confondre le câble en fibre optique avec les brindilles mortes sur lesquelles il se plaît. Parade imaginée par les ingénieurs de Nippon Telegraph and Telephone : gainer les fibres d'un revêtement en polyuréthane qui imite l'écorce vivante que, généralement, les cigales évitent.

• [www.sciencemag.org/content/vol317/issue5843/r-samples.dtl](http://www.sciencemag.org/content/vol317/issue5843/r-samples.dtl)

### Poussez pas le bouchon

Les amateurs de bonnes bouteilles l'ont maintes et maintes fois expérimenté : le bouchon se déloge plus facilement si l'on effectue une torsion avec le tire-bouchon en même temps que l'on tire. La chose vient d'être étudiée en laboratoire par le physicien français Michel Destrad et deux de ses collègues de l'université de Lecce en Italie. L'objectif était d'étudier comment certains solides se déforment de manière parfois contre-intuitive. Par exemple, un bouchon se vrille alors qu'il est tiré tout droit, dans ce que l'équipe appelle une « déformation secondaire ». Commentaire très sobre d'un spécialiste de mécanique appliquée de l'université de Virginie : ce travail est une « application très intéressante de la théorie de l'élasticité non linéaire ».

• [www.sciencemag.org/content/vol317/issue5842/r-samples.dtl](http://www.sciencemag.org/content/vol317/issue5842/r-samples.dtl)



© FRANCE BICHON/PHOTOCLOCK

### Glaneuses-acheteuses

La psychologie évolutionniste ne cesse de nous éclairer sur la nature profonde de l'élément féminin. Voici qu'elle nous explique pourquoi, quand il s'agit de faire les courses, la femme fait mieux que l'homme pour repérer les différentes nourritures qui s'offrent à la vue dans un marché, de la même façon, supposent-ils, qu'elle glanait avec brio les baies comestibles dans son groupe de chasseurs-cueilleurs. L'étude de chercheurs de l'université de Californie portant sur 86 individus montre que les femmes se rappellent mieux de l'emplacement des aliments. Mais s'agissait-il de paquets de pâtes, ou bien de packs de bière ?

• [www.sciencemag.org/content/vol317/issue5843/r-samples.dtl](http://www.sciencemag.org/content/vol317/issue5843/r-samples.dtl)



ThirtyFifty - Wine news



**Wine News**

- [News Homepage](#)
- [UK Wine Show](#)
- [Wine News](#)
- [Top 30 wines](#)
- [Wine Poll](#)
- [Book Reviews](#)
- [Hot Topics](#)
- [Climate Change](#)
- [Wine and Health](#)
- [Wine and the Environment](#)
- [Oak Barrels](#)
- [Wine Labels](#)
- [Wine Pricing](#)
- [Wine Packaging](#)
- [Wine Closures](#)
- [English Wine](#)
- [Organic Wine](#)
- [Terroir Wine](#)
- [Wine Tasting 1](#)
- [Wine Tasting 2](#)
- [Wine Flavours](#)
- [The Law](#)
- [Food & Wine](#)
- [Low Alcohol](#)
- [Wine making](#)

**Wine News**

**Research shows pull and twist corkscrew is best by Sandra Clement Saturday, August 25, 2007**

It is easier to remove a cork from a wine bottle by twisting and pulling rather than pulling alone, according to a team of Italian and French researchers.

The team from Lecce University and the Centre National de la Recherche Scientifique used the theory of nonlinear elasticity to answer a classic wine party dilemma: which kind of corkscrew system requires the least effort to uncork a bottle? Researchers Riccardo De Pascalis, Michel Destrade and Giuseppe Saccomandi provided a mathematical argument – running to some 16 pages – which backed ‘those wine amateurs who favour a system relying on a combination of pulling and twisting over a system relying on pulling only’ because the ‘calculations indicated that it requires more force to pull only than to pull and twist’.

The team, whose paper appears in this month’s *Proceedings of the Royal Society: Mathematical, Physical and Engineering Sciences*, points out that corkscrews based on the pull-only option are more common but the ease of opening with the second option is reflected in some of the commercial names, such as ‘magic corkscrew’ and ‘easy corkscrew’. However, the twist-and-pull kind aren’t as rare as hen’s teeth – you’ll find one at Ikea.

**Interviews and News for Anjou-Gamay**

**Research shows pull and twist corkscrew is best**

It is easier to remove a cork from a wine bottle by twisting and pulling rather than pulling alone, according to a team of Italian and French researchers.

