single-crystal haematite, α-Fe_2O_3 — an electrical insulator that is the most common antiferromagnetic iron oxide. They deposited two thin platinum wires onto the surface of the sample, such that the two wires were parallel to each other, and injected an electric current into one of the wires (Fig. 1). This electric current was converted into a spin current, which in metals is produced by electrons with opposite spins moving in opposite directions, by means of a phenomenon called the spin Hall effect[8]. The spin current flowed into the sample and was transported laterally towards the second wire, where it was converted into an electric current by the inverse spin Hall effect[9]. Finally, this electric current produced a voltage signal that was picked up by a detector.

By reversing the direction of the injected electric current and calculating the difference in the voltages produced by currents in opposite directions, Lebrun *et al.* separated the signals arising from the spin Hall effect from those produced by thermal effects. This voltage difference varies linearly with the magnitude of the injected current and can be used to decode information carried by the spin current. The authors measured the voltage difference as a function of several parameters, such as the spatial separation of the wires, the intensity of an applied external magnetic field, and the angle between the direction of this field and the wires.

There are several key achievements in Lebrun and colleagues' work. First, the authors demonstrated spin transport in an antiferromagnetic insulator over a relatively long distance — tens of micrometres at a temperature of 200 kelvin. This finding suggests that such spin transport could be feasible at room temperature, which would be useful for practical applications. The authors argue that antiferromagnets have an advantage over the well-studied ferromagnetic insulator yttrium iron garnet ($Y_3Fe_5O_{12}$), which has been used in similar spin-transport experiments[10]. In devices based on this material, it is not possible to separate the signals produced by the spin Hall effect from those generated by thermal effects.

A second substantial achievement for device application is the authors' demonstration that the flow of the spin current can be controlled by an external magnetic field. The results also resolve a controversial issue: the physical mechanism responsible for spin transport in antiferromagnets. The dependence of the voltage difference on the spatial separation of the wires shows that the spin transport is mainly caused by the diffusion of excitations called magnons[11], rather than by the spins forming an exotic state of matter known as a superfluid[12].

Despite these achievements, some obstacles must be overcome before antiferromagnets can be used in practical devices requiring the control of spin currents. One challenge is pointed out by Lebrun and colleagues: finding antiferromagnets in which spins can be transported over even longer distances than demonstrated in the current work. Another, more formidable, challenge is to find materials amenable to spin-current control using weaker magnetic fields than those used by the authors. Nevertheless, the current findings provide additional impetus to the emerging field of antiferromagnetic spintronics. ■

Sergio M. Rezende *is in the Department of Physics, Federal University of Pernambuco, 50670-901 Recife, Pernambuco, Brazil.*
e-mail: rezende@df.ufpe.br

1. Lebrun, R. *et al. Nature* **561**, 222–225 (2018).
2. Baibich, M. N. *et al. Phys. Rev. Lett.* **61**, 2472–2475 (1988).
3. Binasch, G., Grünberg, P., Saurenbach, F. & Zinn, W. *Phys. Rev. B* **39**, 4828–4830 (1989).
4. Waldrop, M. M. *Nature* **530**, 144–147 (2016).
5. Jungwirth, T. *et al. Nature Phys.* **14**, 200–203 (2018).
6. Baltz, V. *et al. Rev. Mod. Phys.* **90**, 015005 (2018).
7. Jungfleisch, M. B., Zhang, W. & Hoffmann, A. *Phys. Lett. A* **382**, 865–871 (2018).
8. Hirsch, J. E. *Phys. Rev. Lett.* **83**, 1834–1837 (1999).
9. Saitoh, E., Ueda, M., Miyajima, H. & Tatara, G. *Appl. Phys. Lett.* **88**, 182509 (2006).
10. Cornelissen, L. J., Liu, J., Duine, R. A., Ben-Youssef, J. & van Wees, B. J. *Nature Phys.* **11**, 1022–1026 (2015).
11. Rezende, S. M., Rodríguez-Suárez, R. L. & Azevedo, A. *Phys. Rev. B* **93**, 054412 (2016).
12. Takei, S., Halperin, B. I., Yacoby, A. & Tserkovnyak, Y. *Phys. Rev. B* **90**, 094408 (2014).

BIOPHYSICS

A 3D cell shape found in sheets and tubes

Sheets of cells called epithelia can curve into tubes in embryos. Modelling and *in vivo* observations reveal that cells in tubes adopt an asymmetric cell shape dubbed scutoid, contrary to some previous assumptions.

