Elegant connections

The pursuit of connections both within and between disparate disciplines is a powerful driver for new understanding.

A water tank with a wave-making machine stands in the middle of a room. A blob of water is bounced into the air at regular intervals and is momentarily lit by a flashing light in an otherwise dark chamber. This is not a fluids laboratory; it is an art exhibition by Danish-Icelandic artist Olafur Eliasson hosted at the Tate Modern in London. The artwork confirms what fluid dynamicists have known all along; namely, that fluids can be aesthetically pleasing.

Other scientists also enjoy the aesthetic side of research. Arguably, blackboards are the medium of choice for mathematicians and theoretical physicists to create their own art galleries. In *A Topological Picturebook*, George Francis provides precise instructions for drawing complex topological objects. Of course, computer graphics have developed hugely since the book was first published in 1987, but sketching mathematical objects by hand is not only a great creative outlet: it is also an invaluable way to figure out solutions to problems.

The search for beauty and elegance can be a powerful driver for researchers. Often, however, what we mean by ‘elegance’ is a striking connection. For example, it is pleasing to discover that from a combination of simple scaling behaviour of fluid flow equations and symmetry arguments, a symmetric scallop will never be able to propel itself through honey (Purcell, E. M. *Am. J. Phys.* **45**, 3–11; 1977). For mathematicians, it is particularly satisfying to find the neatest and simplest solution possible. In some cases, such a solution might guide the way in the search for answers for some other, much more complicated problem, if one looks hard enough for the hidden connection.

Consider, for example, a game of pool. Perhaps you are feeling whimsical and have decided to play billiards on an elliptical table and you wish to know whether there might be infinitely many closed trajectories for a ball bouncing off the edges. It is difficult to prove this if one focuses only on the dynamical system of the ball on the pool table. But if you look elsewhere, you might find an answer in everyone’s favourite topological object, the torus. It turns out that taking a few simple steps on a lattice on this

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torus leads to a proof about elliptical billiard trajectories (Dragović, V. & Radnović, M. *Poncelet Porisms and Beyond*; Birkhäuser, 2011).

The periodicity of the trajectories on a pool table might not be society’s most pressing problem, but one cannot always predict what useful knowledge might emerge from problems that seem detached from the real world. Something merely elegant can turn into something very informative.

A fascinating example is the scene of the wildebeest stampede in Disney’s 1994 film *The Lion King*. The scene was rendered using a computer code based on simple rules that ensured that the running wildebeest in the animation behaved as a realistic herd. A few years later, similar rules were used for a model (Vicsek, T., Czirók, A., Ben-Jacob, E., Cohen, I. & Shochet, O. *Phys. Rev. Lett.* **75**, 1226–1229; 1995) that many view as having kicked off the field of active matter — the study of systems of self-driven particles that self-organize. Just like the code used by the animators at Disney, this model is able to reproduce the beautiful movement of flocks of birds, schools of fish and herds of sheep.

The elegance found in one field of research can lead to revelations in another. Let us focus on a common type of active matter — groups of cells in which each individual unit has an elongated shape. Such cells tend to align with their neighbours, creating areas with long-range orientational order, with some mismatch between adjacent domains where the cells form star- or comet-shaped configurations. Such conglomerates might seem random at first, but through the eyes of a liquid-crystal

researcher, the domains of aligned rod-shaped cells look remarkably like nematic liquid crystals and the points of mismatch between the domains can be understood in terms of topological defects.

A journey that started by admiring the movements of herds of wildebeest has taken us all the way to cell conglomerates, topology and liquid crystals, while also equipping us with a range of maths and physics tools for the investigation of systems with moving elongated components, such as epithelial tissues and bacterial colonies. It turns out that topological defects in an epithelium act as sites for squeezing out cells that are no longer needed. These connections between seemingly unrelated fields open up the attractive possibility of influencing biological function by exploiting the topology of the system (Doostmohammadi, A., Ignés-Mullol, J., Yeomans, J. M. & Sagués, F. *Nat. Commun.* **9**, 3246; 2018).

A researcher embarking on an investigation doesn’t always know where it will lead them. There are many reasons driving their pursuit. The search for connections is one possible driver. Sometimes it will enable the discovery of remarkable properties of the world around us. Other times it might produce a result that an artist somewhere will deem worthy of an exhibition. In either case, the pursuit of elegant connections will continue to lead us forward and inspire interdisciplinary research. ■

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