*Wine Club Members*

email address

password

*Register Here!*

*Vote in our poll...*

**How often do you drink wine at home?**

Every day

2 or 3 times a week

About once a week

Only when entertaining

Never



Math In The News

**MathDL**  
The MAA Mathematical Sciences Digital Library

NSDL The Mathematical Association of America

← MathDL Homepage

Register Sign In

[Browse News Archives](#)
[Search News Archives](#)

The Mathematical Association of America



MathDL is a Pathway Project within the National Science Digital Library.



This project is funded in part by the National Science Foundation Grant DUE-0435198.



## Math in the News

[MathDL Home](#)

### Giving a Cork a Mathematical Twist

**October 9, 2007**

Well, now we know: It takes less effort to remove a cork from a bottle by pulling *and* twisting than by just pulling it. The evidence appears in a 15-page mathematical [paper](#) published recently in the *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*.

Modeling a cork as an "incompressible rubber-like material," [Michel Destrade](#) of the Université Pierre et Marie Curie in Paris, along with mathematician Riccardo de Pascalis and engineer [Giuseppe Saccomandi](#) (both from the University of Lecce, in Italy), showed that a cork being pulled from a bottle can twist internally. Adding your own twist to this "secondary deformation" makes the task that much easier.

Their paper, titled "[The stress field in a pulled cork and some subtle points in the semi-inverse method of nonlinear elasticity](#)," shows that solids can deform in counterintuitive ways. As reported in *Science*, applied mathematician [Cornelius Horgan](#) of the University of Virginia called the researchers' analysis a "very nice application of the theory of nonlinear elasticity."


We'll drink to that!

Source: [Science](#), Aug. 31, 2007; [Telegraph](#), Aug. 22, 2007.

[Browse News Archives](#)
[Search News Archives](#)

MathDL Home | MAA Writing Awards | Loci  
Copyright 2010, All Rights Reserved, The Mathematical Association of America.

cyberpresse.ca Plan du site Visa Cyberpresse | Ouvrir une session | S'inscrire



**SCIENTES** cyberpresse.ca | le web | PagesJaunes

Rechercher dans le site

LA PRESSE leSoleil Le Nouvelliste LeQuotidien LaTribune LeDroit LaVoixde l'Est

ACCUEIL LAPRESSEAFFAIRES.COM MONCINEMA.CA MONTTOIT.CA MONVOLANT.CA TECHNAUTE.COM

Actualités | Actuel | Arts & Spectacles | Blogues | Chroniqueurs | Consommation | Cuisine | Environnement | Hockey  
Insolite | International | Lectures | Multimédia | Noël | Opinions | Photos | Santé | Sciences | Sports | Vidéo | Voyages

Accueil » Sciences » Texte complet

Le mercredi 31 octobre 2007

## Des chercheurs se penchent sur le tire-bouchon



Agrandir

Agence Science-Pressé

**Une équipe de physiciens franco-italienne a étudié le plus sérieusement du monde la manière idéale de déboucher une bouteille de vin.**

Sa conclusion: le bouchon sortira plus facilement de la bouteille si vous le tordez en même temps que vous tirez. Michel Destrade et Giuseppe Saccomandi profitaient de cette «énigme» pour réfléchir sur la façon dont un solide (ici, le bouchon) peut se déformer de manière «contre-intuitive»: par exemple, le bouchon de liège se déforme par l'intérieur, même s'il est «tiré» par une force extérieure.

Parions que l'inventeur du tire-bouchon, en 1795, n'avait pas prévu l'usage qu'en feraient des physiciens...

Outils proposés par moncinema.ca

Taille du texte

Imprimer

Envoyer

À consulter aussi

### AUJOURD'HUI SUR CYBERPRESSE

#### Sondage: Marois et le PQ ont le vent dans les voiles

Le Parti québécois de Pauline Marois prend les devants dans... »



#### Schreiber: l'ADQ exige que Charest s'explique

Les partis d'opposition se sont déchainés sur Jean Charest,...



Publicité

**Rajeunissez en 2008**

Courez la chance de GAGNER jusqu'à 25 000 \$ en prix pour vous et 3 amis

Cliquez ici pour trouver un magasin près de chez vous.

Meilleure qualité de sommeil, meilleure qualité de vie !

