Stoking up Ideas

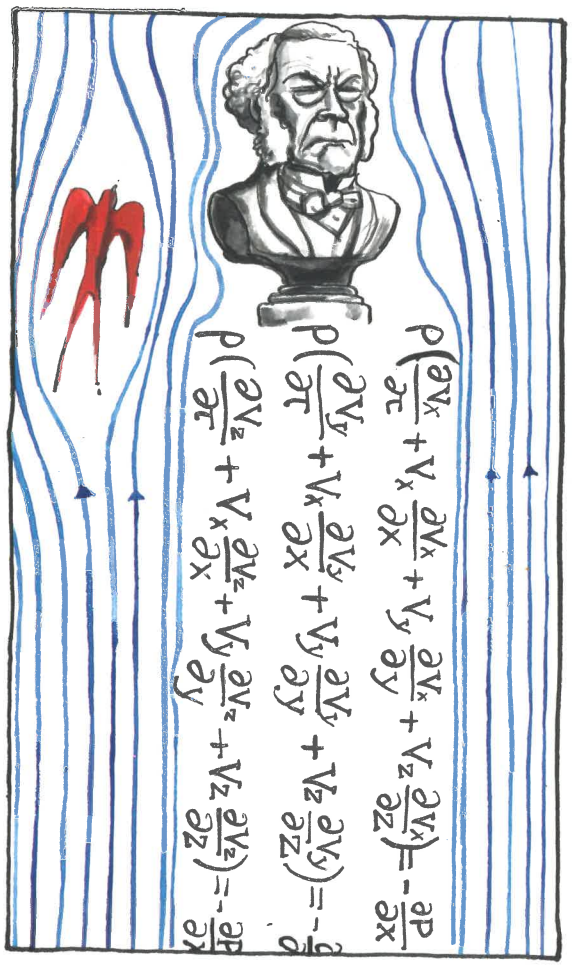
Christopher Ness on the legacy of Sir G. G. Stokes (1837)

Christopher Ness has held the Maudslay-Butler Research Fellowship at Pembroke since October 2016. He was an undergraduate at Clare College, receiving his BA and MEng degrees in 2011, and was subsequently awarded his PhD from the University of Edinburgh in July 2016. His doctoral research combined fluid dynamics with contact mechanics in devising new computational models that predict the mechanical properties of soft solids. He currently works on various problems in soft matter, including suspension rheology and non-equilibrium phase transitions.

Scientists like to name numbers, laws and equations after their discoverers. Sitting in undergraduate engineering lectures in Cambridge I jotted down Péclet numbers, Poisson's ratios and the Boltzmann constant, and while a graduate student in Edinburgh I calculated Reynolds numbers, Mach numbers and Darcy's law. Now a Research Fellow at Pembroke, I find myself face-to-face with the man who gave his name to perhaps more physical quantities than any other, Sir G. G. Stokes.

Stokes is one of only two people to be remembered in Hall in both paint and sculpture. The other is Pitt the Younger, whose dominating presence reflects his status as one of our most memorable Prime Ministers. Despite being the lesser-known of the two, Stokes is regarded today as among the most influential scientific thinkers of the Victorian era and is probably the foremost natural philosopher associated with Pembroke. His reputation stems from the breadth and impact of his intellectual pursuits and his prolificacy as a speaker and letter writer.

Stokes's contributions extend to many fields of mathematics and physics and, indeed, even into public life: he served on several Royal Commissions and was elected to the Cambridge University seat in 1887 on his first attempt, something that Pitt himself had failed to do a century earlier. Born in County Sligo in 1819, Stokes was schooled in Dublin and Bristol before defying the recommendation of his school Principal by matriculating at Pembroke as opposed to Trinity. Upon graduating as Senior Wrangler (one of only seven Pembroke mathematicians ever to do so) he was appointed to a Fellowship at Pembroke, a position he held, with a brief intermission following his marriage and preceding a rule change, until becoming Master in 1902 at the age of 83. In addition to representing the University in Parliament, Stokes was a prominent member of the scientific establishment, holding the Lucasian Chair of Mathematics (1849-1903) and the Presidency of the Royal Society (1885-1890), having been Secretary for the preceding 26 years.



An obituary published in *The Times* following Stokes's death in 1903 recognised his significance, lamenting that 'the country has lost one of its most eminent mathematicians and one of its most distinguished men of science'. Such was the distinction of his reputation that, four years earlier, the University had taken the unprecedented step of officially celebrating the 50th Jubilee of his Professorship – an occasion championed by his long-time correspondent Lord Kelvin and attended by the foremost mathematicians of the day who enjoyed a garden party at Pembroke followed by dinner at Trinity. Perhaps the most important of Stokes's many scientific namesakes are the Navier-Stokes equations, jointly named for Claude-Louis Navier, one of 72 French scientists whose names are engraved on the Eiffel Tower. These equations for fluid motion describe, amongst countless other phenomena, ocean currents, airflow over wings, and blood flow through veins, and they remain an absolutely essential item in the engineer's toolbox.

I came to Pembroke as a Research Fellow hoping to improve our understanding of the natural world, and to make a positive impact on engineering practice. My current research deals with engineering challenges such as tuning the mechanics of consumer suspensions (e.g. pastes, gels), and predicting geophysical phenomena such as subsea landslides and soil liquefaction. These diverse topics are intimately linked by their connection to Stokes. To proceed, we must first modify his fluid equations to take account of suspended microscopic solid particles. Stokes himself provided the starting point for this, relating the force on a sinking sphere to its velocity and the liquid viscosity (leading to the endearing term 'Stokeslet', which refers to point forces in such scenarios).

A key outcome of his analysis is a seemingly trivial conclusion about the force required to slowly move a suspension: it is proportional to the flow rate. Put differently, this predicts that suspensions have constant viscosity. Intuition tells us that this clearly is not the case, yet Stokes's equations could not tell us why. A fun demonstration of this is the cornflour suspension (often compared to Dr Seuss's "Oobleck"), the subject of many public science lectures. Mix cornflour with water and the result is a highly 'shear-thickening' suspension – it can be stirred slowly with ease but solidifies completely on impact. Despite the ubiquity [and 'Oobleckuity' *Ed.*] of this striking demonstration, it has only recently been realised that the phenomenon originates precisely from the breakdown of Stokes equations, rendering the problem one of solid mechanics as well as fluid dynamics. Together with colleagues at Cornell we recently used experiments and simulations to provide evidence for this new picture, leading to a re-evaluation of how we incorporate particles into Stokes's analysis of liquids. Brandishing this insight, I have gone on to devise new formulative and manipulative approaches to controlling the flow of suspensions. These will lead to impact in many fields that involve mixtures of solids and liquids: designing calcium phosphate cements for bone repair; optimising paste extrusion for additive construction; and evaluating the stability of wet sands.

Pembroke will host a conference in September to celebrate the legacy of Stokes, 200 years after his birth. The meeting will be in the spirit of that of 1899, gathering physicists, mathematicians and historians of science. Among them will be the current Lucasian Professor of Mathematics, former and current Stokes Fellows of the College, and leaders in fluid dynamics, optics, and electrodynamics. Lectures will cover historical aspects of Stokes's life and current scientific research in the fields, such as mine, that he inspired. *Stokes 200* takes place at Pembroke on 15-18th September 2019, co-organised by Prof. Silvana Cardoso, Dr Julyan Cartwright (Universidad de Granada), and me.