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CASE STUDY

elasticity, statistical physics, aerodynamics

From Statistical Physics to Hair-Care Innovations

Raymond Goldstein FRS
Schlumberger Professor of Complex Physical Systems
Department of Applied Mathematics and Theoretical Physics

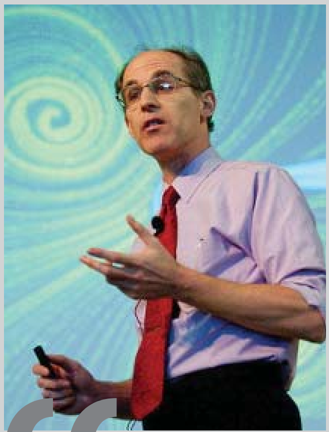
In collaboration with Unilever Research and Development, Professor Raymond Goldstein and colleagues have quantified the curliness of human hair and developed a mathematical theory that can predict the shape of a ponytail. The work has provided Unilever, a global manufacturer of personal care products, with new insights into the dynamics of hair bundles and the physics of hair tangling. One simple equation has the potential to inform the hair-care innovations of the future.

THE CHALLENGE

The global hair care market is a fast-moving, multi-billion pound business. The demand for more sophisticated products increasingly relies on a more sophisticated understanding of how they work. Professor Goldstein was sought out by scientists at Unilever to help them understand the effects of shampoo and conditioner on hair in a quantitative way. He responded with an investigation into hair itself - why are bundles of hair springy? Why does it tangle? What makes different types of hair behave in different ways?

THE SCIENCE

Applying statistical physics to the issue, Goldstein and his team looked for a way to treat 10,000 hairs as one continuous bundle. Combining experimental and theoretical investigations of the properties of hair bundles, they developed a theory for the energy of the bundle, and a differential equation for the shape of a ponytail. They developed a novel stereoscopic imaging technique and a suite of image analysis protocols to allow quantitative studies of the properties of hair. This generated highly reliable 3D representations of the shapes of individual hair fibres, and bundles, enabling the team to describe mathematically different hair types in terms of their random curvature or curliness. Incorporating the effects of these curvatures into a theory for the energy of a hair bundle, they derived the 'Ponytail Shape Equation'. This can determine the shape of a ponytail by considering four competing effects: gravity, tension, an elastic restoring force, and a 'swelling pressure' coming from the curliness.



“Physicists aim to find simplicity out of complexity, and this is a case in point. To be able to reduce this problem to a very simple mathematical form depicting the way in which the random curliness of hair swells a ponytail is deeply satisfying.”

Professor Raymond Goldstein

“Since this is coded in Matlab, which is a standard Unilever application, the Ponytail Shape Equation has been circulated widely and can be used by all researchers in house.”

Unilever Global Senior Vice President for Home and Personal Care R&D

Representing the interaction of large numbers of objects, like the individual hairs in a ponytail, is a challenging mathematical problem.

THE IMPACT

The research provides a new understanding of how a bundle of hair is swelled by the outward pressure arising from collisions between the component hairs. The 'Ponytail Shape Equation' has enabled Unilever to address quantitatively questions about hair in a very straightforward way. And with a deeper understanding of why their products work, they can be improved.

Goldstein's work has implications for understanding the structure of many other materials made up of bundles of long fibres, such as wool, fur and fibreglass. It is also helping computer animators to create more realistic-looking hair movements in their on-screen characters.

The announcement of this research resulted in the team winning the 2012 Ig Nobel Prize in Physics, awarded for achievements that "first make people laugh, then make them think". This generated worldwide media attention, and led to invited presentations in schools and universities that have inspired a new generation.

Find out more:

Professor Goldstein's research group focuses on understanding non-equilibrium phenomena in the natural world, with particular emphasis on biological physics. It strives for a holistic approach in which theory and experiment seamlessly coexist, in the best tradition of DAMTP. Members of the group include theoretical and experimental physicists, chemists, applied mathematicians and biologists, and collaborate broadly with scientists from other departments in Cambridge and beyond.

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