TEMPUR-PEDIC  
MATELAS ET OREILLERS  
SUEDOIS ALLÉGEANT LA PRESSE

### NOUVELLES LES PLUS LUES

Dernière heure | Dernier jour | Dernière semaine

[Sondage: Marois et le PQ ont le vent dans les voiles](#)

[«Femmes en tenue légère»: une néo-démocrate doit s'excuser](#)

[Kiefer Sutherland condamné à 48 jours de prison](#)

[Des propriétaires de bars veulent ouvrir jusqu'à 6h](#)

[Fusillade dans un centre commercial: neuf morts](#)

[Toutes les nouvelles les plus lues »](#)

---

## Editorial

---

In my last editorial, I explained that in order to cope with the large number of papers that were being submitted to *Proc. R. Soc. A*, every paper we received would be pre-assessed by a member of the Editorial Board, and referees for papers that passed this hurdle were asked to apply stringent quality standards. These procedures, initiated by my predecessor Trevor Stuart, have now proved successful in several ways. Referees no longer waste time reporting on papers that have no chance of being accepted—sometimes because they are poor, but more often because although they contain good science their content is deemed suitable for a more specialist journal. Publication has been greatly accelerated: the current receipt to acceptance time is 90 days. Moreover, the rejection rate has been brought down from an unrealistic height of more than 80 per cent to a more reasonable 72 per cent (getting the right rate is delicate: with 100 per cent, nobody would submit papers; with 0 per cent, we would be publishing trash).

These improvements would not have occurred without the efforts of Joanna Harries and Louise Gardner in the journal office, the Society's publications production staff and, of course, indispensable advice from the Editorial Board.

*Proc. R. Soc. A* aims to publish papers across the whole of the physical sciences. I am interpreting this very widely. Recently, we have published serious scientific studies of a painting by Monet (interpreting the position of the sun to determine where and when it was painted; Baker & Thornes 2006), Viking navigation (to determine whether they could have used the polarization of skylight; Hedegus *et al.* 2007), erasing toner on office paper (to enable it to be re-used; Counsell & Allwood 2009), stability of the Millennium bridge (MacDonald 2009), dynamics of golf swings (Sharp 2009), efficiency of gaits (Srinivasan & Ruina 2007), stresses (in the cork) during the opening of wine bottles (De Pascalis *et al.* 2007), etc. These outliers supplement our core papers, reporting substantial, occasionally seminal, advances in quantum physics, engineering, information science, materials science, pure and applied mathematics, and chemistry (for which we are at last starting to attract papers in numbers commensurate with the scientific importance of that subject).

A curse of researchers, publishers and editors is the fashionable emphasis on bibliometric indicators. Chief among these evils is the impact factor. Ours is increasing but still rather low (currently 1.7). But the impact factor is a measure only of short-term success (citations over the preceding 2 years); for *Proc. R. Soc. A*, a better indicator is the citation half-life. Ours is off-scale: greater than ten years, reflecting our aim of publishing slow-burning, long-lasting, papers.

In this anniversary year, celebrating 350 years since the foundation of the Royal Society, we plan to publish a series of invited articles, contributed by world-leading authorities across the range of subjects that we cover. The first



Downloaded from [rspa.royalsocietypublishing.org](http://rspa.royalsocietypublishing.org) on December 10, 2009

2

*M. Berry*

of these, ‘Nanostructured Bainite’, by H.K.D.H. Bhadeshia (Bhadeshia 2010), appears in this issue. These articles will reinforce our position as one of the best, as well as the oldest, journals of physical science.

Michael Berry

### References

- Baker, J. & Thornes, J. E. 2006 Solar position within Monet’s Houses of Parliament. *Proc. R. Soc. A* **462**, 3775–3788. (doi:10.1098/rspa.2006.1754)
- Bhadeshia, H. K. H. D. 2010 Nanostructured Bainite. *Proc. R. Soc. A* **466**, 2113. (doi:10.1098/rspa.2009.0407)
- Counsell, T. A. M. & Allwood, J. M. 2009 Using solvents to remove a toner print so that office paper might be reused. *Proc. R. Soc. A* **465**, 3839–3858. (doi:10.1098/rspa.2009.0144)
- De Pascalis, R., Destrade, M. & Saccomandi, G. 2007 The stress field in a pulled cork and some subtle points in the semi-inverse method of nonlinear elasticity. *Proc. R. Soc. A* **463**, 2945–2959. (doi:10.1098/rspa.2007.0010)
- Hegedűs, R., Ákesson, S., Wehner, R. & Horváth, G. 2007 Could Vikings have navigated under foggy and cloudy conditions by skylight polarization? On the atmospheric optical prerequisites of polarimetric Viking navigation under foggy and cloudy skies. *Proc. R. Soc. A* **463**, 1081–1095. (doi:10.1098/rspa.2007.1811)
- Macdonald, J. H. G. 2009 Lateral excitation of bridges by balancing pedestrians. *Proc. R. Soc. A* **465**, 1055–1073. (doi:10.1098/rspa.2009.0367)
- Sharp, R. S. 2009 On the mechanics of the golf swing. *Proc. R. Soc. A* **465**, 551–570. (doi:10.1098/rspa.2008.0304)
- Srinivasan, M. & Ruina, A. 2007 Idealized walking and running gaits minimize work. *Proc. R. Soc. A* **463**, 2429–2446. (doi:10.1098/rspa.2007.0006)