EDITORIAL

Check for updates

The physics of breakfast

Breakfast is serious business — and involves a lot of physics. This month, we share with you our favourite breakfast-related physics papers.

The best start to the day is with a well-brewed cup of tea, yet tea-drinkers will be familiar with faulty kettle spouts that splash hot water all over the counter when pouring. In 1986, Jean-Marc Vanden-Broeck and Joseph B. Keller solved this problem by calculating the ideal shape of a teapot spout, to stop drips[1], nabbing an Ig Nobel Prize for their work. Unfortunately, the calculations omitted the effects of gravity, possibly explaining why many teapots and kettles continue to drip today.

A cup of tea or coffee is not complete without a biscuit, and biscuits that are dunked into tea release ten times more flavour than when eaten dry. In 1999, Len Fisher calculated the optimal way to dunk a biscuit[2]. Biscuits are porous, and so when dunked in tea, capillary action causes the liquid to be sucked up into the channels. The hot liquid swells and softens the grains and dissolves the sugar, eventually causing part of the biscuit to crumble off. Fisher used the Washburn equation of capillary flow in porous materials (also derived in the absence of gravity, of course) to calculate how long different biscuits could be dunked for. The best way of dunking is at a shallow angle, so that the bottom is wet but the top stays dry.

Having made your cup of tea, or coffee, you may want to walk over to a table or an armchair to enjoy the drink, but in doing so, you risk spilling some. In 2012, Hans-Christian Mayer and Rouslan Krechetnikov studied the physics of sloshing coffee, finding that in a standard-sized mug, the lowest frequency oscillation is readily amplified by noise introduced by the motion of walking[3]. You can try to walk in a more focussed, steadier fashion to minimize the noise, but the best solution is actually to walk backwards[4], as discovered by high-school student Jiwon Han, who won the Ig Nobel for this work in 2017.

If you do spill coffee and fail to mop it up immediately, the resulting stain on your table is likely to form a distinctive ring shape. This phenomenon was first formally described by Robert Deegan and colleagues in a *Nature* paper in 1997 (REF.[5]), which started a whole strand of research — it turns out that what is a curiosity in coffee stains is a big deal for technologies such as inkjet printing. The basic physics is that the edge of the drop cannot move, but surface tension dictates that the cap of the droplet keeps its initial spherical shape. As a result, during evaporation, liquid flows from the centre to the edge of the drop, carrying coffee particles with it and depositing them there.

Later research on the coffee ring effect showed that if coffee particles were ellipsoidal rather than spherical, the stain would be uniform[6]. Ellipsoidal particles on the surface of the drop are strongly attracted to each other and form a loosely packed structure that eventually forms a uniform stain as the liquid evaporates. The attraction between the particles comes from another phenomenon from the physics of breakfast: capillary attraction, also known as the Cheerios effect[7]. Particles floating on liquid — such as breakfast cereal in a bowl of milk — deform the surface of the liquid, and this deformation affects other particles.

What if you prefer toast to cereal? Murphy's law — that everything that can go wrong, will go wrong — states that toast always falls buttered-side down. Intuitively, this seems unlikely, as surely a thin layer of butter cannot influence the aerodynamics of a slice of toast so much. In 1995 Robert Matthews found that the way the toast lands is determined by two parameters: the surface properties of the toast and the height from which it falls[8]. The toast starts off on a table, butter-side up. As it slides off, it begins to rotate due to gravitational torque. To avoid landing butter-side down, it would have to make a full rotation. In practice, the roughness of a slice of toast, and the average height of a table makes this unlikely. Matthews provides a tip though: swipe the toast forward as it slides. Adding a large horizontal velocity reduces the torque, so that the toast won't rotate much and will simply land butter-side up.

At *Nature Reviews Physics* we usually deal with abstract and counter-intuitive physical systems — our bread and butter — but we appreciate the physics of the everyday, which can provide surprising insights into deeper topics.

1. Vanden-Broeck, J. & Keller, J. B. Pouring flows. *Phys. Fluids* **29**, 12 (1986).
2. Fisher, L. Physics takes the biscuit. *Nature* **397**, 469 (1999).
3. Mayer, H. C. & Krechetnikov, R. Walking with coffee: Why does it spill? *Phys. Rev. E* **85**, 046117 (2012).
4. Han, J. A Study on the coffee spilling phenomena in the low impulse regime. *Achiev. Life Sci.* **10**, 87–101 (2016).
5. Deegan, R. et al. Capillary flow as the cause of ring stains from dried liquid drops. *Nature* **389**, 827–829 (1997).
6. Yunker, P. et al. Suppression of the coffee-ring effect by shape-dependent capillary interactions. *Nature* **476**, 308–311 (2011).
7. Vella, D. & Mahadevan, L. The "Cheerios effect". *Am. J. Phys.* **73**, 817 (2005).
8. Matthews, R. Tumbling toast, Murphy's Law and the fundamental constants. *Eur. J. Phys.* **16**, 172 (1995).