GUY B. BLANCHARD

Embryo and organ development is driven in large part by the sculpting of sheets of cells called epithelia. Epithelial sheets have a remarkable repertoire of behaviours — they can narrow and elongate in plane, change thickness, and bend out of plane to form structures such as pits and furrows that develop into the body's tubes. However, our understanding of the 3D shapes of the cells that make up these structures, and of how they change during development, has been dominated by inferences often made from looking only at the most easily imaged surface of an epithelial-cell sheet. Writing in *Nature Communications*, Gómez-Gálvez *et al.*[1] use a modelling approach to predict how cells are packed to form tubes, and the authors give a name to a type of epithelial-cell shape involved in this packing, which they also find occurs *in vivo*.

Cells in single-layered epithelia have approximately parallel tops (apices) and bases. The cells are therefore usually thought of as prisms that join together in a honeycomb-like arrangement (Fig. 1a). When either the apices or the bases of cells constrict in all directions (isotropic constriction), wedge-shaped cells called frusta emerge (Fig. 1b), resulting in the formation of a pit[2] or furrow[3].

During the elongation of fruit-fly embryos, cell–cell junctions at the apices[4] or bases[5] of epithelial sheets can also contract in just one orientation in the plane of the sheet. This anisotropic constriction can lead to the formation of different contacts between neighbouring cells at the apical end of the cell from contacts at the basal end. Such constriction produces cells that are neither prisms nor frusta — but the shape that they form has had no name.

Gómez-Gálvez *et al.* analysed 3D cell shapes in epithelia by using computer modelling to study how cells pack into curved epithelia. For epithelia on a sphere, surface curvature is the same in all directions, and inverted frusta are expected. But the authors realized that, when epithelia form tubes and so curve in only one orientation, or form egg shapes that also have differential surface curvature, the cells' inner and outer surfaces can contact different neighbours. This change in contacts requires the formation of a triangular face on one side of the cell (Fig. 1c) — a 3D shape similar to that seen in the epithelial sheets of elongating fruit-fly embryos. The researchers name this 3D cell shape scutoid, from the Latin word for shield.

So why are scutoids predicted to occur in tubes? It is possible for 3D shapes resembling frusta to form tubes. But this requires the cells' apical or basal surfaces to be elongated, and Gómez-Gálvez *et al.* based their modelling on the plausible assumption that apical and basal surfaces of epithelial cells both tend towards isotropic shapes as the most energy-efficient ('relaxed') packing solution to differential curvature. This is in contrast to the sheets of fruit-fly embryos, in which the formation of scutoids is a dynamic, temporary process driven by active cell rearrangement[5]. When the authors modelled cells that had near-isotropic shapes on both the inner and outer surfaces

© 2018 Springer Nature Limited. All rights reserved.

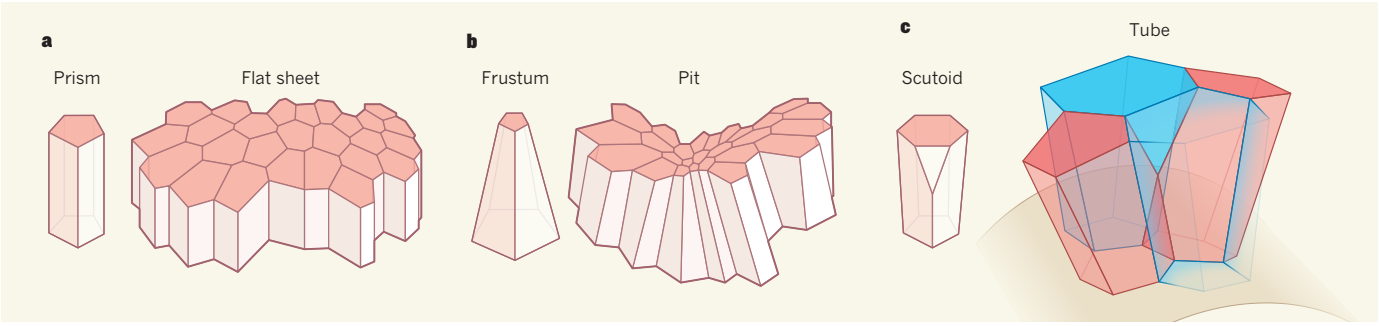

Figure 1 | 3D cell shapes in epithelial sheets. **a**, Sheets of cells called epithelia are most simply composed of prism shapes when flat. **b**, Frusta — prismatoids in which one end is constricted — bend epithelia into pits. **c**, Gómez-Gálvez *et al.*[1] provide evidence that cells can adopt a shape that the authors dub scutoid when epithelia form tubes. Scutoid cells have a triangular face towards one end and have different contacts with neighbouring cells at the inner and outer surfaces of the tube. For example, here the pink cells make contact only towards the inner surface of the tube. (Adapted from Fig. 1 of ref. 1.)

of tubes, they found topological differences between the inner and outer surfaces that required the cells to be scutoid. The authors then confirmed this finding using a mechanical model of the outer surface, in which the lengths of cell–cell interfaces were minimized, encouraging isotropic shapes.

Gómez-Gálvez and colleagues went on to search for scutoids *in vivo*. They found scutoid-shaped cells in snapshots of various embryonic epithelia, although, interestingly, not at the frequency predicted by their modelling. For example, the larval salivary glands of fruit flies have fewer scutoids than are predicted by the curvature of the gland tube. Furthermore, the authors found scutoids in the spherically curved surface layers of zebrafish embryos where none would be predicted.

There are several possible reasons for these discrepancies. First, scutoid predictions will be altered if they take into account other forces, either generated within the epithelium (for example, caused by anisotropic contractility) or acting on it. Second, in the current model, the authors used 2D modelling of the inner and outer surfaces of cells to infer 3D cell shapes — predictions might differ if modelling was extended to cell shapes that are explicitly 3D. However, a better understanding of the mechanics of the shared interfaces on the sides of cells will be needed before cell shapes more complex than prisms and frusta can be modelled accurately in three dimensions[6].

Third, the assumption that apical and basal cell shapes will tend towards isotropy is based on the assumption that the cells' cortex — a contractile, mesh-like network of proteins that gives cells their structure — acts as a ring at the cell–cell junctions at the ends of cells. But the cortex also spans the rest of the exposed apical and basal surfaces, and the contraction of this medial web seems not to tend to isotropic shapes in the same way[3]. Finally, scutoid formation might be highly dynamic in some epithelia, or might involve more-convoluted 3D shapes than those considered here, rendering measurement of scutoid frequency difficult.

Prisms, frusta and scutoids found in single-cell layered epithelia are discrete classes of shape, but belong in a continuum of cell shape and 3D arrangement. This continuum has recently been quantified as an additive combination of cell wedging and interleaving[2,7]. Wedging describes how cell shapes become wider or narrower with depth, whereas interleaving describes changes in how interdigitated a group of cells is with depth, equivalent to a rate of change of cell arrangement from bases to apices. Both wedging and interleaving can be quantified in units of radius of curvature, so are ideal for characterizing curved epithelia. A formal relationship between the degree of interleaving and the frequency of scutoids seems possible, which would make these continuous and discrete measures usefully interchangeable.

With Gómez-Gálvez and colleagues' characterization of the scutoid, we are beginning to recognize the kinds of 3D shapes and arrangements to look for in epithelia, and to develop the tools for quantifying them. Where else in nature should we expect scutoids? I would not bet against scutoids being found in plants, given the diversity of plant architectures. But because plant development is driven by cell growth and division without rearrangement, any mechanism of scutoid formation is likely to be rather different from that seen in animals. Nest comb construction by bees or wasps might also result in scutoids, particularly on curved surfaces, as in the nests of some paper wasps[8]. We shall have to wait and see. ■

Guy Blanchard *is in the Department of Physiology, Development and Neuroscience, University of Cambridge, Cambridge CB2 3DY, UK.*
e-mail: gb288@cam.ac.uk

1. Gómez-Gálvez, P. *et al. Nature Commun.* **9**, 2960 (2018).
2. Sanchez-Corrales, Y. E., Blanchard, G. B. & Röper, K. *eLife* **7**, e35717 (2018).
3. Chanet, S. *et al. Nature Commun.* **8**, 15014 (2017).
4. Rauzi, M., Lenne, P.-F. & Lecuit, T. *Nature* **468**, 1110–1114 (2010).
5. Sun, Z. *et al. Nature Cell Biol.* **19**, 375–383 (2017).
6. Bielmeier, C. *et al. Curr. Biol.* **26**, 563–574 (2016).
7. Deacon, W. J. PhD thesis, Univ. Cambridge (2012).
8. Wenzel, J. W. *J. Insect Behav.* **2**, 679–699 (1989).

ENVIRONMENTAL SCIENCE

The future of tidal wetlands is in our hands

Computational simulations suggest that future losses of tidal wetlands attributable to sea-level rise could be greatly offset by the landward advance of these ecosystems into newly sea-inundated areas. SEE LETTER P.231

JONATHAN D. WOODRUFF

Coastal communities around the globe depend on tidal marshes and mangroves for the diverse ecological, economic and flood-mitigating services they provide. These relatively flat wetland systems (Fig. 1) commonly reside just above mean sea level, making them one of the ecosystems most at risk of being drowned by rising sea levels. But tidal wetlands will not disappear without a fight. On page 231, Schuerch *et al.*[1] present global-scale modelling that suggests that tidal wetlands are less vulnerable to sea-level rise than was thought. However, the scale of future wetland loss or gain depends greatly on the degree to which coastal communities accept or prevent the landward advances of these living coastal systems into newly inundated areas.

Tidal wetlands are dynamic, living systems

© 2018 Springer Nature Limited. All rights reserved.